Diversity and distribution of birds in villages in the Kalahari

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ABSTRACT

Urbanisation and human settlements affects natural habitats in South Africa and around the world through the removal of vegetation, construction of roads and houses, and by various forms of pollution. The Bophirima District of the North West province is a desert margin area – a fragile ecosystem facing the threat of desertification and land degradation. The area has a high diversity of bird species, but is also an area where small villages and human settlements are continuing to modify the natural environment. To determine the effect of urbanisation in a desert margin area, bird surveys were done in three of these settlements. Three habitat types were present at each village – natural, edge, and village habitat. The structure within the villages consisted of unpaved roads, small houses, and several other small buildings. Data was collected in and around the villages by plotting out evenly-spaced point count sites on a 250 x 250 m grid across each village, covering all three habitat types. Bird species were identified, and the number of individuals per species was recorded at each site over four surveys. Surveys were done with the expectation that bird numbers and species richness would be higher within the villages, as predicted by the "intermediate disturbance hypothesis". Bird numbers and species diversity were expected to decrease toward the edges and outskirts of the villages, where the opportunities created by urbanisation were missing. Different guilds were also expected to show different responses to urbanisation and habitat change. Geostatistical analyses, analyses of variance (ANOVA) and an indicator species analysis was performed. The results did indeed indicate that urbanisation increased the overall species richness and number of birds. The reasons for this can be attributed to an increase in additional food and water sources within the villages, as well as the availability of nesting sites, shelter and perches created by buildings, rooftops, poles, fences and other man-made structures. At the edges of the village and in the surrounding habitat, bird numbers and species diversity were often significantly lower, probably due to the absence of these man-made structures and anthropogenic resources. In terms of feeding guilds, an increase in granivores was observed within the villages, while insectivores and carnivores showed higher abundances in the natural habitats. Nesting guilds which responded positively to urbanisation were tree- and structure-nesters, while ground- and shrub-nesters preferred the natural habitats. It was concluded that bird distribution was very much affected by areas where their food and nesting requirements could best be fulfilled. In a desert margin area, where avian diversity is currently threatened by global warming and land degradation, these villages could serve as important conservation sites for birds. Several questions still need to be answered through future research, but it is recommended that proper management strategies and sustainable development plans are implemented to ensure the maintenance of species richness and bird numbers in such villages.

OPSOMMING

Verstedeliking en menslike nedersettings affekteer natuurlike habitats in Suid-Afrika en regoor die wêreld deur die verwydering van plantegroei, die bou van paaie en huise, en deur verskeie vorme van besoedeling. Die Bophirima-distrik in die Noordwesprovinsie is ‘n woestyn-randgebied – ‘n sensitiewe ekosisteem wat bedreig word deur verwoestyning en landdegradasie. Dié gebied beskik oor ‘n hoë diversiteit van voëlspesies, maar is ook ‘n area wat voortdurend deur klein dorpies en menslike nedersettings verander word. Om die effek van verstedeliking in ‘n woestyn-randgebied te bepaal, is voëlopnames in drie van hierdie dorpies uitgevoer. Drie habitattipes is by elke dorpie geïdentifiseer, naamlik natuurlike-, rand- en dorphabitat. Die struktuur binne die dorpies is saamgestel deur grondpaaie, klein huisies en verskeie ander klein geboue. Data is in en rondom elke dorpie versamel deur opnamepunte op ‘n 250 x 250 m matriks uit te plot oor elke dorpie ten einde al drie habitattipes te dek. Voëlspesies is geïdentifiseer en die aantal individue per spesie is vir elke punt aangeteken oor vier opnames. Opnames is gedoen met die verwagting dat die getal voëls en spesierykheid binne die dorpies sou verhoog, soos voorgestel deur die intermediêre versteuringshipotese. Die verwagting was ook dat voëlgetalle en spesierykheid sou verlaag nader aan die rande en aan die buitekant van die dorpies, waar die geleenthede wat deur verstedeliking geskep word, afwesig was. Daar is ook verwag om verskillende reaksies teenoor verstedeliking by verkillende gildes waar te neem. Geostatistiese analises, analises van variansie (ANOVA) en indikatorspesie-analises is uitgevoer. Die resultate het inderdaad aangedui dat verstedeliking gelei het tot ‘n verhoging in algehele voëlgetalle en spesierykheid. Die redes hiervoor kan toegeskryf word aan addisionele voedsel- en waterbronne binne die dorpies, asook die beskikbaarheid van broeiplek, sitplek en skuiling wat deur geboue, dakke, pale, grensdrade en ander mensgemaakte strukture geskep word. Voëlgetalle en spesierykheid was dikwels aansienlik laer aan die rande van die dorpies en in die natuurlike habitats rondom die dorpies, waarskynlik weens die afwesigheid van hierdie antropogeniese strukture en hulpbronne. In terme van gildes is ‘n toename in graanvreters binne die dorpies opgemerk terwyl insekvreters en karnivore meer volop in die natuurlike habitats was. Broeigildes wat positief reageer

het teenoor verstedeliking was voëls wat in bome en strukture broei, terwyl dié wat op die grond of in struike broei, ‘n voorkeur vir die natuurlike habitats getoon het. Die gevolgtrekking is gemaak dat die verspreiding van voëls onderheweig was aan areas waar hul voedings- en nesmaakvereistes die beste vervul kon word. Hierdie dorpies kan as belangrike bewaringsareas vir voëls dien in ‘n woestyn-randgebied waar voëldiversiteit tans deur globale verhitting en verwoestyning bedreig word. Verskeie vrae moet nog deur verdere navorsing beantwoord word, maar dit word aanbeveel dat behoorlike bestuurstrategieë en volhoubare ontwikkelingsplanne geïmplementeer word om te voorsien dat die spesierykheid en voëlgetalle in sodanige dorpies onderhou word.

LIST OF ABBREVIATIONS

ANOVA: Analysis of Variance

DMP: Desert Margins Programme

GEF: Global Environmental Facility

GPS: Global Positioning System

ICRISAT: International Crops Research Institute for the Semi-Arid Tropics

IFAD: International Fund for Agricultural Development

IPCC: International Panel on Climate Change

NMS: Non-metric Multi-dimensional Scaling

NWU: North-West University

OIV: Observed Indicator Value

SD: Standard Deviation

UN: United Nations

UNCCD: United Nations Conference to Combat Desertification

UNEP: United Nations Environmental Program

CHAPTER 1:
GENERAL INTRODUCTION

1.1 INTRODUCTION

Desertification is a global problem caused by climate change, anthropogenic pressures, and other factors (Kellner, 2000). The United Nations Conference to Combat Desertification (UNCCD) defines the process of desertification as “land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities”.

Desertification accelerates the loss of normally-present species and also impacts human development in areas where it occurs. Over one billion people worldwide are threatened by desertification, and approximately 135 million people face the threat of being driven off their land as it continues to desertify. Dr. William Dar, Director General of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), claims that poor people can be made less vulnerable with greater science and knowledge-based interventions. According to Dr. Dar, the nexus of climate change and desertification, combined with land degradation, biodiversity loss, water shortage and fossil fuel shortage, will make it even riskier for farmers to farm in the drylands of the world. They will find it more difficult to invest in farming, and there could be an increase in diseases and death. Thus, scientific intervention to combat desertification and protect biodiversity is of great importance.

The financial cost of desertification is around $42 billion per annum (Kellner, 2000). African countries alone lose around $9 billion yearly due to desertification. Estimations show that up to 73% of Africa’s drylands are either moderately or severely affected by desertification (Kellner, 2000). Drylands span a third of the earth’s land surface in 110 countries, which makes it critical for conservation efforts to focus on desertification. Each year 12 million hectares are lost to deserts – that is enough land to grow 20 million tons of grain (GEF-IFAD Partnership, 2002).

Desert margins can be described as the transitional zones between typical deserts and regions where there is an adequate supply of moisture for plant growth during the warm season. Low rainfall, high evaporation, and high variability of rainfall characterise desert margin areas. Studies have shown that desert margins are most prone to desertification (Reich *et al.,* 2000).

The Bophirima District of the North West province in South Africa, where this study took place, is a typical desert margin area. It is located in the north-western corner of the Province where the Kalahari starts. The true Kalahari Desert lies to the north, stretching into Botswana. The less arid parts of the North West province form the southern and eastern borders. The Bophirima District is thus a transitional zone between the Kalahari Desert and the moister parts of South Africa.

Studies have found that via the process of desertification, the Sahara Desert has expanded in size during the past century, with its southern border continuously expanding into the semi-arid grasslands of the Sahel zone which lies directly to the south of the Sahara (Tucker and Nicholson, 1999). The concern is that the true desert conditions of the Kalahari Desert will spread into the semi-arid Bophirima District if proper precautions are not taken and strategies to combat desertification are not implemented.

In addition to the impact of desertification, several poor communities live in villages within the Bophirima District. As the population grows, urban areas are continually expanding into wilderness and replacing natural habitat, placing additional stress on an already fragile landscape. Due to the widespread utilisation of desert margins in South Africa for agricultural and pastoral purposes, increased pressure is placed on these fragile ecosystems due to grazing, general utilization, and management practices (Kellner, 2000).

The purpose of this study was to determine what effects villages have on the distribution and numbers of birds in a desert margin area.

1.1.1 FACTORS INFLUENCING DESERTIFICATION

Desertification can result from many different factors, including climatic variation and human activities (Kellner, 2002). According to Gonzalez (2002), the relative importance of the influence of climatic and anthropogenic factors on desertification is still undetermined.

1.1.1.2 ANTHROPOGENIC FACTORS

If human population growth increases, the land area subjected to unsustainable agricultural practices, overgrazing, and deforestation will be the driving force for desertification (Gonzalez, 2002). These anthropogenic factors usually lead to land degradation. Land degradation can be defined as a process where a reduction in or a loss of productivity can be observed, accompanied by denudification, soil erosion, bush encroachment and a change in rangeland status to a poorer condition (Kellner, 2002).

In South Africa, commercial and communal stock farmers widely utilize desert margins (Kellner, 2000) and the Bophirima District is no exception. Across the globe, many regions have especially been affected by grazing. According to Kauffman and Pyke (2001), grazing can lead to:

- the reduced density and biomass of plant and animal species
- a reduced biodiversity
- the spread of exotic species and disease
- the alteration of ecological succession
- landscape heterogeneity
- the acceleration of erosion
- the alteration of nutrient cycles
- reduced productivity and land-use options for future generations

Gonzalez (2002) names unsustainable agricultural practices and overgrazing as the two main anthropogenic factors that disturb ecosystems and drive the process of desertification. Any severe disturbance in an ecosystem can lead to land degradation which, in desert margins, can lead to desertification.

The issue of habitat quality can be approached by examining anthropogenic and natural disturbances which may affect the sustainability of the habitat for certain species, or suites of species (Doherty *et al.,* 2000). Begon *et al.* (1996) define disturbance as the process by which the natural processes within an ecosystem are altered. According to Doherty *et al.* (2000), the key agents of habitat disturbance include fire, pollution, water supplementation, fragmentation, and land-use activities such as agriculture, forestry and mining. It is important to note that these agents are present in the Kalahari:

- Fire is frequently used as a management tool in the area, even though its effectiveness has been questioned due to the slow recovery rate of the veldt in a desert margin area like the Bophirima District (Low and Rebelo, 1998).
- Pollution is often a problem in poor communities. Expanding settlements and urban sprawl leads to the destruction of natural habitat and the loss of high potential agricultural land. Unsustainable settlements also lead to the degradation of ecosystems through waste production and pollution (Kilian *et al.*, 2005).
- Water supplementation in arid areas usually leads to a concentration of livestock and game in areas where watering points are established. The veldt surrounding these watering points are degraded as a result of the high concentration of animal movement to and from the water, especially during the drier months of the year (James *et al.,* 1999). By exceeding the carrying capacity of the area, the quality and quantity of the habitat is reduced.
- Habitat fragmentation is known to have a negative effect on species in the area where it occurs (Meffe and Carroll, 1997). In the Bophirima area, further fragmentation can take place due to overgrazing, bush clearing, bush encroachment and the expansion of villages.
- The land-use activity that has the greatest negative impact in the current study area is communal farming (Kellner, 2000). The people living in the local villages tend to overstock on cattle, goats and donkeys, which all overgraze the natural habitat surrounding the villages.

1.1.1.3 CLIMATIC FACTORS

Climate exerts a strong influence over dry land vegetation, biomass, and diversity (Sivakumar and Stefanski, 2007). Climatic stresses are responsible for over 60% of all the stresses on land degradation in Africa. These stresses cause high soil temperature, seasonal excess water, shortened duration of low temperatures, seasonal moisture stress, and extended moisture stress (Sivakumar and Stefanski, 2007).

Climate change affects the range and rate of desertification by altering the spatial and temporal patterns in rainfall, temperature, solar isolation, and wind. Desertification, in return, can aggravate climate change through the release of carbon dioxide from dead and cleared vegetation, as well as through the reduction of the carbon sequestration potential of desertified land (Gonzalez, 2002).

Rainfall is the most important factor in determining areas at risk of land degradation and potential desertification. Rainfall plays a vital role in the development and distribution of plant life, but the variability and extremes of rainfall can lead to soil erosion and land degradation (Sivakumar and Stefanski, 2007).

Few organisms on the planet will escape the effects of climate change in the coming decades. As weather patterns change and worldwide temperatures increase, largely due to human carbon and other gas emissions, ecosystems will track the changing conditions with profound consequences for the species that inhabit them (McKechnie, 2007).

Desert margins are fragile ecosystems with a low resilience with regard to changes brought on by disturbances, making them highly susceptible to land degradation (Reich *et al.,* 2000). If land degradation takes place in these ecosystems, it can lead to the advancing of deserts. The only way to minimize the spread of deserts is to control land degradation in desert margin areas (Gonzalez, 2002).

1.1.2 CONCEPTS OF URBAN ECOLOGY

Urban sprawl affects the environment in many different ways. Although the expansion of urban areas has resulted in the conversion of croplands, pastures, and woodland into built environments on a massive scale, little is known about the effects of urbanisation at any level of biological organisation (Blair, 2004). In earlier years, ecologists commonly worked in relatively pristine habitats, not incorporating humans and their institutions as agents in the functioning of terrestrial ecosystems (McDonnell and Pickett, 1990), although urban ecology is gaining rapidly in recognition and effort. In recent years, urban ecology has received increasing attention from ecologists, anthropologists, and social scientists (Grimm *et al.,* 2000).

Generally, anthropogenic land-use changes alter native habitats, create similar habitat types across wide ranges, and facilitate the introduction of cosmopolitan species which are able to coexist with humans. It potentially increases local diversity, but seems, ultimately, to decrease diversity at regional and global levels (McKinney and Lockwood, 2001). Urbanisation may be one of the biggest drivers of habitat homogenisation, and birds have been found to be one of the top five groups of organisms affected by homogenisation (Olden *et al.*, 2006). Blair (1996) demonstrated that species richness initially increases with suburbanisation and then decreases with further urbanisation. Surveys were done in three urban gradients in different regions of the United States and the results indicated that overall, species richness, species evenness and Shannon diversity increased initially at intermediate levels of urbanisation, and then decreased significantly as development increased (Blair and Johnson, 2008). However, it is important to note that most of the studies that show these diversity decreases in urban areas were conducted in the more temperate regions of the northern hemisphere. Warmer areas, such as South Africa, have abiotic and biotic constraints that differ significantly from where those studies took place, which may lead to different results (Caula *et al*., 2008).

It is important to realize that different forms of urban landscapes exist. Suburban neighbourhoods differ significantly from metropolitan city centres and from small rural villages – which were the focus of the current study. Since this study's focus is on birds in small villages, it is important to look at how urbanisation affects birds, keeping in mind that all species will not be affected in the same way. According to Chase and Walsh (2004), urbanisation initially tends to select for omnivorous, granivorous and cavity-nesting species. Increased urbanisation typically leads to an increase in avian biomass but a reduction in species richness. However, it has been found that species richness and diversity will peak at moderate levels of urbanisation (Blair, 2004). The importance of this study is that it will focus on an area which is largely being affected by two problems brought on by man – desertification in a desert margin region, and urbanisation. The reasons why birds were chosen for this study will be discussed in the following section.

1.1.3 THE GENERAL, ECOLOGICAL AND SCIENTIFIC IMPORTANCE OF BIRDS

In general, birds are important for the following reasons:

- Many people notice birds and enjoy watching them. The public often becomes concerned when birds die or disappear (Adamus, 2002).
- Bird-watching and other bird-related activities such as game bird hunting generate enormous revenue worldwide, making birds economically important (O'Halloran *et al.*, 2002).
- Many bird species adapt easily to urban development, sometimes making them the dominant vertebrates in towns and cities (Chase and Walsh, 2004).
- Birds are often the focus of conservation efforts because of human affinity towards them (Adamus, 2002).
- Birds often play the role of “umbrella” species in conservation efforts, leading to entire ecosystems being protected under the umbrella of the bird species in question (O'Halloran *et al.*, 2002).
- Some birds are seen as “flagship” species, with a high public profile, whose conservation is seen as a high priority (O'Halloran *et al.*, 2002).

Birds are of ecological importance for the following reasons:

- Birds can be indicators of the health, integrity, or condition of a landscape. Assessing the integrity of a landscape is vital to assessing the cumulative effects of human activities (Adamus, 2002).
- Birds play an important role in the dispersal of seeds (O'Halloran *et al.*, 2002).
- Birds provide a source of food for many predators such as carnivorous mammals and reptiles, as well as raptorial birds (O'Halloran *et al.*, 2002).
- Insectivorous birds play an important role in the natural control of pest species (Anon, 2002).

Scientifically, birds are significant for the following reasons:

- Most birds are easily surveyed and there is no need to collect and analyze samples or to struggle with complex taxonomic keys (Adamus, 2002).
- Most birds are active and abundant by day making surveys easier (Adamus, 2002).
- There are many interested data collectors who are proficient at bird identification or can be trained to do so. Many are willing to help with surveys on a volunteer basis (Adamus, 2002).
- The study of different feeding and nesting guilds in birds can be useful to other scientific research (Bibby *et al.,* 2000).
- Birds are positioned near the top of the food chain, making them useful focal species in research (Adamus, 2002).

1.2 MOTIVATION AND PROBLEM STATEMENT

Urbanisation and human settlements in rural areas is a growing phenomenon in South Africa and around the world. In South Africa, the rate of urbanisation has been rapid since the 1950s (Anon, 2001). Humans are increasingly sprawling into natural habitats and creating new environments by removing and changing vegetation, constructing houses and other buildings, and polluting the surrounding areas. Urban sprawl affects the environment in a myriad of ways and at multiple levels of biological organization (Blair, 2004). Today, 57% of all South Africans live in towns or cities (Anon, 2001), and these urban areas are constantly expanding.

Over the years, certain bird species have adapted to these changing environments, while others have been completely disadvantaged. The Bophirima District of the North West province is an area with a high diversity of bird species adapted to an arid environment (Maclean, 1993), but is also an area where small villages and human settlements are continuing to grow and modify the natural environment. It forms the desert margin between the drier Kalahari Desert to the north-west and the moister remainder of the North West province to the south-east. It is an ideal research area, since little is known about the diversity patterns of birds in urban habitats that are located in desert margin areas. Recent studies have discovered records of 45 species which were previously not known to occur in the area (Hudson and Bouwman, 2006).

Problem statement: Do villages in desert margin areas have an effect on the number of birds as well as the number of species?

The motivation for this study can be summarized as follows:

- The Bophirima District falls within a desert margin area, which is a fragile ecosystem constantly utilized for communal and commercial farming.
- Urbanisation is a growing phenomenon in the region, placing more pressure on the landscape.
- In accordance with the World Summit on Sustainable Development (2002), South Africa is obliged to implement sustainable use of natural resources.
- In order to implement sustainable use of resources, sustainability of present management of resources needs to be assessed.
- It is important to determine whether birds could be used as surrogates to assess land degradation in the area.
- Very little is known about the effects of urbanisation on birds in Africa, and even less on birds in desert margins worldwide.
- Avian diversity could be indicative of how villages and human activity affect the environment.

In order to address the objectives of this study, a literature review will be done in the following chapter.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

In order to address the issues and problem statement mentioned in Chapter 1, a review of relevant literature needs to be done. Since very little is known about avian demography in urbanised desert margin areas, it is important to accumulate as much information as possible in order to formulate hypotheses that can be tested in the study. No previous research has been done on the exact current research topic; however, there is much literature available on birds and their reactions to urbanisation and land degradation. By researching these topics and integrating the relevant aspects, more information can be accumulated to formulate hypotheses.

The following literature study contains a general review of biodiversity, urban ecology, and other topics influencing bird diversity.

2.2 GENERAL CONCEPTS OF BIODIVERSITY

Biodiversity is an important part of ecology, but a somewhat ambiguous term due to conflicting or misinterpreted terminology. Biodiversity can be defined as the variety of organisms considered at all levels, from genetic variants belonging to the same species through arrays of species to arrays of genera, families and still higher taxonomic level; includes variety of ecosystems, which comprise both the communities of organisms within particular habitats and the physical conditions under which they live (Wilson, 1992). Harrison *et al.* (2004) provide a slightly simpler definition, stating that biodiversity is the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it.

Most definitions of biodiversity are problematic because they tend to become synonymous with "all life", making it questionable whether any researcher could measure or provide indicators of biodiversity *per se*. This creates the need for working definitions that specify the units used in its measurement (Doherty *et al.,* 2000).

According to Doherty *et al.* (2000), a key element to all the existing definitions of biodiversity is that it operates over several biological levels of organization and at different scales. Furthermore, it is an interdisciplinary concept (Gaston, 1996).

The problem with measuring biodiversity comes from the multiple levels of biological organization existing under the term of biodiversity (Gaston, 1996). It is impossible to evaluate all components within one study; therefore biodiversity is commonly broken down into four compartments: ecosystem, habitat, species, and genetic diversity (Doherty *et al.,* 2000). When evaluating these components, the potential use of habitat diversity needs to be taken into account.

- Ecosystem diversity refers to the largest units of biodiversity, comprising of several different habitats, the organisms found within them, the genetic diversity found within those organisms, and the interactions between the biotic and abiotic components found within the system (Doherty *et al.,* 2000).
- Habitat diversity refers to the diversity found within habitats. Southwood (1981) defines habitats as areas where the resource requirements for an animal or plant's life are provided.
- Species diversity refers to the variation of organisms within an area. In terms of readily measurable field entities, species are the fundamental unit of organization in ecology. Species are also the most commonly used measurement of biodiversity since there are effective ways to assess the composition of assemblages using species as units of distinction (Doherty *et al.,* 2000).
- Genetic diversity is a 'fine scale' level of biodiversity measured in the variety of expressed genes or characters among organisms (Williams *et al.,* 1996). Genetic diversity is the fundamental currency of diversity that is responsible for variation between individuals, populations and species (Harrison *et al.,* 2004). However, as a basic unit for measuring biodiversity, it has been dismissed as too difficult and costly to use (Moritz, 1994).

Harrison *et al.* (2004) stated that there is an important spatial component to biodiversity. The structure of communities and ecosystems can vary in different parts of the world. Similarly, the functions of these communities and ecosystems may differ from one location to another. Since the structural, functional and spatial aspects of biodiversity can vary over time, there is a temporal component to biodiversity. For example, there can be daily, seasonal or annual changes in the composition of species and the manner in which they interact with each other.

2.2.1 HABITAT COMPLEXITY, QUALITY AND DISTURBANCES

Habitat complexity can be explained on the basis of species characteristics in the ecosystem (Pimm, 1984). Habitat complexity is often considered synonymous for habitat heterogeneity. However, habitat heterogeneity refers to spatial and temporal change across a landscape, while habitat complexity refers more to the level or strength of interaction between a species and its environment (Doherty *et al.,* 2000). Habitat complexity is an important factor which often influences species richness as well as habitat selection in birds. Although some species respond specifically to habitat complexity, the role that productivity and resource availability play in influencing species richness should also be taken into account (Cousin and Phillips, 2008). Habitat heterogeneity may differ from habitat complexity in definition, but has been found to be just as important a factor in avian distribution. Studies have found that birds respond strongly to habitat heterogeneity and often decrease in numbers and diversity when habitats become homogenous (Cam *et al.,* 2000; Drapeau *et al*., 2000; Glennon and Porter, 2005; Aerts *et al.,* 2008).

Habitat quality is usually determined by examining any anthropogenic and natural disturbances which may affect the suitability or quality of a habitat for a particular species or group of species. Habitat quality can be directly related to the responses of species to changes in any of the biotic or abiotic factors which may affect individuals or populations. These factors can range from fine-scale factors to the fragmentation of previously large, continuous areas. In order for habitat quality to have applicable meaning, it should be defined in a species-specific manner (Doherty *et al.,* 2000). For example, degradation alters the local structure of native habitat structure, often reducing habitat quality for many native species and increasing habitat quality for early successional and non-native species (Donnelly *et al.,* 2006). As has been mentioned in Chapter 1, the primary agents for habitat disturbance are fire, pollution, water supplementation, fragmentation, and land-use practices. These disturbances all have an effect on the ultimate quality of the habitat. Biogeographic characters such as the size and shape of a habitat usually also play a significant role in the quality of habitats. Another important factor influencing the habitat quality is the overall general composition of the habitat, consisting of abiotic factors such as temperature, rainfall and slope, and biotic factors such as the vegetation composition (Doherty *et al.,* 2000). For the current study, however, the most important disturbances are urbanisation and the associated impact of grazing.

2.2.2 THE EFFECTS OF DISTURBANCE ON DIVERSITY

Most habitats are subject to disturbances. A disturbance can be anything which changes a habitat, usually fairly dramatically (Cronin, 2007), and a number of disturbances have already been mentioned. Disturbances can change which species live in a habitat, and can also change how common each species is. Generally, when there is very little disturbance in a habitat, the species that are best at competing with each other will eventually take over. When there are very high levels of disturbance, colonising species or other species which are able to recover quickly from the disturbance, will take over the disturbed area. Thus, as the size and frequency of disturbance in an area changes, the distribution of species in that area will also change (Cronin, 2007).

The intermediate disturbance hypothesis was formulated by Connell (1978, 1979). This hypothesis states that an intermediate level of disturbance will lead to the highest biodiversity. Too little or excessive disturbance will lead to a decrease in species diversity. Miller (1982) stated that the size of disturbance provides an extension of the intermediate disturbance hypothesis. The hypothesis suggests that disturbance may allow the coexistence of species with different life history strategies. Where there is no or very low levels of disturbance, the stronger competitors will eliminate other species. On the other hand, when disturbance levels are high, species with high growth and dispersal rates may persist through rapid colonisation while competitive species may be excluded. At intermediate rates of disturbance, colonising species may be eliminated locally by the succession within patches of competitively superior species, but will persist globally by colonising newly available resources in recently disturbed areas (Miller, 1982).

According to Tainton (1999), fire is a disturbance which may occur naturally or as a management tool implemented by humans. Studies have shown different results regarding the effectiveness of using fire as a means to increase plant diversity. Fox and Fox (1986) found that fire did indeed help to increase species diversity, while another study, conducted by Low and Rebelo (1998), indicated that fire may have several negative effects on diversity. When studying the effects of fire as a disturbance, it must be taken into account that the type of fire regime, the habitat in which the fire occurs, and the type of fire are factors which ultimately affect the outcome. A very hot fire, for example, may be detrimental to large trees, while a colder fire will remove excess material. If climax sweetveldt grassland is burned regularly, it will lead to a loss in plant species diversity as well as denudification (Tainton, 1999). According to Fox and Fox (1986), using fire too frequently will lead to the loss of seedling regenerators, which will ultimately reduce plant species diversity, while by using the same type of fire at the correct frequency, species diversity will be increased.

Regardless of the long-term effects that fire may have on plants, Bouwman and Hoffman (2007) discovered that bird numbers and species richness increased in burned areas immediately following burns in South African grassland. In these areas, more species were attracted to the burned areas than were lost. After a few months, avian species richness and densities returned to the pre-burn conditions. On the other hand, an unpublished study conducted in the Molopo Nature Reserve – which also falls within the Bophirima District – found that fire had a significant decreasing effect on bird numbers and species richness (H. Bouwman, personal communication, November 2, 2009). This decrease could possibly be attributed to the reduction in food, shelter, and nesting sites caused by the fire. Since this particular area is continually overgrazed and also experiences extended periods of drought, the fire-altered vegetation structure would take longer to recover back to normal, which in turn would extend the effect on bird numbers and species richness.

Fragmentation of habitats leads to these habitats becoming increasingly vulnerable to invasion by exotic species. Species occupying these habitats also become susceptible to local extinctions due to stochastic events (Doherty *et al.,* 2000). When it comes to animal species, predation increases in diminished patch size, since predators have better access to areas within the patch where they are usually excluded from. The diversity of bird species has been found to be directly related to fragment size, decreasing as areas become more fragmented and habitat fragments become smaller (Askins *et al*., 1987; Bennet, 1987; Hobbs, 1993).

The major focus of this study was to determine the effect the change in landscape – from natural to urbanised - on bird diversity and distribution. Urbanisation and its effects on species diversity will be examined in a later section of this chapter.

2.3. FACTORS INFLUENCING BIRD DIVERSITY

In order to understand the distribution and abundance of a species, we need to know its history, the resources it requires, the individuals' rates of death, migration, their interactions with their own and other species, and the effects of environmental conditions (Begon *et al.,* 2006). When humans drastically alter the environment, the factors determining birds' ability to utilize those areas are changed, which usually leads to a change in the bird species composition of those areas (Hockey, 2003) since birds are mobile and are able to move away and escape the initial habitat transformation. However, birds are also capable of observational learning (Klopfer, 1961) and that, together with their high mobility, makes them able to easily occupy altered habitats such as villages and use the opportunities created by them. Important factors influencing birds – and most other organisms – are the resources and conditions which they need to survive and thrive. The distribution of birds is determined by their needs and the availability of the resources and conditions needed to fulfil those needs, as well as their ability to learn to adapt to new environments and exploit new resources.

Tilman (1982) defined resources as all things consumed by an organism. But 'consumed' does not refer only to being 'eaten' (Begon *et al.,* 2006). In the case of birds, resources may refer to the food available for them to feed on, the trees available for them to nest in, partners available for them to mate with, and so on. All of these things can be 'consumed' in the sense that the stock or availability can be reduced by the activity of organisms.

A condition is an abiotic environmental factor that influences the function of living organisms. Examples include temperature, relative humidity, pH, salinity and the concentration of pollutants. A condition may be modified by the presence of other organisms. For example, temperature may be altered under a forest canopy. Unlike resources, conditions are not consumed or used up by organisms (Begon *et al.,* 2006).

According to Begon *et al.* (2006), each of the conditions affecting organisms should be understood within the framework of the ecological niche. The term ‘ecological niche’ is frequently misunderstood or misused. It is often used to describe the sort of place in which an organism lives, when in fact a niche is not a place but rather an idea – a summary of an organism’s tolerances and requirements (Begon *et al.,* 2006). For example, the habitat of a particular bird species may be a forest. Each habitat, however, provides many different niches: many other organisms may live in the same forest as the bird, but with quite different lifestyles. A niche describes how, rather than just where, an organism lives (Begon *et al.,* 2006). To summarise: a bird’s habitat may be a large forest, but its niche will be a particular part of the forest where certain food sources grow and where specific nesting or roosting requirements are met and so on.

Birds respond more to the physical structure of the environment than to its botanical make-up. Human intervention can lead to negative effects on species diversity and numbers. Development by humans usually leads to deforestation, land degradation, invasion of exotic species – all of which may cause the area to become unsuitable for certain species. The destruction of a forest, for example, will lead to the loss of forest specialists, but man-altered habitats create environments that can be exploited by generalist species (Hockey, 2003).

In southern Africa, man-made structures form suitable breeding places for certain species while some water-dependent species, such as Burchell’s Sandgrouse, have benefitted from the construction of dams and miniature wetlands created by man for irrigation and stock watering purposes (Hockey, 2003). So while habitats are sometimes lost with development, new habitats and niches are also created, depending on the kind of development taking place and the level thereof. This is once again where the intermediate disturbance hypothesis comes into play – with new opportunities being created and different resources and conditions being available for organisms at intermediate levels of disturbance.

It is thus important to determine exactly what the most important resources and conditions are that influence the lifestyles of birds, keeping in mind that in the Bophirima District, all these factors are influenced by desertification and urbanisation.

2.3.1 FOOD AVAILABILITY

Many studies have been done to determine to what extent the availability of food influences the movement and distribution of birds. It has been found that there is a definitive correlation between frugivorous species and fruit availability in tropical rainforests (Doherty *et al.,* 2000). The distribution of insectivores may also be affected by food availability, but since insects are quite widespread, the results may not be quite as profound as with frugivores. Similarly, in savanna and grassland habitats, seed-bearing grasses are quite abundant, with the result that food availability may not be a definitive indicator of granivore distribution in such areas.

Carnivorous birds are to a much greater extent influenced by the availability of food sources (Casey and Hein, 1983). Raptors also tend to be much greater specialists than birds of other feeding guilds, with many species being dependent on specific kinds of prey. Since there are raptors with different hunting techniques, some of them may also be dependent on perches to hunt from or large open areas to hunt in (Casey and Hein, 1983).

Johnson and Sherry (2001) found that the availability of food does influence the distribution of birds. However, their study did not take vegetation structure into account when selecting their research sites. If the availability of food is not a limiting factor, or if birds cannot track variations in food availability in different habitats, then food availability will not be a determining factor in the distribution of bird species.

2.3.2 WATER AVAILABILITY

To survive in a desert landscape, birds need to balance water loss with water intake (Dean, 2004; McKechnie, 2007). Different bird species have different needs for water.

Many birds that occur in the drier areas of southern Africa do not need a regular supply of water (Maclean, 1993). On the other hand, some granivorous species and birds such as certain lark and sandgrouse species are dependent on a daily supply of water, which obviously restricts their distribution (Hockey, 2003). According to McKechnie (2007), desert birds fall into one of three categories. Many species are obligate drinkers and need a regular supply of water, particularly species that feed predominantly on dry seeds. Sandgrouse, doves, pigeons, bulbuls, starlings, sparrows, waxbills and finches fall into this category and need to visit waterholes on a daily basis.

Other species such as mousebirds and partly granivorous birds can survive for long periods on water obtained from their food, but need to drink occasionally in order to balance their water budgets. Species that are totally independent of water, such as certain falcons, most insectivorous larks and certain chat species, belong to the final category. Some of these species can survive and breed in totally waterless places. Thus, water availability will have a different impact on different bird species.

2.3.3 VEGETATION STRUCTURE

The role of vegetation structure in the shaping of faunal communities is not entirely clear, but vegetation can provide resources for nesting, foraging, and protection for a variety of taxa (DeWalt *et al.,* 2003). Studies have found a positive correlation between vertical height diversity of vegetation and the number of birds in forest areas (MacArthur and MacArthur, 1961). Dean (2000) found that bird species richness increased with an increase in taller, woody vegetation when compared to the surrounding shrubland of the Karoo areas of South Africa. A similar study in the semi-arid savanna of the Northern Cape also found a strong positive association between bird species richness and foliage height diversity (Ward and Kaphengst, 2008). Other studies conducted in forests (Wilson, 1974) and desert scrub (Tomoff, 1974) showed no positive correlation between vegetation height diversity and bird species diversity. According to Flather *et al.* (1992), the vertical habitat structure alone cannot account for bird species distribution, and spatial heterogeneity also needs to be taken into account in order to effectively predict avian species diversity. The planting of trees in afforested grasslands in Illinois, USA caused a rapid decline in grassland species as well as the total number of species found in the afforested area (Naddra and Nyberg, 2001). During a study conducted in the Colorado River valley by Meents *et al.* (1983), it was found that responses to vegetation varied among species.

These conflicting findings indicate that bird distribution is either more dependent on other factors than vegetation structure and spatial heterogeneity, or that these studies were affected by variables which were overlooked by the researchers.

2.3.4 NESTING SITES

Many organisms often use a non-random portion of their habitat for nesting (Rotenberry and Wiens, 1998; Clark and Shutler, 1999). Lim and Sodhi (2004) believe that the availability of nesting sites is an important factor in the decline of certain bird species in urban habitats. Bird species can be classified into different nesting guilds, according to their nesting preferences, and their presence and/or abundance in an area is often affected by the availability of suitable nesting places. Nesting guilds will be further examined in the next chapter.

2.3.5 COMPETITION AND PREDATION

Species are affected by the conditions they live in and the resources that they obtain, but no organism lives in isolation. Each is a member of a population composed of individuals of its own species, and these individuals have very similar requirements for survival, growth and reproduction. Their combined demand for a resource may exceed the immediate supply, causing them to compete with each other for those particular resources (Begon *et al.,* 2006). This is called intraspecific competition.

In addition, individuals from two or more different species may have similar resource requirements which may lead to interspecific competition. Subsequently, certain species or individuals become deprived of resources because they are unable to compete efficiently enough with stronger competitors (Begon *et al.,* 2006).

Completion in birds can be for food, nesting sites, song perches or hunting perches and is usually strongest among species of the same feeding or nesting guild, thus competing for the same food sources or nesting sites.

Predation is the consumption of one organism (the prey) by another organism (the predator), in which the prey is alive when the predator first attacks it. The effects of predation are a reduction in prey population size, "weeding out" of older and weaker individuals, and reducing intraspecific completion within the prey species.

Humans can increase the effects of predation through the fragmentation of habitat (Keyser, 2002), the destruction of suitable nesting habitats for birds (Collias and Collias, 1984) and the introduction of predators such as domestic cats and dogs (Maestas *et al.,* 2003).

2.4 THE SCOPE AND CONTENT OF URBAN ECOLOGY

Urban ecology is a concept that has obtained many different definitions over the past two decades. To give the most basic definition, one must look at the two words on their own. The word "urban", according to the Oxford dictionary, refers to something which has a connection with a town or city. "Ecology" is defined as the study of the relation of living creatures to each other and to their environment. Thus, by putting the two together, urban ecology refers to the manner in which organisms relate to each other and their surroundings within a habitat dominated by humans, such as a city, town, or village. According to Niemelä (2000), urban ecology is simply ecological research being done in cities and towns. Urbanisation can be characterized as an increase in human habitation, coupled with increased per capita energy consumption and extensive modification of the natural landscape (McDonnell and Pickett, 1990).

Urban ecology is a growing field of study which is gaining importance since more and more people are moving into urban areas, causing these areas to expand and replace natural habitats. In the last couple of millennia, the earth has been transformed from an expanse of neighbouring habitats that were only interrupted by natural barriers to a patchwork of natural, human-modified and thoroughly destroyed habitats (Meffe and Carroll, 1997). There is irrefutable evidence that humans have altered virtually all of the earth's ecosystems, even the most remote ones (McIntyre *et al.,* 2001). These facts, accompanied by the statement by the UN Human Settlements Program (2004) that urbanisation is currently proceeding globally at a rapid rate, proves why it is important to study urban areas and their impact on ecological processes.

As a natural science, urban ecology is still a young discipline. For a very long time urban areas were not deemed worthy of being studied with regards to ecology. Any plant and animal life in cities were considered coincidental. Urban ecologists have since found that urban communities were not merely coincidental and that by understanding the influences, disturbances and extent of modification in urban areas, ecologists could contribute to conservation, healthier cities, and happier people (Sukopp, 1998).

Urbanisation is increasing at a tremendous rate. With the current trends, 65% of the world's population will live in urban environments by the year 2025 (Pacione, 2003). It is commonly known that urban areas are complex and heterogeneous places with many different human influences and disturbances which lead to pollution and other problems (Sukopp, 1998), thus placing any patches of urban nature in danger if sustainable development is not implemented. Pacione (2003) defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. He elaborates by stating that the concept of sustainable development is based on three principles, namely:

1) Intergenerational equity, which requires that natural capital assets of at least equal value to those of the present are passed on to future generations
2) Social justice, which requires that fair and equitable use is made of present resources in terms of meeting the basic needs of all and extending to all the opportunity to satisfy their aspiration to a better life
3) Trans-frontier responsibility, which requires the recognition and control of cross-border pollution and other effects

2.4.1 DIFFERENT TYPES OF URBAN LANDSCAPES

The urban environment is a complex of habitats developed by humans from natural sites or agricultural land. Houses, villages, towns, cities, buildings, roads, and other features that characterize the urban environment have gradually and irrecoverably changed the landscape of natural areas. As part of this change, some habitats and their associated plant and animal communities were eliminated, while others were expanded and some new ones were created (Robinson, 2005).

Urban landscapes are generally understood as being the existing landscape of urban settlements and their surroundings where urban land-use forms are present. Urban landscapes consist of a mixture of land-use forms, from typically urban types such as residential estates or industrial areas, to cultivated types such as former agricultural remnants and forest landscapes. Comparing these areas is difficult because they differ in aspects such as the density of built-up areas, the elements of the land-use mixture and the parts of the pre-existing landscape that remain (Breuste, 2003).

Gilbert (1989) distinguishes between three different types of urban landscapes, namely technological, gardenesque and ecological landscapes.

- Technological landscapes are those where the biological landscape has been substantially replaced by artificial substitutes. These landscapes dominate in city centres where the density of people requires most surfaces to be hard. Machinery creates the most of these expensive unnatural areas characterized by materials such as concrete, tarmac and fibre glass. Few types of plant material are used in these areas, displayed mainly as a static, highly designed, costly landscape solution, functional rather than aesthetic.
- Gardenesque landscapes are landscapes where the biological elements are able to function only under continuous management. Most people are thought to prefer picturesque landscapes that are managed, which represents a controlled and improved aspect of nature. These landscapes are primarily aesthetic, requiring big design and maintenance inputs which include mowing, weeding, sweeping and so on.
- Ecological landscapes are a low-cost low-maintenance type of landscape in which man coexists with nature without dominating it. Natural elements are allowed to function in a natural manner.

Villages in the Kalahari can be classified as ecological landscapes although it does not quite fit the definition advanced by Gilbert (1989). A certain amount of natural vegetation and wildlife remains within these villages, but these elements are not necessarily able to function entirely in a natural manner as Gilbert claims. Even though nature coexists with humans, all urban areas, including ecological landscapes, are designed to accommodate people, and their needs will always come first.

Gilbert (1989) explains three ways in which these landscapes arise:

- Firstly, it can be formed by encapsulated countryside that persisted by chance. This usually occurs near the urban fringe. Kendle and Forbes (1997) state that it is relict countryside that happened to escape development as a consequence of land ownership constraints, soil, topography or poor accessibility. They also state that there are social and biodiversity reasons for conserving such sites that have maintained their original status.
- Secondly, ecological landscapes can be created by local authorities, who felt that they were making useful additions to the land-use mosaics in towns (Gilbert, 1989). Kendle and Forbes (1997) refer to these as “man-made ecological landscapes”. Approximately 60-70% of urban vegetation is deliberately planted (Gilbert, 1989) and planted landscapes are likely to include many different styles (Kendle and Forbes, 1997), with urban gardens being an important source of alien plants (Sullivan *et al*., 2001; Raloff, 2003).
- Lastly, there are landscapes that develop as unofficial wild spaces where nature has a free hand (Gilbert, 1989). Kendle and Forbes (1997) refer to these areas as “spontaneous flora and fauna”. These spaces can vary in size from railway banks to a crack in the pavement, but all tend to be informal and exhibit various degrees of local character. There is usually minimal or no design input with low management, which enables plant succession. Wildlife is usually present and ecotones develop where edges are supposed to be, with native and naturalized species dominating (Gilbert, 1989). Because of the unique environmental and biotic factors caused by human disturbances, specific plant and animal communities are able to establish. Urban communities of plants and animals are the result of the action of a complex dynamic of interacting forces, making them valid subjects for study (Kendle and Forbes, 1997).

According to Pickett *et al.* (1997) there are two reasons why integrated research into urban areas is required:

1) Urban areas represent new combinations of stresses, disturbances, structures, and functions in ecological systems. Understanding how urban ecosystems function could add to the understanding of ecosystems in general.
2) The spread of urbanisation into agricultural lands or into relatively wild forests is one of the three major global impacts of humans.

Furthermore, most people live in urban areas and urban nature can play an important role in recreation and residential wellbeing (Niemelä, 1999). The ecological processes in urban areas are comparable to those outside them, meaning that population biology and ecological processes can be studied. In addition, the poorly documented variation in urban habitat types and their species diversity needs to be studied so that explanations can be found for the phenomena and predictions of changes due to urbanisation (Sukopp and Numata, 1995).

2.4.2 THE EFFECT OF URBANISATION ON BIODIVERSITY

The full extent of humans' involvement in determining the present pattern of vegetation in semi-natural areas emerged only recently. The shortage of detailed ecological studies carried out in urbanised areas means that only incomplete evidence and scattered examples are available to illustrate anthropogenic influences. This lack is greatest with regard to animal diversity (Gilbert, 1989). Urban areas need to be studied intensively to determine what the influence of urbanisation is on species richness, the spreading of exotic taxa, and to determine how certain plant and animal species are adapted to survive in urban areas.

Every year, more and more exotic plant species are introduced into urban areas. The most common garden plants are mostly exotic species and the establishment of alien plants has been identified as an important influence of urban areas (Alston, 2006). People seldom plant indigenous flora in their gardens, mostly because nurseries tend to supply a larger number of exotic species than indigenous ones, and people tend to beautify their gardens with modern cultivars and hybrids. The large numbers of foreign organisms that are introduced into urban areas, whether intentionally or unintentionally, could impose a considerable inoculation pressure on urban habitats, with the result that many of the species might eventually find a vacant niche and manage to become established in the area. When exotic species become established, they directly influence the species native to the area (Gilbert, 1989).

In a study conducted by White *et al.* (2005) in Melbourne, Australia, four broad habitat types were identified within the urban environment, representing a continuum of modification ranging from parks with remnant vegetation, to streetscapes dominated by native vegetation, and those dominated by exotic species. The aim of the study was to determine how birds reacted to changes in vegetation. The four identified habitat types were:

1) Parks: areas which consisted predominantly of woodland or forest remnants of indigenous vegetation, including revegetated areas and plantings of non-indigenous natives.
2) Native streetscapes: these areas included established residential streetscapes that contained predominantly native (but not necessarily locally indigenous) trees.
3) Exotic streetscapes: established residential streetscapes that contained predominantly mature, exotic trees.
4) Recently developed streetscapes: recently landscaped residential streetscapes lacking mature trees. These areas occurred mainly in new housing estates characterized by limited planting and structural diversity. Native and exotic species were present in this habitat.

Urban parks with forest remnants were chosen to represent the units of least modification. Recently developed streetscapes represented the highest level of modification. Bird censuses were conducted throughout the urban area and it was found that the four habitat types supported significantly different bird communities based on species richness, abundance and composition, suggesting that bird assemblages of urban environments are non-uniform. Parks and native streetscapes generally supported fewer introduced bird species than the exotic and recently developed streetscapes. Overall abundance and species richness were lower in the exotic and recently developed streetscapes than in parks and native streetscapes – an indication that indigenous vegetation may attract more indigenous birds (White *et al.,* 2005).

However, many other studies found that vegetation structure, rather than species composition, has an impact of bird species and their distributions (MacArthur and MacArthur, 1961; Dean, 2000; DeWalt *et al*., 2003).

White *et al.* (2005) also observed significant differences in foraging guilds within the four habitat types, with parks having the most foraging guilds and recently developed streetscapes having the fewest. One of the most notable changes in assemblage composition was the loss of insectivorous bird species with the transition from native streetscapes to exotic and recently developed streetscapes.

Despite their global ubiquity, surprisingly little is known about how insects and other arthropods respond to urbanisation, even though urbanisation has been identified as one of the leading causes of declines in arthropod diversity and abundance (McIntyre *et al.,* 2001), which in turn may explain why insectivorous birds might be scarcer in certain urban areas (Blair and Johnson, 2008).

White *et al.* (2005) claim that the implementation of effective strategies and incentives which encourage the planting of structurally diverse native vegetation in urban areas should be paramount if avian diversity is to be retained and enhanced in urban environments. Furthermore, it is important to encourage the maintenance of the existing remnant vegetation in urban environments. By protecting existing indigenous vegetation and planting native plants within streetscapes and gardens, more complex bird communities, largely composed of native species, should be favoured (White *et al.,* 2005).

It is important to note that despite the high stress levels caused by various factors associated with urban life such as noise (Katti and Warren, 2004), chemical contaminants (Burger *et al.,* 2004), and threats from domestic predators (Sorace, 2002), a number of new ecological niches have been created through urbanisation (Gilbert, 1989; Blair and Johnson, 2008) and urban habitats worldwide are characterized by high population densities of various taxa (Marzluff *et al.*, 2001; Beckmann and Berger, 2003). Unique nesting and foraging opportunities are created through urbanisation, and some species are able to achieve great success by exploiting those opportunities (Lancaster and Rees, 1979; Beissinger and Osborne, 1982; DeGraaf and Wentworth, 1986; Miller *et al.,* 2003).

Today, urban habitats worldwide are characterized by high population densities of various plant and animal taxa (Marzluff *et al.,* 2001; Beckmann and Berger, 2003). The new niches created by urbanisation are increasingly being occupied by vertebrates, especially birds and mammals. In a study attempting to explain the phenomenal success of the House Sparrow *Passer domesticus*, Summers-Smith (1963) suggested that the bird's secret was that while becoming adapted to living close to humans it had not become so highly specialized that it was restricted to a very limited niche. It is a general feeder, flexible in choice of nest sites, has few successful enemies, and is very tolerant of disturbance. In South Africa, other species that have become accustomed to using buildings for nesting sites include various swallow species, the Speckled Pigeon *Columba guinea*, and the Common Mynah *Acridotheres tristis*.

Since a major urban food source is often available in the form of scraps of human food, or domestic pet food, non-territorial seed eaters and omnivores that gather food on the ground are at an advantage and certain species are to some extent pre-adapted to the new niches (Gilbert, 1989), especially generalist feeders (Campbell, 2009).

Safe nest sites, safe roosting sites and an absence of natural enemies or persecution by farmers are additional reasons why urban areas are favourable to birds (Sodhi, 1992; Petit *et al.,* 1999; Gering and Blair, 1999). Goldstein *et al*. (1986) advances that ordinary habitat factors such as these remain the main determinant of bird success in urban areas. Vertebrates poorly adapted to urbanised areas are those with specialized habitat or feeding requirements (Gilbert, 1989). When it comes to birds, granivores, omnivores and cavity-nesting species are usually quite common in urban areas (Miller *et al*., 2003; Blair and Johnson, 2008; Chamberlain *et al.,* 2009) while insectivores and ground-nesters are scarce (Blair, 1996; Marzluff, 2001; White *et al.,* 2005; McKinney, 2006; Clergeau *et al.,* 2006; Clark *et al.,* 2007; Blair and Johnson, 2008).

2.5. THE EFFECTS OF CLIMATE CHANGE AND DESERTIFICATION ON BIRDS

According to Simmons and Barnard (2005), the grand sweep of environmental change has always been impressive in the African continent. Climate change has always been a fact of life for the continent, which without a doubt helped drive the evolution and diversification of Africa's extraordinary mammals, plants, insects, reptiles and birds. It has been a powerful shaper of the continent's biodiversity, but that was before 850 million people inhabited the continent.

Human population pressure alone alters everything about the vulnerability of birds as well as other wildlife and ecosystems. It also brings on global environmental change and especially climate change. For poorer communities in Africa, the additional pressure of climate change is potentially devastating (Simmons and Barnard, 2005). Africa has been identified as the continent most vulnerable to the effects of global warming (Hulme, 1996). This is partly because of the large proportions of arid and semi-arid landscapes in the continent, and partly due to Africa's low financial, technical and institutional capacity to mitigate the impacts of climate change (IPCC, 2001).

Global climate warming has been conclusively linked to anthropogenically-increased CO_2 levels in the atmosphere and is predicted to threaten over a million species with extinction by 2050 (Simmons *et al.,* 2004). Climate change will affect individual species within ecosystems differently. This will cause some species relationships to uncouple and ecosystem composition to change in complex ways. In southern Africa, birds are probably already responding in different ways, some of which may be hard to predict, especially since studies of the impact of climate change on Africa's biodiversity have lagged badly behind the rest of the world. Unlike birds from more temperate areas like Europe, many birds breed in response to rainfall, rather than rising temperature. In arid regions, rainfall can spark intense nesting activity in birds and can also help predict clutch size and the number of clutches laid in a season. It can thus be expected that birds will breed less regularly and less successfully under lower rainfall regimes. Larger birds may be physically better buffered against these effects than smaller species, because they can store resources obtained during good times for use under more stressful conditions. On the other hand however, larger birds are more vulnerable to other environmental changes, such as habitat fragmentation and pollution (Simmons and Barnard, 2005).

Birds migrating from Europe may be especially affected by climate change in southern Africa. These birds may spend more time searching for food from rain front to rain front and spend less time actually feeding. This could eventually lead to later migration departures and arrivals and overall population declines (Simmons and Barnard, 2005). Species with specialized feeding niches, such as pollinators, are also at risk of population declines, based on low ability to adapt to new environments. Small nomadic species with short generation times may be least at risk (Simmons *et al.,* 2004).

In a study of birds, mammals, reptiles and insects, it was found that 78% of species are likely to shift their ranges under a climate in which mean temperature is raised by only 2°C. Most species moved in an easterly direction and a few were expected to become locally extinct (Simmons and Barnard, 2005). The reason for the changes in the range of bird species is not immediately obvious, but it is suggested that the border of the arid zone itself is moving (Hockey, 2003). Birds, like many other species, have been through climate shifts in their evolutionary history, and have usually been able to adapt to these changes (Simmons and Barnard, 2005). Desert birds in particular have evolved several physiological characteristics that make them suitable to their environments. These adaptations include slower metabolism and the ability to regulate their body temperature (McKechnie, 2007). A current concern is that climate is changing so rapidly – in evolutionary terms – that some birds, particularly larger species with slow breeding rates, will be unable to adapt in time (Simmons and Barnard, 2005).

Research has also focussed on the likely prospects for six smaller species in South Africa. All are likely to be threatened by climate change and prediction models suggested that the average range reduction in these six species would be 40% (Simmons and Barnard, 2005).

Being mobile organisms, birds should be able to respond to climate change more rapidly than sessile plants or terrestrial animals which require contiguous habitat corridors for dispersal. Landscapes that have been transformed by agriculture, urbanisation or fragmentation are more difficult for certain organisms to disperse across. Land transformation and development severely strains the ability of many species, including birds, to move away (Simmons *et al.,* 2004).

As ecosystems are altered by climate change, the birds that inhabit them will simultaneously be affected. The on-the-edge existence of many birds in arid habitats makes them particularly vulnerable to changes in their physical environment. Higher temperatures will increase the amount of water required by desert birds and may lead to catastrophic mortality events during future heatwaves (McKechnie, 2007).

Climate change is expected to bring on major habitat transformation in some desert areas, including devastating effects on several African deserts, particularly the Kalahari Desert. Permanent vegetation will be lost, which will affect bird communities, and avian diversity in large parts of the Kalahari will be decimated (Thomas *et al.,* 2005).

2.6. SYNTHESIS AND HYPOTHESES

2.6.1 SYNTHESIS

The purpose of the literature review was to highlight the most significant factors influencing the distribution, diversity and abundance of birds. Studies by Schluter and Repasky (1991), Gonnet (2001) and Johnson and Sherry (2001), identified the availability of food as the most important factor. Keyser (2002) highlighted the importance of nesting sites while nest predation was indicated as important by Liebezeit and George (2002). The composition of plant species was discussed by Dean *et al.* (2001) and while there was some disagreement in different studies about the importance of vegetation structure, it is important to note that vegetation structure plays a role in most of the other factors influencing birds. The type and structure of vegetation growing in a habitat directly determines the amount of food and nesting sites available (Chase, 2002), which in turn impacts the degree of competition existing among birds. Birds also seek refuge among vegetation, which can save them from predation (DeWalt et al., 2002). Different species of birds have different foraging methods – some feeding off the ground, others among trees or directly from grass tufts. The vegetation cover and structure in an area thus influences the foraging opportunities for different species (Hino *et al.,* 2002). Vegetation also provides song perches (Koford and Best, 1996) as well as perches for raptors to hunt from (Maclean, 1993).

Various studies have found that changes in vegetation structure brought on by land-use have an impact on biodiversity (Flather *et al.,* 1992; Knick, 2000; Gonnet, 2001; Maestas, *et al.,* 2003) and urbanisation is an important cause of habitat alteration. It is important to take into account that in addition to altering vegetation structure and composition, urbanisation imports another aspect of habitat complexity, namely the erection of structures, increased movement, disturbance, pollution, additional food and water sources, and the presence of humans. The combination of these creates opportunities for those bird species that can tolerate, adapt, and even thrive. It is important to note that all of the factors influencing birds are ultimately impacted by climate change.

2.6.2 AIMS OF THE STUDY

The aims of this study were:

- To investigate the effects of villages on avian diversity by comparing species richness and number of birds within the village habitat to that of the natural habitat
- To determine how different feeding and nesting guilds respond to urbanisation
- To determine whether certain species can be used as indicators of urban land-use

2.6.3 HYPOTHESES

Hypothesis 1: At intermediate levels of disturbance, represented by small rural villages in the Kalahari, bird numbers and species richness will increase.

Hypothesis 2: Bird numbers and species richness will decrease towards the edges of the villages and outside the villages, where the opportunities brought on by intermediate disturbance become less or are located further away.

Hypothesis 3: Different guilds will respond differently to urbanisation; some increasing in richness while others decrease

In order to test these hypotheses, I carried out a study of bird populations in three different villages in the Bophirima District, which is classified as a desert margin area in the Kalahari region of the North West province of South Africa. The research framework and methodology used in the study are discussed in Chapter 3.

CHAPTER 3:
RESEARCH METHODOLOGY

3.1 INTRODUCTION

The Bophirima District is an arid environment classified as a desert margin area and has been earmarked for research by the Desert Margins Program (DMP).

The area was ideal for this study since there is quite a diversity of birds, with over 160 species occurring in the area (Maclean, 1993). A single vegetation type exists throughout most of the region, making it easier to see where a change in vegetation influences bird diversity. Furthermore, the Bophirima District is an area with many small villages – which are the target areas for this study. These villages vary in size, but have the same basic structure and composition of small houses, schools, clinics and mostly unpaved roads. A fair amount of natural vegetation remains intact within all of the villages. Studying these villages is the key to testing hypotheses 1, 2 and 3.

There is communal farming in and between the villages, with some cattle, goats and donkeys being kept in yards, and others grazing freely around in the natural habitat surrounding the village. The degree of land degradation in and around the villages varies from one village to another.

There is very little variation in the topography of the area, which is good since topography changes can bring on changes in vegetation structure and composition which in turn affects bird diversity (Waterhouse *et al.,* 2002). According to Low and Rebelo (1998), the geomorphology is also consistent throughout the area, which also keeps the vegetation type and structure consistent.

Variations in bird abundance and local distribution will be identified and statistically tested in order to investigate hypothesis 4.

3.2 RESEARCH FRAMEWORK

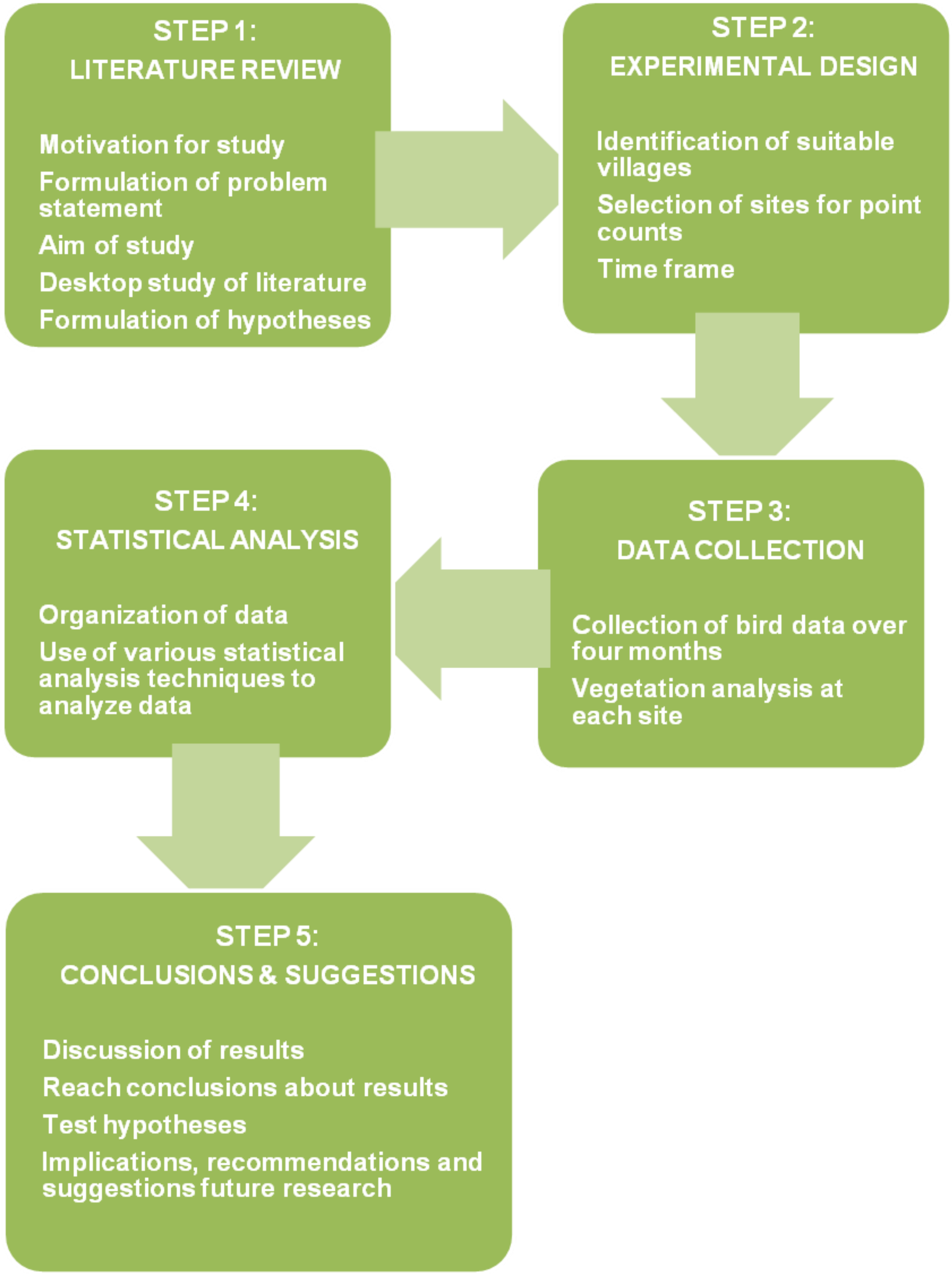

Figure 3.1: A diagrammatic representation of the research framework

3.3 RESEARCH AREA

The North West province is the sixth largest province in South Africa and occupies an area of 116 320 km^2. The North West province borders Limpopo to the north-east, Gauteng to the east, the Free State to the south and the Northern Cape to the west. Botswana lies on the northern border of the province (Mangold *et al.,* 2002).

Many villages have developed in the Bophirima District of the province, where urban sprawl is an ongoing process, with human settlements expanding and continually replacing natural habitat. The study area consists of three villages at which the research was done. The villages were chosen according to the following criteria:

- The settlements must be reasonably compact and have the appearance of a village or small town
- The villages must be some distance apart so that they don’t have an effect on each other
- The surroundings of the settlement must have natural vegetation
- The natural environment surrounding the villages should have as little as possible impact from other anthropogenic factors (such as roads), although this might be difficult to achieve
- The natural habitat surrounding the villages have to be accessible, since part of the research would take place in these areas

3.3.1 POSITION OF STUDY AREA

The study area lies between the 26° South and 27° South lines of latitude and between the 24° East and 25° East lines of longitude. The three villages were chosen; Austray (S26°28’ E24°10’), Mmagabue (S26°37’ E24°8’) and Southey (S26°46’ E24°1’).

Figure 3.2: The position of the study area is indicated by the red oval

3.3.2 CLIMATE AND RAINFALL

The North West province is characterized by great seasonal and daily variations in temperature. Summers can be very hot, with daily average high temperatures of 32°C in January. Winters are mild to cold, with daily average low temperatures of 0.9°C in July. Seasonal fluctuations in mean temperatures between the warmest and coldest temperatures exceed 15°C in the western region, where the study took place. The north-western parts receive between 1 and 30 days of heavy frost per year (Mangold *et al.,* 2002). Relative humidity is typically low throughout the province, being below 28% in the winter. In February, which is the month with the highest relative humidity, it can range between 64-66%. This gives rise to high potential evapo-transpiration rates, which affects the resident fauna and flora (Mangold *et al.,* 2002). Rainfall is highly variable across the entire North West province, with the western parts receiving less than 300 mm per annum. Rainfall in the area usually takes place in the late summer, with a peak in February. High variability in annual rainfall has been documented in the area. Evaporation exceeds precipitation levels in most of the North West province, but especially in the more arid, north-western region of the province where the study took place. Runoff as a percentage of the rainfall is less than 1% in the western parts (Mangold *et al.,* 2002).

3.3.3 VEGETATION TYPE

Most of the North West province falls within the savanna biome with its associated bushveld vegetation. According to Low and Rebelo (1998), nine different vegetation types are found in the province. Given the arid and semi-arid conditions of the western parts, the vegetation of this region largely comprises xerophytes – plants that are adapted to these hot and dry conditions. As a result, the western part of the province has a lower biomass, productivity and species richness compared to the eastern half of the province (Mangold *et al.,* 2002).

The entire Bophirima District of the province falls within the savanna biome and can be divided into two veldt types. The first veldt type is known as the Mafikeng Bushveld which is located in the North West province west of Mafikeng and south of the Botswana border. It stretches westwards to around Vergeleë, and southwards to Piet Plessis and Setlagoa. It has an altitude of 1100 – 1400 meters (Mucina and Rutherford, 2006).

The vegetation and landscape features include well-developed tree and shrub layers, with dense strands of *Terminalia sericia*, *Acacia luederitzii* and *A. erioloba* in certain areas. Shrubs include *Acacia karroo*, *A. hebeclada*, *A. mellifera*, *Grewia flava*, *G. retinervis*, *Rhus tenuinervis* and *Ziziphus mucrunata*. A well developed grass layer is also present (Mucina and Rutherford, 2006).

The second veldt type is known as the Molopo Bushveld, which is distributed in the North West and Northern Cape provinces. It is located in the Molopo area from Bray and Werda in the north (on the border of Botswana), southwards through Morokweng and Tosca in the east and Vorstershoop and Eldorado in the west to Bendell in the south. The altitude is 1000 – 1300 meters (Mucina and Rutherford, 2006).

The vegetation and landscape features consist of open woodland to a closed shrubland with the trees *Acacia erioloba* and *Boscia albitrunca* and the shrubs *Lycium cinerum*, *L. hirsitum* and *Rhigozom trichotomum*. The grass layer is well developed in parts of the north-east, but is usually fairly open (Mucina and Rutherford, 2006).

The low rainfall of the area, together with the sandy soil and grazing by livestock can heavily impact the structure of these vegetation types. In addition, these vegetation types are poorly conserved (Low and Rebelo, 1998) with people constantly altering or removing vegetation where villages are located.

3.3.4 SITE VARIABLES

The locations of the individual villages are indicated in Figure 3.3 below.

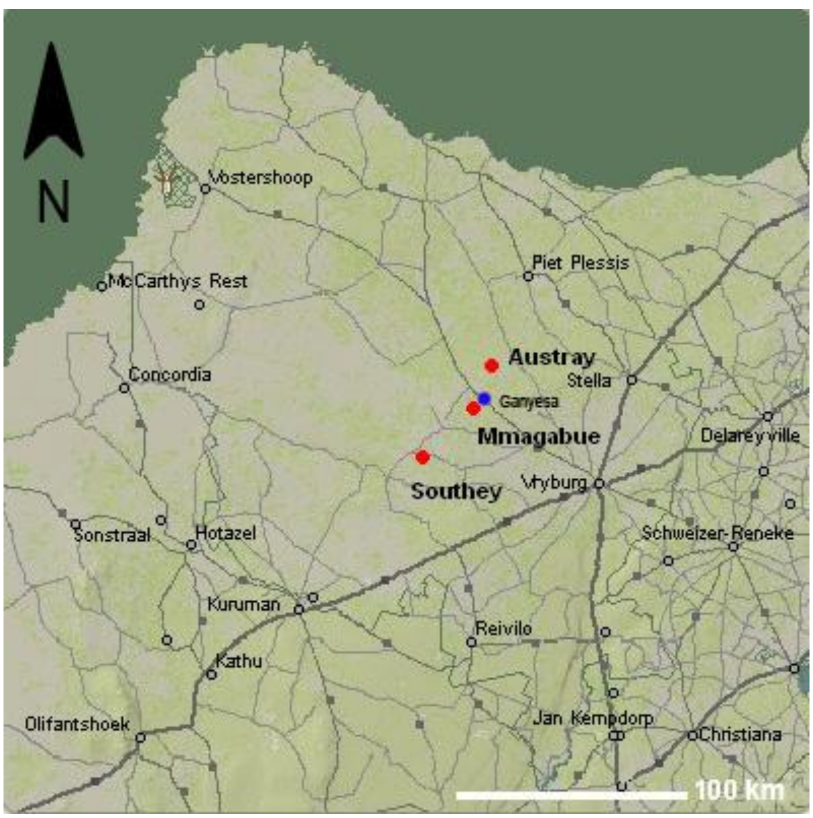

Figure 3.3: The positions of the three research sites relative to each other within the Bophirima District of the North West province. Ganyesa, indicated by the blue mark, is another village which will be referred to later on.

A detailed description of each of the three villages will be given in the following sections of this chapter.

AUSTRAY

Austray is the largest of the three villages that were used in this study and comprises and area of approximately 152 hectares. The population size is approximately 742 people. Structures in the village consist mainly of houses, which are built relatively close to each other. A school, clinic, cemetery and a small cafe are present. A few open, undeveloped areas do exist between some of the houses. Roads throughout the village are unpaved, and the areas adjacent to the roads do not consist of planted lawns, but comprise natural vegetation.

Most of the grass in the village, especially next to the roads, consists of *Cynodon dactylon* and *Urochloa mosambicensis*, which are species commonly associated with disturbed areas. Most yards are bare, with grass removed from around the houses. Many villagers do, however, enjoy gardening and some of them have quite a diversity of flowering garden plants, although their gardens are rather small.

Most of the villagers have domestic chicken, turkey, or geese which they keep in their gardens. The feeding of their poultry provides a source of food for wild birds as well. Domestic dogs are quite common and some villagers also have cats. Rock Doves (Feral Pigeons) live freely on the rooftops of houses with only a few kept in cages. These birds were never observed in the natural habitat surrounding the village which indicates that they were probably introduced to the area by humans.

Cattle, goats and donkeys are the most common livestock in and around the village. In the centre of the village, a medium-sized field remains where no man-made structures exist. It is used mainly for grazing purposes. On the northern side of the field, where it joins with the rest of the natural habitat, there are two small waterholes for livestock. The water holes were also important drinking spots for birds, and on occasion some waders were noted.

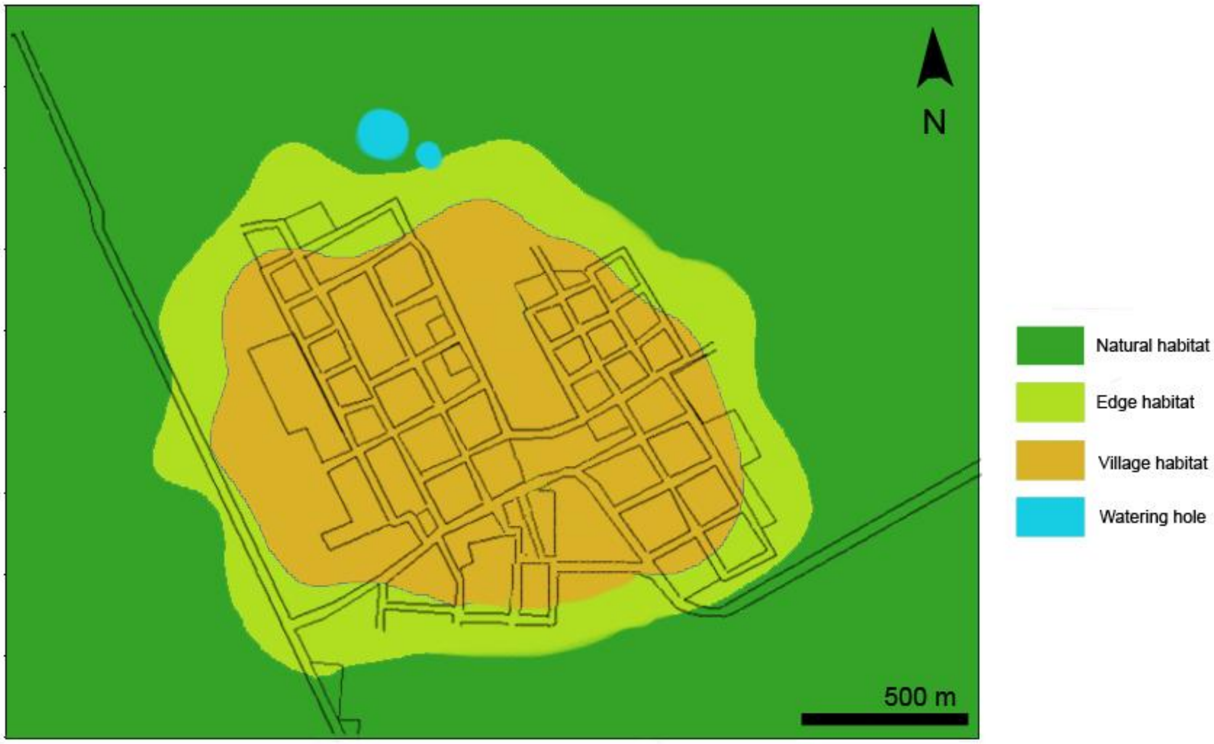

Figure 3.4: Map of Austray indicating the positions of the three habitat types.

Figure 3.5: A photo taken in Austray. Note the way in which most of the grass cover is removed from around the houses.

SOUTHEY

Southey is slightly smaller and more compact than Austray, and comprises an area of approximately 138 hectares. Even though the village is smaller than Austray in size, its population is larger, with approximately 858 people. The village is roughly 1.3 x 1.2 km in size. Roads are unpaved and natural vegetation exists along the roads and in open spaces between properties.

All houses are surrounded by absolute bare ground, with small flower gardens planted in most of the yards. Structures consist of mainly houses, which are built very close to each other, with less open spaces than in Austray. Other buildings include two schools, a church, two cafes, and a clinic. A large bare-ground soccer field is also present. A large number of poultry, feral pigeons, domestic dogs and livestock are kept by the villagers. A small pan is located just outside of the south-eastern perimeter of the village, serving as a waterhole for livestock as well as birds.

Figure 3.6: Map of Southey indicating the positions of the three habitat types.

Figure 3.7: A photo of a typical house and garden in Southey.

MMAGABUE

Mmagabue is the smallest of the three villages, stretching over an area of approximately 80 hectares. The population consists of roughly 350 people. Structures consist primarily of houses, with quite a few open areas between some of them where natural vegetation is kept somewhat intact. There is a large area of bare ground in the centre of the village, which is used as a soccer field. All the roads are unpaved, with sparse natural vegetation on the verges.

Once again, grass is removed from around the houses, resulting in homes surrounded by completely bare ground. The people tend small gardens and keep poultry, pets, and livestock, but to a lesser extent than Austray, since their village is much smaller, seemingly poorer, and slightly less developed. A small pan exists in the natural habitat at the south-eastern side of the village. This is an important water source for the village’s livestock, and some waders were occasionally noted.

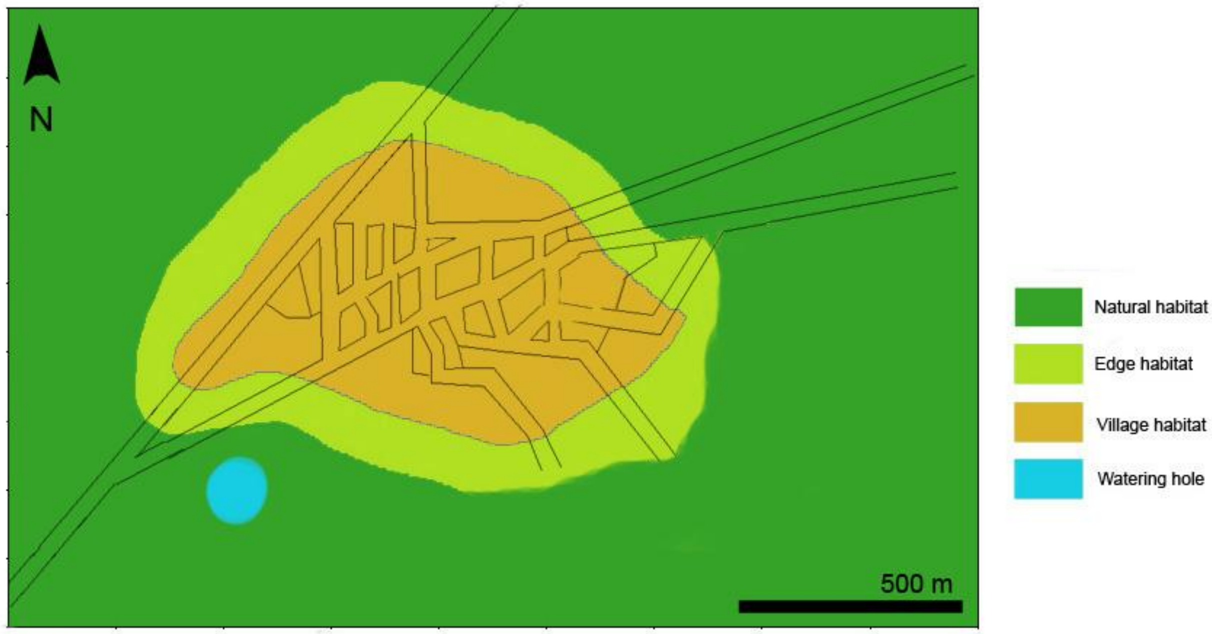

Figure 3.8: Map of Mmagabue indicating the locations of the three habitat types.

Figure 3.9: A photo of a typical homestead in Mmagabue.

3.4 MATERIALS AND METHODS

3.4.1 SITE SELECTION

Point count sites were selected according to the criteria mentioned earlier in this chapter. With the three villages that were ultimately picked for research, a good variation of different sized villages was represented. Since all three villages are located within a 50 km transect, the rainfall, topography and vegetation types is assumed to be similar for each.

Once the villages were selected after a reconnaissance, a representative of the North-West Department of Agriculture's office in Ganeysa was consulted, who then contacted the chief of each village to inform them of the proposed study. I then personally visited the chief of each village and gained permission to conduct the study by explaining what the process of the study would be.

At each village, point count sites were chosen in and around the village on a 250 x 250 m grid. The position of each point was noted using a Garmin 12 global positioning system (GPS). Points were thus plotted in a grid formation as shown in Figure 3.4.

Points were placed in three different habitat types at each village. The areas surrounding the villages, which consisted mainly of natural vegetation, were classified as the natural habitat. The interior parts of the village were classified as village habitat and a point located between a village and a natural point was classified as edge habitat. Since the three villages varied in size, they each had different numbers of point count sites; Austray had 75 points, Mmagabue 35 and Southey 60, bringing the total number of point count sites to 170.

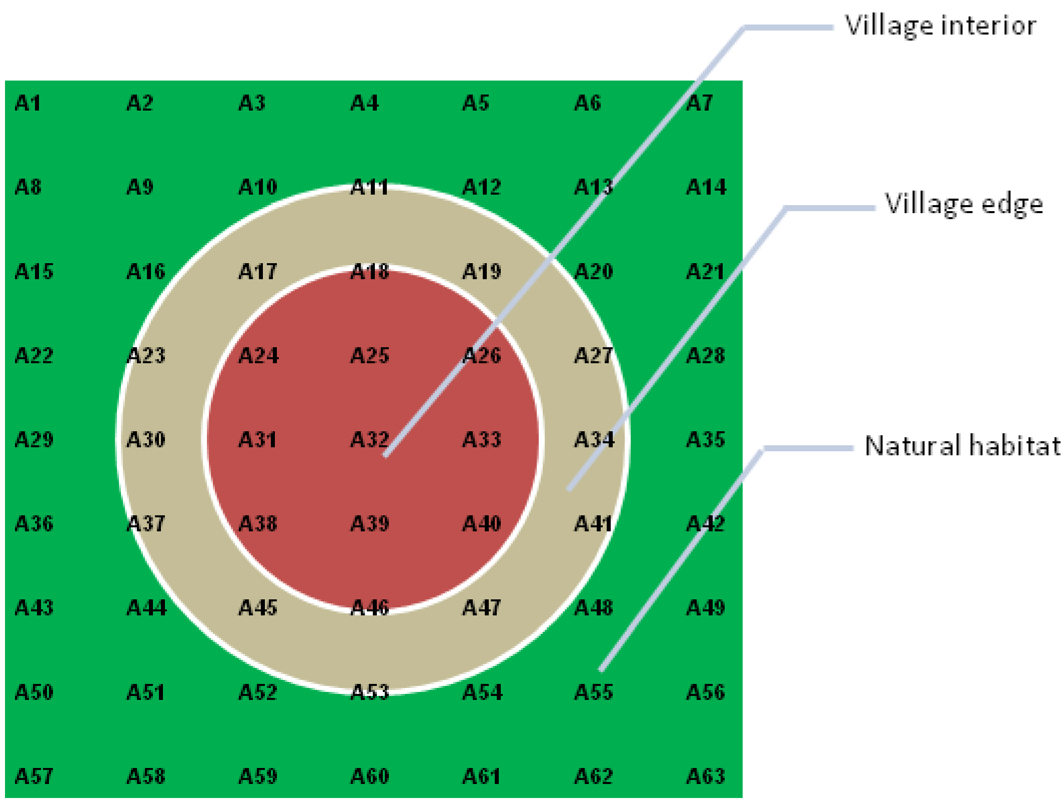

Figure 3.10: A schematic of how points were laid out. The green, grey and red areas represent the natural, edge, and the village habitats, respectively. A1 through A63 represent the points plotted across the village area on a 250 x 250 m grid.

3.4.2 TIME OF STUDY

Sampling was done in November 2007, February 2008, March 2008 and April 2008, resulting in four repetitions of data collecting at each village during summer. Sampling was not spread across all four seasons since the study did not focus on seasonal variation. Each point was surveyed once during each of the four visits to the study area, thus giving a total of 680 point surveys for the study.

3.4.3 CALCULATION OF VEGETATION STRUCTURE

The vegetation structure was calculated at each site by making use of the structural classification described by Edwards (1983). The structural classification is hierarchical and based on a set of primary growth form types, cover, height and particularly on substrata. Studies have shown that biodiversity is more dependent on the structure of the vegetation, rather than the actual species composition (Hockey, 2003), which is why it was so important to calculate the vegetation structure. This particular method was used due to the simplicity and ease of use. The primary attributes used in Edwards' (1983) structural classification are:

- A primary set of four growth form types
- A primary set of four cover classes
- A set of four height classes for each growth form type

The method made use of four different growth form types – trees, shrubs, forbs and grasses. The percentage cover and the average height of each growth form were then calculated and used to determine the vegetation structure of a specific area. The basic procedure followed to determine the structural classes is to establish a matrix or two-way table as follows:

Growth form x cover = structural group
Structural group x height = formation class

This method was used to determine the vegetation structure at each point count site.

3.4.4 BIRD SURVEYS

Surveys were conducted at every site beginning at just before dawn each morning, when birds are most active and thus best to observe. At each point count site, an area of a hundred meter radius was observed and bird species and numbers within that radius were noted over a period of 7 minutes, using 8 X 40 binoculars. Birds were identified using a combination of visual, audible and behavioural cues, as required.

The point count method of survey was evaluated by Bibby *et al.* (2000). Point counts have the advantage over line transects of being easier to incorporate into a formally designed study. It is easier to locate points randomly or systematically than it is to lay-out transect routes, because routes require better access, which may bias the habitats sampled. A well-spaced sample series of points in an area will provide more representative data than a few transects. Points are also preferred to transects in more fine-grained habitats if identification of habitat determinants of bird communities is an objective of the study Bibby *et al*., 2000).

The main disadvantage of point counts is that they are difficult to analyze. The area surveyed is proportional to the square of the distance from the observer, while with line transects it is only linearly proportional to lateral distance, with the other dimension coming from the transect length. Therefore, density estimates from point transects are more susceptible to errors arising from inaccurate distance estimation or from violation of assumptions about moving birds (Bibby *et al*., 2000).

Points are similar to line counts in requiring a high level of observer skill. By waiting at each point, there is slightly more time to identify difficult birds, whereas with line transects the observer is constantly on the move and can't always identify difficult species. In some habitats, there is also the advantage of being able to identify and count birds without the noise and distraction of avoiding obstacles while walking (Bibby *et al.,* 2000).

Smaller birds become less detectable with an increase in distance from the observer, at a rate faster than for larger birds (Bibby *et al.* 2000). Considering the differences in vegetation and anthropogenic structures between point count sites, it cannot be stated that observation conditions were the same at each site, and that some of the smaller species might have been missed or short-counted due to obstructed visibility. Correction of counts for observability was considered; however, not enough data was gathered per habitat type per small species to do such conversions. The intensity and reproducibility of the sampling design, as well as the activity of birds (most individuals will be detected due to movement), taken together, was considered robust enough to achieve the main purpose of the study.

3.4.5 GUILD CLASSIFICATION

An analysis of the different feeding and nesting guilds was done for each species at each village by dividing bird species were divided into guilds according to their diet and nesting habits. Tables 3.1 and 3.2 reflect the criteria used to assign species to guilds.

Table 3.1: Classification of birds' feeding guilds

FEEDING GUILD	DESCRIPTION OF GUILD MEMBERS
Insectivores	Species that feed only or mainly on insects as adults
Granivores	Species that feed only or mainly on seeds as adults
Frugivores	Species that feed only or mainly on fruit as adults
Omnivores	Species that feed on a variety of foods as adults
Nectarivores	Species that feed only or mainly on nectar as adults
Carnivores	Species that feed only or mainly on meat as adults, including raptors
Scavengers	Species that feed mainly on carrion as adults

Table 3.2: Classification of birds' nesting guilds

NESTING GUILD	DESCRIPTION OF GUILD MEMBERS
Ground-nesting	Species that nest in a scrape, hole or burrow on or in the ground
Tree-nesting	Species that nest in trees, usually higher that 3 meters off the ground
Shrub-nesting	Species that nest within the shrub layer, usually lower than 3 meters off the ground
Structure- or Cliff-nesting	Species that nest on cliff faces or man-made structures
Grass-nesting	Species that nest in the grass above ground level
Reed-nesting	Species that nest in reeds
Brood-parasites	Species that do not build nests, but lay their eggs in the nest of another species
Extralimital breeders	Species that do not breed in Southern Africa

3.5 DATA ANALYSIS

Strictly speaking, since uncorrected data (numbers per species) was used, abundance cannot be measured. Therefore, the distribution maps should be interpreted as the likelihood of observing a particular variable (species, numbers, or diversity) in a 100 m radius from any location on the map. Detected trends in numbers however, is considered to closely follow real abundance. Species diversity is not considered to be affected by observability constraints, due to activity (movement) of the birds and the length of time spent at each point count site in the early mornings when the birds are normally most active.

Microsoft Excel™ was used to compile a species list for each village and to compare which birds were present or absent during which of the four months. The program was also used to construct graphs illustrating the differences in bird species richness, bird numbers and guild compositions between the different villages and habitat types.

The program called GS+™ version 7 was used to interpolate the data. Interpolation means estimating values for points not actually sampled, thereby producing a map or some other spatial model for an area that was not exhaustively sampled. There are many different interpolation techniques, ranging from simple linear techniques that average the values of nearby sampled points, to more complex techniques like kriging that uses nearby points weighted by distance from the interpolate location, plus the degree of autocorrelation for those distances (Anon, 2004).

Kriging is a method of interpolation in which interpolation estimates are made based on values at neighbouring locations plus knowledge about the underlying spatial relationships in a data set. Knowledge about the underlying relationships is provided by variograms. Kriging is usually superior to other means of interpolation because it provides an optimal interpolation estimate for a given coordinate location, as well as a variance estimate for the interpolation value (Anon, 2004). Kriging allows one to construct interpolated maps indicating differences in diversity at the different points sampled. The coordinates of each point count site were used as the x- and y-axes, while the numbers of birds or species found at each site are represented on the z-axis. The kriging function then interpolates the z-values between the different sites and produces a colour-coded variable map of the area, with the different colours representing different intervals of values.

An Indicator Species Analysis was done with PC-ORD™ version 5. This was done to detect and describe the value of different species for indicating environmental conditions. If environmental differences are conceptualized as groups of sample units, then Dufrene and Legendre's (1997) method of calculating species indicator values provides a simple, intuitive solution. The method combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group. It produces indicator values for each species in each group. These are tested for statistical significance using a randomization technique (McCune and Grace, 2002). A p-value is also presented for each species, indicating its significance to a particular group. In the case of this study, groups were defined by habitat type, the result being that indicator species were identified for the three habitat types – village, edge and natural.

Multivariate analyses were also conducted using PC ORD™ to determine the patterns of associations between species compositions of point count sites in the three habitat types. Non-metric Multidimensional Scaling (NMS) was used since it is considered a good method of graphic representation of relationships (McCune and Grace, 2002). NMS uses ranked distances to linearise the relationships between measured distances in ordination space, thereby avoiding the assumption of linear relationships among variables. It also allows the use of any distance measure or relativisation, and deals much better with minimum values than other ordination methods (McCune and Grace, 2002). Sorensen (Bray-Curtis) distance measure was used. Random starting points were used with 50 runs of real data, and Monte Carlo tests were also done with 50 runs of real data. Final stress can be interpreted as follows: <5 excellent, 5-10 good, 10-20 general picture good but not in detail, >20 not good.

Analyses of Variance (ANOVA) were performed on different sets of data using GraphPad Prism® version 4.00. ANOVA are an important technique for analysing the effect of categorical factors on a response. For example, how bird species richness responds to the different habitat types can be analysed. ANOVA make it possible to determine which factors have a significant effect on the response and how much of the variability in the response variable is attributed to each factor. One-way ANOVA compare the means of three or more columns if, for example, the columns represent three or more different factors you wish to compare (Motulsky, 2003). In the case of this study, the factors (columns) were the three habitat types. Nonparametric Kruskal-Wallis test and Dunn's post test were performed. Dunn's post test compares all columns (habitat types) to each other and rates the significance of the variance between them. The most important results are the p-values and post-tests. P-values can be interpreted as follows: if the p-value is large (>0.05) there is no reason to conclude that the means differ. If the p-value is small (<0.05) there was a significant variance. Dunn's post test compares the difference in sum of ranks between two columns with the expected average difference, based on the number of groups and their size. For each pair of columns, Prism reports the p-value as >0.05, <0.05, <0.01, or <0.001. The lower the p-value, the more significant the variance is (Motulsky, 2003). Graphical representations of the results are presented in scatter plots.

Two-way ANOVA were conducted to determine how a response is affected by two factors. The groups are defined by the different rows (for one factor) and different columns (for the other factor) with replicates in side-by-side sub-columns (Motulsky, 2003). In this case, the rows represented the three habitat types and the columns represented the three villages. The two-way ANOVA breaks down the overall variability between measurements into three components; interaction between row and column, variability among columns, and variability among rows. For each of these components, Prism reports a p-value, which indicates whether there was a significant variance or not (Motulsky, 2003). A post-test for linear trend was also performed to determine the significance of the slope, or gradient from the natural, over the village edge, to the village interior. This test was considered valid as the distances between the point count sites were the same in all cases (250 m). The results are presented as bar charts.

The results of the research as well as an analysis of the collected data are presented in Chapter 4.

CHAPTER 4: RESULTS

4.1 VILLAGES

4.1.1 AUSTRAY

Although Austray was the largest of the three villages in terms of area (±152 ha), it must be noted that there were many open spaces where natural vegetation remained, combined with some exotic species. The area surrounding the village was somewhat untouched, although certain areas were disturbed by grazing of cattle and donkeys. In fact, some areas had clearly trampled livestock trails.

4.1.1.1 VEGETATION

The vegetation structure in Austray can be classified into three groups, namely the vegetation within the village interior (village habitat), the vegetation at village edges (edge habitat) and the natural vegetation surrounding the village (natural habitat). Vegetation in the village habitat was quite sparse due to the space taken up by buildings, roads, and cleared space around most of the houses. Although vegetation cover varied at different points within the village, the mean tree cover was less than 10%, with a mean height of 6.5 m. Shrub cover was less than 10%, with a 0.9 m mean height. Grass and forbs covered 40% and 15% of the area, respectively. Mean grass height was 0.2 m and mean forb height was 0.25 m. 45% of the area was covered in bare ground and anthropogenic structures occupied about 30% of the total area. The vegetation within the village was classified as short open woodland (Edwards, 1983).

The edge habitat had less man-made structures and a little more vegetation. Mean tree cover was less than 10%, with a mean height of 5 m. Shrubs covered 20% of the area and had a mean height of 1.2 m. The herbaceous layer was represented by 50% grass cover, with a mean height of 0.15 m, and 20% forbs cover, with a mean height of 0.25 m. Bare ground amounted to 40% of the area and anthropogenic structures covered 10% of the area. The edge vegetation can therefore be classified as low thicket (Edwards, 1983).

The natural habitat consisted of 10% tree and 30% shrub cover, with mean heights of 5 m and 1.6 m, respectively. Grass cover was 60%, with a mean height of 0.3 m and forb cover 15%, with a mean height of 0.2 m. Bare ground accounted for 40% of the area. No man-made structures were present and the only human disturbances were human footpaths and grazing by livestock in certain areas. This vegetation is classified as short bushland (Edwards, 1983).

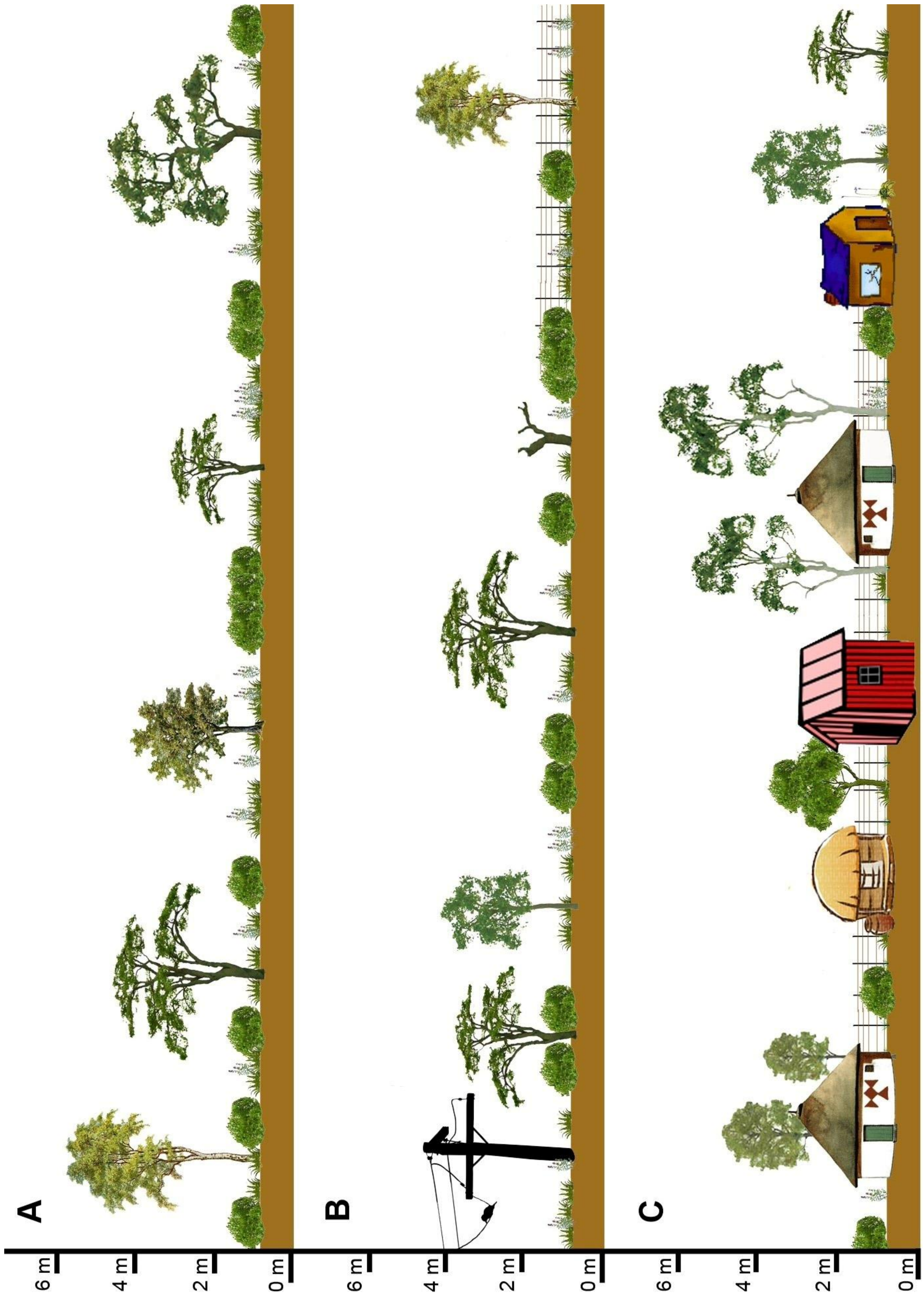

Figure 4.1: Graphical representation of the vegetation structure at Austray (A: Natural habitat; B: Edge habitat; C: Village habitat)

4.1.1.2 BIRD SPECIES

The data recorded at Austray is listed in Table 4.1. An aggregate of 80 species and 4806 individuals were recorded.

Table 4.1 All bird species and numbers noted for the village of Austray

ROBERT'S NUMBER	COMMON NAME	BIOLOGICAL NAME	NOV	FEB	MAR	APR	TOTAL
94	Hadeda Ibis	*Bostrychia hagedash*	4	1			**5**
99	White-faced Duck	*Dendrocygna viduata*		1			**1**
143	Black-chested Snake Eagle	*Circaetus pectoralis*	1				**1**
149	Steppe Buzzard	*Buteo vulpinus*		1			**1**
172	Lanner Falcon	*Falco biarmicus*		4		2	**6**
179	Red-footed Falcon	*Falco vespertinus*	1				**1**
193	Orange River Francolin	*Francolinus levaillantoides*			1	1	**2**
203	Helmeted Guineafowl	*Numida meleargis*			1		**1**
239	Northern Black Korhaan	*Eupodotis afra*	3	3	2		**8**
255	Crowned Lapwing	*Vanellus coronatus*	25	62	57	56	**200**
258	Blacksmith Lapwing	*Vanellus melanopterus*				2	**2**
344	Namaqua Sandgrouse	*Pterocles namaqua*	5				**5**
345	Burchell's Sandgrouse	*Pterocles burchelli*				8	**8**
348	Rock Dove	*Columba livia*	18	12	8	10	**48**
349	Speckled Pigeon	*Columba guinea*	29	35	39	73	**176**
352	Red-eyed Dove	*Streptopelia semitorquata*	6	5	16	8	**35**
354	Cape Turtle-dove	*Streptopelia capicola*	40	24	35	59	**158**
355	Laughing Dove	*Streptopelia senegalensis*	74	27	37	48	**186**
356	Namaqua Dove	*Oena capensis*	60	16	10	27	**113**
375	African Cuckoo	*Cuculus gularis*	1				**1**
386	Diderick Cuckoo	*Chrysococcyx caprius*	12	7			**19**
425	White-backed Mousebird	*Colius colius*	13	9	4	30	**56**
426	Red-faced Mousebird	*Urocolius indicus*		14	29	19	**62**
438	European Bee-eater	*Merops apiaster*	41	27	6	3	**77**
440	Blue-cheecked Bee-eater	*Merops persicus*	9	3			**12**
444	Little Bee-eater	*Merops pusillus*			3	1	**4**
445	Swallow-tailed Bee-eater	*Merops hirundineus*	6		3	8	**17**
451	African Hoopoe	*Upupa epops*	17	11	2	10	**40**
454	Common Scimitarbill	*Rhinopomastrus cyanomelas*				1	**1**
459	Southern Yellow-billed Hornbill	*Tockus leucomelas*	3	3	4	8	**18**
465	Acacia Pied Barbet	*Tricholaema leucomelas*	2	3	1	1	**7**
483	Golden-tailed Woodpecker	*Campethera abingoni*				1	**1**
495	Cape Clapper Lark	*Mirafra apiata*		1			**1**
498	Sabota Lark	*Mirafra sabota*	1				**1**
518	Barn Swallow	*Hirundo rustica*	55	113	106	17	**291**
520	White-throated Swallow	*Hirundo albigularis*		15			**15**
524	Red-breasted Swallow	*Hirundo semirufa*			3		**3**
532	Sand Martin	*Riparia riparia*	46				**46**
534	Banded Martin	*Riparia cincta*		3	2	14	**19**
541	Fork-tailed Drongo	*Dicrurus adsimilis*	16	15	25	29	**85**
548	Pied Crow	*Corvus albus*	1		1	3	**5**
552	Ashy Tit	*Parus cinerascens*		6	1	3	**10**
557	Cape Penduline-tit	*Anthoscopus minutus*	2	1	12	5	**20**
563	Southern Pied Babbler	*Turdoides bicolor*	3	12		12	**27**
580	Groundscraper Thrush	*Turdus litsitsirupa*	8	7	7	11	**33**
589	Familiar Chat	*Cercomela familiaris*	12	12	10	10	**44**
615	Kalahari Scrub-robin	*Erythropygia paena*	43	19	25	38	**125**
621	Chestnut-vented Tit-babbler	*Parisoma subcaeruleum*	17	16	15	30	**78**
651	Long-billed Crombec	*Sylvietta rufescens*		7			**7**
653	Yellow-bellied Eremomela	*Eremomela icteropygialis*		3			**3**

685	Black-chested Prinia	*Prinia flavicans*	26	34	73	67	**200**
689	Spotted Flycatcher	*Muscicapa striata*	7				**7**
695	Marico Flycatcher	*Melaenornis mariquensis*	10			12	**22**
697	Chat Flycatcher	*Melaenornis infuscatus*		2	7	4	**13**
713	Cape Wagtail	*Motacilla capensis*		10	3	4	**17**
716	African Pipit	*Anthus cinnamomeus*		4	2	4	**10**
731	Lesser Grey Shrike	*Lanius minor*	17	18	21		**56**
732	Common Fiscal	*Lanius collaris*	1	3		1	**5**
733	Red-backed Shrike	*Lanius collurio*	8	8	7		**23**
739	Crimson-breasted Shrike	*Laniarius atrococcineus*				1	**1**
760	Wattled Starling	*Creatophora cinerea*		12			**12**
764	Cape Glossy Starling	*Lamprotornis nitens*	23	15	17	30	**85**
779	Marico Sunbird	*Nectarinia mariquensis*	10	14	5	13	**42**
801	House Sparrow	*Passer domesticus*	24	12	19	36	**91**
803	Cape Sparrow	*Passer melanurus*	161	173	230	232	**796**
804	Southern Grey-headed Sparrow	*Passer diffusus*	15	7	6	5	**33**
806	Scaly-feathered Finch	*Sporopipes squamifrons*	45	42	49	46	**182**
814	Southern Masked-weaver	*Ploceus velatus*	67	55	36	58	**216**
821	Red-billed Quelea	*Quelea quelea*	40			85	**125**
842	Red-billed Firefinch	*Lagonosticta senegala*		7	4	19	**30**
845	Violet-eared Waxbill	*Uraeginthus granatinus*	9	7	2	27	**45**
847	Black-faced Waxbill	*Estrilda erythronotos*				2	**2**
856	Red-headed Finch	*Amadina erythrocephala*	30	63	74	81	**248**
861	Shaft-tailed Whydah	*Vidua regia*	3	6		15	**24**
862	Long-tailed Paradise-whydah	*Vidua paradisaea*		4		3	**7**
867	Village Indigobird	*Vidua chalybeata*		9			**9**
870	Black-throated Canary	*Serinus atrogularis*	45	68	52	41	**206**
878	Yellow Canary	*Serinus flaviventris*	42	47	52	34	**175**
884	Golden-breasted Bunting	*Emberiza flaviventris*	12	8	2	15	**37**
887	Lark-like Bunting	*Emberiza impetuani*	2				**2**
	Total species richness		**53**	**58**	**48**	**56**	**81**
	Total number of birds		**1171**	**1126**	**1126**	**1383**	**4806**

4.1.1.3 SPECIES OCCURRING ONLY WITHIN VILLAGE AND EDGE HABITATS

Most species occurred in and around the village, with the exception of six species that were absent from the natural habitat and were found only in the village and edge habitats. A list of these species' feeding and nesting guilds is given in Table 4.2.

Table 4.2: Species occurring only within the village and edge habitats of Austray

COMMON NAME	FEEDING GUILD	NESTING GUILD	TOTAL OBSERVED
Blacksmith Lapwing	Insectivore	Ground-nesting	**2**
Rock Dove	Granivore	Structure-nesting	**48**
Golden-tailed Woodpecker	Insectivore	Tree-nesting	**1**
Cape Wagtail	Insectivore	Shrub-nesting	**17**
House Sparrow	Granivore	Structure-nesting	**91**
Southern Grey-headed Sparrow	Granivore	Tree-nesting	**33**
			192

4.1.1.4 SPECIES OCCURRING ONLY IN NATURAL HABITAT

Some species occurred only in the natural areas surrounding the village and were absent from the village and its edges. Table 4.3 gives a list of these 23 species and their feeding and nesting guilds.

Table 4.3: Species occurring only in natural habitat surrounding Austray

COMMON NAME	FEEDING GUILD	NESTING GUILD	TOTAL OBSERVED
White-faced Duck	Insectivore	Ground-nesting	**1**
Black-chested Snake Eagle	Carnivore	Tree-nesting	**1**
Steppe Buzzard	Carnivore	Extralimital	**1**
Red-footed Falcon	Carnivore	Extralimital	**1**
Orange River Francolin	Insectivore	Ground-nesting	**2**
Helmeted Guineafowl	Insectivore	Ground-nesting	**1**
Northern Black Korhaan	Insectivore	Ground-nesting	**8**
Namaqua Sandgrouse	Insectivore	Ground-nesting	**5**
Burchell's Sandgrouse	Insectivore	Ground-nesting	**8**
African Cuckoo	Insectivore	Brood-parasite	**1**
Blue-cheeked Bee-eater	Insectivore	Structure-nesting	**12**
Common Scimitarbill	Insectivore	Tree-nesting	**1**
Southern Yellow-billed Hornbill	Omnivore	Tree-nesting	**18**
Cape Clapper Lark	Insectivore	Ground-nesting	**1**
Sabota Lark	Insectivore	Ground-nesting	**1**
Cape Penduline-tit	Insectivore	Tree-nesting	**20**
Southern Pied Babbler	Insectivore	Tree-nesting	**27**
Long-billed Crombec	Insectivore	Shrub-nesting	**7**
Yellow-bellied Eremomela	Insectivore	Shrub-nesting	**3**
Crimson-breasted Shrike	Insectivore	Tree-nesting	**1**
Wattled Starling	Omnivore	Tree-nesting	**12**
Black-faced Waxbill	Granivore	Tree-nesting	**2**
Lark-like Bunting	Granivore	Ground-nesting	**1**
			135

4.1.1.5 SPECIES OCCURRING WITHIN VILLAGE AND NATURAL HABITAT

The rest of the species were found within the village and natural habitats. Some of them however, occurred in abundance within the village but were uncommon outside the village and vice versa. Table 4.4 lists the species in and around the village of Austray.

Table 4.4: Species occurring both in and around the village of Austray

COMMON NAME	FEEDING GUILD	NESTING GUILD	NUMBERS IN VILLAGE	NUMBERS IN NATURAL HABITAT	TOTAL OBSERVED
Hadeda Ibis	Insectivore	Tree-nesting	3	1	**4**
Lanner Falcon	Carnivore	Cliff-nesting	1	5	**6**
Crowned Lapwing	Insectivore	Ground-nesting	64	136	**200**
Speckled Pigeon	Granivore	Structure-nesting	138	38	**176**
Red-eyed Dove	Granivore	Tree-nesting	25	10	**35**
Cape Turtle-dove	Granivore	Tree-nesting	103	55	**158**
Laughing Dove	Granivore	Tree-nesting	127	59	**186**
Namaqua Dove	Granivore	Shrub-nesting	99	14	**113**
Diderick Cuckoo	Insectivore	Brood-parasite	10	9	**19**
White-backed Mousebird	Frugivore	Tree-nesting	33	23	**56**
Red-faced Mousebird	Frugivore	Tree-nesting	38	24	**62**
European Bee-eater	Insectivore	Structure-nesting	9	68	**77**
Little Bee-eater	Insectivore	Structure-nesting	1	3	**4**
Swallow-tailed Bee-eater	Insectivore	Structure-nesting	3	14	**17**
African Hoopoe	Insectivore	Tree-nesting	34	6	**40**
Acacia Pied Barbet	Frugivore	Tree-nesting	1	6	**7**
Barn Swallow	Insectivore	Extralimital	146	145	**291**
White-throated Swallow	Insectivore	Structure-nesting	7	8	**15**
Red-breasted Swallow	Insectivore	Structure-nesting	14	2	**16**
Sand Martin	Insectivore	Extralimital	21	25	**46**
Banded Martin	Insectivore	Structure-nesting	13	6	**19**
Fork-tailed Drongo	Insectivore	Tree-nesting	23	62	**85**
Pied Crow	Scavenger	Tree-nesting	2	3	**5**
Ashy Tit	Insectivore	Tree-nesting	1	9	**10**
Groundscraper Thrush	Insectivore	Tree-nesting	24	9	**33**
Familiar Chat	Insectivore	Structure-nesting	30	14	**44**
Kalahari Scrub-robin	Insectivore	Shrub-nesting	11	114	**125**
Chestnut-vented Tit-babbler	Insectivore	Shrub-nesting	9	69	**78**
Black-chested Prinia	Insectivore	Shrub-nesting	56	142	**198**
Spotted Flycatcher	Insectivore	Extralimital	1	6	**7**
Marico Flycatcher	Insectivore	Tree-nesting	4	18	**22**
Chat Flycatcher	Insectivore	Shrub-nesting	4	9	**13**
African Pipit	Insectivore	Ground-nesting	2	8	**10**
Lesser Grey Shrike	Insectivore	Extralimital	10	46	**56**
Common Fiscal	Carnivore	Shrub-nesting	3	2	**5**
Red-backed Shrike	Carnivore	Extralimital	2	21	**23**
Cape Glossy Starling	Omnivore	Tree-nesting	60	25	**85**
Marico Sunbird	Nectarivore	Tree-nesting	26	16	**42**
Cape Sparrow	Granivore	Tree-nesting	596	200	**797**
Scaly-feathered Finch	Granivore	Tree-nesting	93	86	**179**
Southern Masked-weaver	Granivore	Tree-nesting	180	36	**216**
Red-billed Quelea	Granivore	Tree-nesting	74	51	**125**
Red-billed Firefinch	Granivore	Grass-nesting	13	17	**30**
Violet-eared Waxbill	Granivore	Shrub-nesting	1	44	**45**
Red-headed Finch	Granivore	Tree-nesting	168	80	**248**
Shaft-tailed Whydah	Granivore	Brood-parasite	19	11	**30**
Long-tailed Paradise-whydah	Granivore	Brood-parasite	2	5	**7**
Village Indigobird	Granivore	Brood-parasite	7	2	**9**
Black-throated Canary	Granivore	Tree-nesting	189	52	**241**
Yellow Canary	Granivore	Shrub-nesting	115	57	**172**
Golden-breasted Bunting	Granivore	Shrub-nesting	9	28	**37**
			2624	**1899**	**4523**

4.1.2 SOUTHEY

In terms of area, Southey was larger (±138 ha) than Mmagabue, but slightly smaller than Austray, even though it had a larger human population. Houses were much more compact, with much less space between them, resulting in less open fields within the village. The area surrounding the village was disturbed by grazing.

4.1.2.1 VEGETATION

As with the other two villages, the vegetation structure was calculated within the village, edge, and natural habitats of the village. The village habitat had about 10% tree cover, many of which were planted by villagers in their gardens. The mean tree height was 5 m. Shrub cover was less than 5%, with a mean height of 1.7 m. Grass cover was 30%, but very short, with a mean height of 0.15 m. Forbs covered 10% of the area, with a mean height of 0.3 m. This vegetation type was classified as short open woodland (Edwards, 1983). Bare ground amounted to 50% of the total area, mainly due to broad unpaved roads throughout the village. Houses and other buildings covered 40% of the area.

The edge habitat was classified as tall open shrubland, with trees covering less than 1% of the area, and shrubs covering 15%, with a mean height of 1.8 m. Grass cover was 45%, with a mean height of 0.3 m, and forbs covered 20%, with a mean height of 0.4 m. Man-made structures covered less than 10% of the area.

The vegetation in the natural habitat had been modified somewhat in that many trees and shrubs around the village had been removed to provide space for communal livestock grazing. Tree and shrub cover was less than 5%, with mean heights of 6 m and 1.5 m, respectively. Grass was the dominant growth form, covering 60% of the habitat, with a mean height of 0.3 m. Forbs with an average height of 0.3 m covered 20% of the area. Roughly 20% of the area was bare ground. This vegetation was classified as Low closed grassland (Edwards, 1983).

Figure 4.2: Graphical representation of the vegetation structure at Southey (A: Natural habitat; B: Edge habitat; C: Village habitat)

4.1.2.2 BIRD SPECIES

The total data for Southey is listed in Table 4.5. An aggregate of 79 species and 3488 individuals were recorded.

Table 4.5: All bird species and numbers noted for the village of Southey

ROBERT'S NUMBER	COMMON NAME	BIOLOGICAL NAME	NOV	FEB	MAR	APR	TOTAL
71	Cattle Egret	*Bulbulcus ibis*				2	**2**
127	Black-shouldered Kite	*Elanus caeruleus*		1			**1**
149	Steppe Buzzard	*Buteo vulpinus*	2				**2**
161	Gabar Goshawk	*Micronisus gabar*	1	1		2	**4**
172	Lanner Falcon	*Falco biarmicus*			1	1	**2**
183	Lesser Kestrel	*Falco naumanni*				4	**4**
193	Orange River Francolin	*Francolinus levaillantoides*				2	**2**
239	Northern Black Korhaan	*Eupodotis afra*	1	3		2	**6**
255	Crowned Lapwing	*Vanellus coronatus*	10	20	9	39	**78**
258	Blacksmith Lapwing	*Vanellus melanopterus*	3	2	2	3	**10**
344	Namaqua Sandgrouse	*Pterocles Namaqua*	5	4	1		**10**
345	Burchell's Sandgrouse	*Pterocles burchelli*		4			**4**
348	Rock Dove	*Columba livia*	34	20	15	32	**101**
349	Speckled Pigeon	*Columba guinea*	7	30	23	35	**95**
352	Red-eyed Dove	*Streptopelia semitorquata*	7		5	12	**24**
354	Cape Turtle-dove	*Streptopelia capicola*	18	16	9	13	**56**
355	Laughing Dove	*Streptopelia senegalensis*	37	36	27	46	**146**
356	Namaqua Dove	*Oena capensis*	28	25	22	31	**106**
375	African Cuckoo	*Cuculus gularis*	1				**1**
386	Diderick Cuckoo	*Chrysococcyx caprius*	8	4	2		**14**
425	White-backed Mousebird	*Colius colius*		8			**8**
426	Red-faced Mousebird	*Urocolius indicus*		7	11	16	**34**
438	European Bee-eater	*Merops apiaster*	10	21	19	4	**54**
440	Blue-cheecked Bee-eater	*Merops persicus*	1		7		**8**
444	Little Bee-eater	*Merops pusillus*				1	**1**
445	Swallow-tailed Bee-eater	*Merops hirundineus*				2	**2**
447	Lilac-breasted Roller	*Coracias caudata*	3	7	5	5	**20**
451	African Hoopoe	*Upupa epops*	9	5		6	**20**
483	Golden-tailed Woodpecker	*Campethera abingoni*	4			1	**5**
487	Bearded Woodpecker	*Thripias namaquus*		2		1	**3**
494	Rufous-naped Lark	*Mirafra africana*	3	7	7	3	**20**
495	Cape Clapper Lark	*Mirafra apiata*	7	8	3	10	**28**
498	Sabota Lark	*Mirafra sabota*	4				**4**
506	Spike-heeled Lark	*Chersomanes albofasciata*		18	11	24	**53**
507	Red-capped Lark	*Calandrella cinerea*		4			**4**
518	Barn Swallow	*Hirundo rustica*		21	161		**182**
520	White-throated Swallow	*Hirundo albigularis*	25	23	5		**53**
524	Red-breasted Swallow	*Hirundo semirufa*	9				**9**
532	Sand Martin	*Riparia riparia*	60	15			**75**
534	Banded Martin	*Riparia cincta*		15	13	25	**53**
541	Fork-tailed Drongo	*Dicrurus adsimilis*	18	12	16	23	**69**
548	Pied Crow	*Corvus albus*	9	3	9	9	**30**
552	Ashy Tit	*Parus cinerascens*	3	5	1		**9**
567	African Red-eyed Bulbul	*Pycnonotus nigricans*	8	11	3	13	**35**
580	Groundscraper Thrush	*Turdus litsitsirupa*	5	5	4	12	**26**
586	Mountain Wheatear	*Oenanthe monticola*	1	2			**3**
587	Capped Wheatear	*Oenanthe pileata*	1		1		**2**
589	Familiar Chat	*Cercomela familiaris*	14	17	17	13	**61**

595	Ant-eating Chat	*Myrmecocichla formicivora*	4	4	5	6	**19**
615	Kalahari Scrub-robin	*Erythropygia paean*	20	9	10	19	**58**
621	Chestnut-vented Tit-babbler	*Parisoma subcaeruleum*	2	11	9	10	**32**
653	Yellow-bellied Eremomela	*Eremomela icteropygialis*				1	**1**
665	Desert Cisticola	*Cisticola aridula*		5	2	3	**10**
685	Black-chested Prinia	*Prinia flavicans*	33	22	28	37	**120**
713	Cape Wagtail	*Motacilla capensis*	3	3	7	7	**20**
716	African Pipit	*Anthus cinnamomeus*	29	10	29	21	**89**
731	Lesser Grey Shrike	*Lanius minor*	4	6	14		**24**
732	Common Fiscal	*Lanius collaris*		3		3	**6**
733	Red-backed Shrike	*Lanius collurio*		2	5		**7**
739	Crimson-breasted Shrike	*Laniarius atrococcineus*	2	3			**5**
764	Cape Glossy Starling	*Lamprotornis nitens*	11	9	14	24	**58**
779	Marico Sunbird	*Nectarinia mariquensis*	15	7	8	11	**41**
799	White-browed Sparrow-weaver	*Plocepasser mahali*	36	15	28	47	**126**
801	House Sparrow	*Passer domesticus*	33	29	21	25	**108**
803	Cape Sparrow	*Passer melanurus*	35	60	46	55	**196**
804	Southern Grey-headed Sparrow	*Passer diffuses*	12	6	3	5	**196**
806	Scaly-feathered Finch	*Sporopipes squamifrons*	22	24	40	35	**121**
814	Southern Masked-weaver	*Ploceus velatus*	31	39	46	31	**147**
821	Red-billed Quelea	*Quelea quelea*				35	**35**
824	Southern Red Bishop	*Euplectes orix*	25			10	**35**
842	Red-billed Firefinch	*Lagonosticta senegala*		17	11	27	**55**
845	Violet-eared Waxbill	*Uraeginthus granatinus*				2	**2**
856	Red-headed Finch	*Amadina erythrocephala*	40	49	40	47	**176**
861	Shaft-tailed Whydah	*Vidua regia*	1	10	1	4	**16**
862	Long-tailed Paradise-whydah	*Vidua paradisaea*				7	**7**
867	Village Indigobird	*Vidua chalybeate*			8		**8**
870	Black-throated Canary	*Serinus atrogularis*	27	44	72	101	**244**
878	Yellow Canary	*Serinus flaviventris*	31	26	43	62	**162**
884	Golden-breasted Bunting	*Emberiza flaviventris*		4			**4**
	Total species richness		**54**	**59**	**51**	**57**	**79**
	Total number of birds		**772**	**800**	**900**	**1016**	**3488**

4.1.2.3 SPECIES OCCURRING ONLY WITHIN VILLAGE

8 species were absent from the natural habitat and were observed only in the village and edge habitats. Table 4.6 lists these species.

Table 4.6: Species occurring only within the village and edge habitats of Southey

COMMON NAME	FEEDING GUILD	NESTING GUILD	TOTAL OBSERVED
Rock Dove	Granivore	Structure nesting	**101**
White-backed Mousebird	Frugivore	Tree-nesting	**8**
Little Bee-eater	Insectivore	Structure-nesting	**1**
House Sparrow	Granivore	Structure-nesting	**108**
Southern Grey-headed Sparrow	Granivore	Tree-nesting	**26**
Red-billed Quelea	Granivore	Tree-nesting	**35**
Southern Red Bishop	Granivore	Reed-nesting	**35**
Village Indigobird	Granivore	Brood-parasite	**8**
			322

4.1.2.4 SPECIES OCCURRING ONLY IN NATURAL HABITAT

27 species were absent from the village and edge habitats and were found only in the natural habitat surrounding the village. A list of these species and their respective feeding and nesting guilds is given in Table 4.7.

Table 4.7: Species occurring only in natural habitat surrounding Southey

COMMON NAME	FEEDING GUILD	NESTING GUILD	TOTAL OBSERVED
Cattle Egret	Insectivore	Tree-nesting	**1**
Black-shouldered Kite	Carnivore	Tree-nesting	**1**
Steppe Buzzard	Carnivore	Extralimital	**2**
Gabar Goshawk	Carnivore	Tree-nesting	**4**
Lesser Kestrel	Carnivore	Tree-nesting	**4**
Orange River Francolin	Insectivore	Ground-nesting	**2**
Northern Black Korhaan	Insectivore	Ground-nesting	**6**
Blacksmith Lapwing	Insectivore	Ground-nesting	**10**
Namaqua Sandgrouse	Insectivore	Ground-nesting	**10**
Burchell's Sandgrouse	Insectivore	Ground-nesting	**4**
African Cuckoo	Insectivore	Brood-parasite	**1**
Swallow-tailed Bee-eater	Insectivore	Structure-nesting	**2**
Lilac-breasted Roller	Insectivore	Tree-nesting	**20**
Bearded Woodpecker	Insectivore	Tree-nesting	**3**
Rufous-naped Lark	Insectivore	Ground-nesting	**20**
Cape Clapper Lark	Insectivore	Ground-nesting	**28**
Sabota Lark	Insectivore	Ground-nesting	**4**
Spike-heeled Lark	Insectivore	Ground-nesting	**53**
Mountain Wheatear	Insectivore	Ground-nesting	**3**
Capped Wheatear	Insectivore	Ground-nesting	**2**
Ant-eating Chat	Insectivore	Ground-nesting	**19**
Yellow-bellied Eremomela	Insectivore	Shrub-nesting	**1**
Desert Cisticola	Insectivore	Grass-nesting	**10**
Red-backed Shrike	Carnivore	Extralimital	**7**
Crimson-breasted Shrike	Insectivore	Tree-nesting	**5**
Violet-eared Waxbill	Granivore	Shrub-nesting	**2**
Long-tailed Paradise-whydah	Granivore	Brood-parasite	**7**
			231

4.1.2.5 SPECIES OCCURRING WITHIN VILLAGE AND NATURAL HABITAT

The remaining species were present in both the village and natural habitats. Table 4.8 lists these species and their numbers in the different habitats.

Table 4.8: Species occurring both in and around the village of Southey

COMMON NAME	FEEDING GUILD	NESTING GUILD	NUMBERS IN VILLAGE	NUMBERS IN NATURAL HABITAT	TOTAL OBSERVED
Lanner Falcon	Carnivore	Cliff-nesting	1	1	**2**
Crowned Lapwing	Insectivore	Ground-nesting	10	68	**78**
Speckled Pigeon	Granivore	Structure-nesting	90	5	**95**
Red-eyed Dove	Granivore	Tree-nesting	22	2	**24**
Cape Turtle-dove	Granivore	Tree-nesting	27	29	**56**
Laughing Dove	Granivore	Tree-nesting	132	14	**146**
Namaqua Dove	Granivore	Shrub-nesting	89	17	**106**
Diderick Cuckoo	Insectivore	Brood-parasite	9	5	**14**
Red-faced Mousebird	Frugivore	Tree-nesting	28	6	**34**
European Bee-eater	Insectivore	Structure-nesting	19	35	**54**
Blue-cheeked Bee-eater	Insectivore	Structure-nesting	1	7	**8**
African Hoopoe	Insectivore	Tree-nesting	17	3	**20**
Golden-tailed Woodpecker	Insectivore	Tree-nesting	4	1	**5**
Red-capped Lark	Insectivore	Ground-nesting	1	3	**4**
Barn Swallow	Insectivore	Extralimital	53	129	**182**
White-throated Swallow	Insectivore	Structure-nesting	23	30	**53**
Red-breasted Swallow	Insectivore	Structure-nesting	8	1	**9**
Sand Martin	Insectivore	Extralimital	35	40	**75**
Banded Martin	Insectivore	Structure-nesting	19	34	**53**
Fork-tailed Drongo	Insectivore	Tree-nesting	20	49	**69**
Pied Crow	Scavenger	Tree-nesting	4	26	**30**
Ashy Tit	Insectivore	Tree-nesting	2	7	**9**
African Red-eyed Bulbul	Frugivore	Shrub-nesting	34	1	**35**
Groundscraper Thrush	Insectivore	Tree-nesting	22	4	**26**
Familiar Chat	Insectivore	Structure-nesting	55	6	**61**
Kalahari Scrub-robin	Insectivore	Shrub-nesting	7	51	**58**
Chestnut-vented Tit-babbler	Insectivore	Shrub-nesting	2	30	**32**
Black-chested Prinia	Insectivore	Shrub-nesting	29	91	**120**
Cape Wagtail	Insectivore	Shrub-nesting	19	1	**20**
African Pipit	Insectivore	Ground-nesting	13	76	**89**
Lesser Grey Shrike	Insectivore	Extralimital	2	22	**24**
Common Fiscal	Carnivore	Shrub-nesting	5	1	**6**
Cape Glossy Starling	Omnivore	Tree-nesting	42	16	**58**
Marico Sunbird	Nectarivore	Tree-nesting	37	4	**41**
White-browed Sparrow-weaver	Granivore	Tree-nesting	10	116	**126**
Cape Sparrow	Granivore	Tree-nesting	192	4	**196**
Scaly-feathered Finch	Granivore	Tree-nesting	63	58	**121**
Southern Masked-weaver	Granivore	Tree-nesting	136	11	**147**
Red-billed Firefinch	Granivore	Grass-nesting	49	6	**55**
Red-headed Finch	Granivore	Tree-nesting	156	20	**176**
Shaft-tailed Whydah	Granivore	Brood-parasite	14	2	**16**
Black-throated Canary	Granivore	Tree-nesting	233	11	**244**
Yellow Canary	Granivore	Shrub-nesting	128	24	**152**
Golden-breasted Bunting	Granivore	Shrub-nesting	1	4	**5**
			1863	1071	**2934**

4.1.3 MMAGABUE

Mmagabue was the smallest of the three villages (±80 ha), with houses and other structures being less compacted and more spread out than the other two. Open fields with natural vegetation remained within the village. Most of the surrounding habitat was disturbed only by low levels of grazing, except for one area where most trees and shrubs had been removed for livestock grazing.

4.1.3.1 VEGETATION STRUCTURE

The vegetation structure in Mmagabue was calculated in the village, edge, and natural habitats. Due to building and development in the village habitat, plenty of vegetation was removed, but a fair amount of tree, shrub and grass cover still remained. Tree cover was around 5%, with a mean tree height of 7 m. Shrub cover was less than 5% with a mean height of 1.7 m. The herbaceous layer was made up of 40% grass and 30% forbs, with mean heights of 0.2 m and 0.3 m, respectively. This vegetation was classified as short open woodland (Edwards, 1983). Mmagabue was less developed than the other two villages, with anthropogenic structures occupying only 25% of the total village area.

The edge habitat had less than 1% tree cover and about 5% shrub cover, with shrubs at a 1.7 m mean height. Grass cover was 60% and forb cover was 35%, both with mean heights of 0.2 m. Less than 10% of the edge habitat contained man-made structures. The edge vegetation was classified as short sparse woodland (Edwards, 1983).

The only disturbance in the natural habitat was communal livestock grazing, which in some areas around the village occurred at higher levels than others. The mean tree cover in the natural habitat was less than 5%, with a mean height of 6 m. Shrubs covered 25% of the area with a mean height of 1.6 m. Grass cover was 55%, with a mean height of 0.35 m and forbs covered 20% of the area, with a mean height of 0.25 m. Roughly 30% of the area consisted of bare ground. The natural vegetation was classified as short open shrubland (Edwards, 1983).

Figure 4.3: Graphical representation of the vegetation structure at Mmagabue (A: Natural habitat; B: Edge habitat; C: Village habitat)

4.1.3.2 BIRD SPECIES

Mmagabue had an aggregate species richness of 66, and 1967 birds were noted, over the four surveys. The data is shown in Table 4.9.

Table 4.9: All bird species and numbers noted for the village of Mmagabue

ROBERT'S NUMBER	COMMON NAME	BIOLOGICAL NAME	NOV	FEB	MAR	APR	TOTAL
62	Grey Heron	*Ardea cinerea*		2			**2**
71	Cattle Egret	*Bulbulcus ibis*				1	**1**
94	Hadeda Ibis	*Bostrychia hagedash*	1				**1**
116	Spur-winged Goose	*Plectropterus gamber*	1				**1**
143	Black-chested Snake Eagle	*Circaetus pectoralis*		1			**1**
149	Steppe Buzzard	*Buteo vulpinus*		2			**2**
161	Gabar Goshawk	*Micronisus gabar*				1	**1**
193	Orange River Francolin	*Francolinus levaillantoides*		5			**5**
239	Northern Black Korhaan	*Eupodotis afra*	3	4	1	1	**9**
255	Crowned Lapwing	*Vanellus coronatus*	14	6	5	11	**36**
274	Little Stint	*Calidris minuta*			2	2	**4**
301	Double-banded Courser	*Smutsornis africanus*		1			**1**
348	Rock Dove	*Columba livia*	12	5	8	15	**40**
349	Speckled Pigeon	*Columba guinea*	8	15	11	24	**58**
354	Cape Turtle-dove	*Streptopelia capicola*	9	4	7	7	**27**
355	Laughing Dove	*Streptopelia senegalensis*	12	10	20	18	**50**
356	Namaqua Dove	*Oena capensis*	6	3	12	12	**33**
386	Diderick Cuckoo	*Chrysococcyx caprius*	1	4			**5**
426	Red-faced Mousebird	*Urocolius indicus*		5	9		**14**
438	European Bee-eater	*Merops apiaster*	6		1	6	**13**
440	Blue-cheeked Bee-eater	*Merops persicus*	22				**22**
447	Lilac-breasted Roller	*Coracias caudata*	7	1	6	3	**17**
451	African Hoopoe	*Upupa epops*	8	7	5	2	**22**
454	Common Scimitarbill	*Rhinopomastrus cyanomelas*	3				**3**
465	Acacia Pied Barbet	*Tricholaema leucomelas*	3		1		**4**
494	Rufous-naped Lark	*Mirafra africana*	2				**2**
495	Cape Clapper Lark	*Mirafra apiata*		10	4	2	**16**
506	Spike-heeled Lark	*Chersomanes albofasciata*				16	**16**
518	Barn Swallow	*Hirundo rustica*	22	227	78	2	**329**
520	White-throated Swallow	*Hirundo albigularis*		3			**3**
524	Red-breasted Swallow	*Hirundo semirufa*	5	2			**7**
532	Sand Martin	*Riparia riparia*	15				**15**
534	Banded Martin	*Riparia cincta*				15	**15**
541	Fork-tailed Drongo	*Dicrurus adsimilus*	5	11	11	20	**47**
548	Pied Crow	*Corvus albus*	3	2	8	3	**16**
552	Ashy Tit	*Parus cinerascens*	2	2	1	2	**7**
557	Cape Penduline-tit	*Anthoscopus minutus*			1		**1**
589	Familiar Chat	*Cercomela familiaris*	4	2	5	6	**17**
595	Ant-eating Chat	*Myrmecocichla formicivora*		2	4	5	**11**
615	Kalahari Scrub-robin	*Erythropygia paena*	19	12	8	15	**54**
621	Chestnut-vented Tit-babbler	*Parisoma subcaeruleum*	5	4	3	5	**17**
665	Desert Cisticola	*Cisticola aridula*			2	3	**5**
685	Black-chested Prinia	*Prinia flavicans*	12	32	31	35	**110**
689	Spotted Flycatcher	*Muscicapa striata*	3				**3**
713	Cape Wagtail	*Motacilla capensis*		1	1	2	**4**
716	African Pipit	*Anthus cinnamomeus*	5	22	11	20	**58**
731	Lesser Grey Shrike	*Lanius minor*	4	12	16		**32**
732	Common Fiscal	*Lanius collaris*				4	**4**
733	Red-backed Shrike	*Lanius collurio*	2	3	10		**15**

760	Wattled Starling	*Creatophora cinerea*		8			**8**
764	Cape Glossy Starling	*Lamprotornis nitens*	15	12	7	15	**49**
779	Marico Sunbird	*Nectarinia marquensis*	3	1	3	6	**13**
799	White-browed Sparrow-weaver	*Plocepasser mahali*	12	34	42	43	**131**
801	House Sparrow	*Passer domesticus*	12	2	1	17	**32**
803	Cape Sparrow	*Passer melanurus*	19	22	22	72	**135**
804	Southern Grey-headed Sparrow	*Passer diffusus*	7	6			**13**
806	Scaly-feathered Finch	*Sporopipes squamifrons*	6	5	22	15	**48**
814	Southern Masked-weaver	*Ploceus velatus*	53	18	18	11	**100**
821	Red-billed Quelea	*Quelea quelea*				38	**38**
842	Red-billed Firefinch	*Lagonosticta senegala*				3	**3**
845	Violet-eared Waxbill	*Uraeginthus granitinus*				4	**4**
856	Red-headed Finch	*Amadina erythrocephala*		10		14	**24**
861	Shaft-tailed Whydah	*Vidua regia*		1	4	3	**8**
870	Black-throated Canary	*Serinus atrogularis*	11	24	46	25	**106**
878	Yellow Canary	*Serinus flaviventris*	10	31	12	25	**78**
884	Golden-breasted Bunting	*Emberiza flaviventris*	1				**1**
	Total species richness		**42**	**45**	**39**	**43**	**66**
	Total number of birds		**373**	**596**	**459**	**549**	**1967**

4.1.3.3 SPECIES OCCURRING ONLY WITHIN VILLAGE

Five species were absent from the natural habitat and occurred only in the village and edge habitats. A list of these species and their guilds is given in Table 4.10.

Table 4.10: Species occurring only within the village and edge habitats of Mmagabue

COMMON NAME	FEEDING GUILD	NESTING GUILD	TOTAL OBSERVED
Gabar Goshawk	Carnivore	Tree-nesting	**1**
Rock Dove	Granivore	Structure-nesting	**40**
Namaqua Dove	Granivore	Shrub-nesting	**33**
Common Scimitarbill	Insectivore	Tree-nesting	**3**
House Sparrow	Granivore	Structure-nesting	**32**
			109

4.1.3.4 SPECIES OCCURRING ONLY IN NATURAL HABITAT

An aggregate of 22 species were found only in the natural habitat surrounding Mmagabue. The data for these species is listed in Table 4.11.

Table 4.11: Species occurring only in natural habitat surrounding Mmagabue

COMMON NAME	FEEDING GUILD	NESTING GUILD	TOTAL OBSERVED
Grey Heron	Carnivore	Tree-nesting	**2**
Cattle Egret	Insectivore	Tree-nesting	**1**
Hadeda Ibis	Insectivore	Tree-nesting	**1**
Spur-winged Goose	Granivore	Ground-nesting	**1**
Black-chested Snake Eagle	Carnivore	Tree-nesting	**1**
Steppe Buzzard	Carnivore	Extralimital	**2**
Orange River Francolin	Insectivore	Ground-nesting	**5**

Northern Black Korhaan	Insectivore	Ground-nesting	**9**
Little Stint	Insectivore	Extralimital	**4**
Double-banded Courser	Insectivore	Ground-nesting	**1**
Rufous-naped Lark	Insectivore	Ground-nesting	**2**
Cape Clapper Lark	Insectivore	Ground-nesting	**16**
Spike-heeled Lark	Insectivore	Ground-nesting	**16**
White-throated Swallow	Insectivore	Structure-nesting	**3**
Cape Penduline-tit	Insectivore	Tree-nesting	**1**
Desert Cisticola	Insectivore	Grass-nesting	**5**
Spotted Flycatcher	Insectivore	Extralimital	**3**
Red-backed Shrike	Carnivore	Extralimital	**15**
Wattled Starling	Omnivore	Tree-nesting	**8**
Red-billed Firefinch	Granivore	Grass-nesting	**3**
Violet-eared Waxbill	Granivore	Shrub-nesting	**4**
Golden-breasted Bunting	Granivore	Shrub-nesting	**1**
			96

4.1.3.5 SPECIES OCCURRING WITHIN VILLAGE AND NATURAL HABITAT

The rest of the species were found in both the natural and village habitats, although most of them were more abundant in one habitat than the other. Table 4.12 represents a summary of these species.

Table 4.12: Species occurring both in and around the village of Mmagabue

COMMON NAME	FEEDING GUILD	NESTING GUILD	NUMBERS IN VILLAGE	NUMBERS IN NATURAL HABITAT	TOTAL OBSERVED
Crowned Lapwing	Insectivore	Ground-nesting	23	13	**36**
Speckled Pigeon	Granivore	Structure-nesting	45	13	**58**
Cape Turtle-dove	Granivore	Tree-nesting	16	11	**27**
Laughing Dove	Granivore	Tree-nesting	45	15	**60**
Diderick Cuckoo	Insectivore	Brood-parasite	5	1	**6**
Red-faced Mousebird	Frugivore	Tree-nesting	8	6	**14**
European Bee-eater	Insectivore	Structure-nesting	6	7	**13**
Blue-cheeked Bee-eater	Insectivore	Extralimital	4	18	**22**
Lilac-breasted Roller	Insectivore	Tree-nesting	12	5	**17**
African Hoopoe	Insectivore	Tree-nesting	18	4	**22**
Acacia Pied Barbet	Frugivore	Tree-nesting	4	1	**5**
Barn Swallow	Insectivore	Extralimital	127	202	**329**
Red-breasted Swallow	Insectivore	Structure-nesting	6	1	**7**
Sand Martin	Insectivore	Extralimital	14	1	**15**
Banded Martin	Insectivore	Structure-nesting	9	6	**15**
Fork-tailed Drongo	Insectivore	Tree-nesting	21	16	**37**
Pied Crow	Scavenger	Tree-nesting	4	12	**16**
Ashy Tit	Insectivore	Tree-nesting	2	5	**7**
Familiar Chat	Insectivore	Structure-nesting	16	1	**17**
Ant-eating Chat	Insectivore	Ground-nesting	3	8	**11**
Kalahari Scrub-robin	Insectivore	Shrub-nesting	9	45	**54**
Chestnut-vented Tit-babbler	Insectivore	Shrub-nesting	5	12	**17**
Black-chested Prinia	Insectivore	Shrub-nesting	9	89	**98**
Cape Wagtail	Insectivore	Shrub-nesting	3	1	**4**
African Pipit	Insectivore	Ground-nesting	13	45	**58**
Lesser Grey Shrike	Insectivore	Extralimital	6	26	**32**
Common Fiscal	Carnivore	Shrub-nesting	1	3	**4**
Cape Glassy Starling	Omnivore	Tree-nesting	43	6	**49**

Marico Sunbird	Nectarivore	Tree-nesting	12	1	**13**
White-browed Sparrow-weaver	Granivore	Tree-nesting	77	54	**131**
Cape Sparrow	Granivore	Tree-nesting	99	36	**135**
Southern Grey-headed Sparrow	Granivore	Tree-nesting	12	1	**13**
Scaly-feathered Finch	Granivore	Tree-nesting	15	33	**48**
Southern Masked-weaver	Granivore	Tree-nesting	73	27	**100**
Red-billed Quelea	Granivore	Tree-nesting	25	13	**38**
Red-headed Finch	Granivore	Tree-nesting	22	2	**24**
Shaft-tailed Whydah	Granivore	Brood-parasite	4	4	**8**
Black-throated Canary	Granivore	Tree-nesting	88	18	**106**
Yellow Canary	Granivore	Shrub-nesting	42	36	**78**
			946	798	**1744**

4.1.4 COMBINED DATA

4.1.4.1 VEGETATION

Although the vegetation type is consistent throughout most of the Bophirima District, urbanisation and land-use results in changes to the structure of the vegetation. At all three villages, similar vegetation structures were found within the villages. The vegetation structures of the edge and natural habitats, however, differed somewhat at each village. A list of the different habitats and their respective vegetation structures is given in Table 4.13.

Table 4.13: Summary of the different vegetation structures found at each village

VILLAGE	HABITAT	PRIMARY GROWTH FORM	% TREE COVER	% SHRUB COVER	% GRASS COVER	TREES: HEIGHT CLASS	SHRUBS: HEIGHT CLASS	GRASS: HEIGHT CLASS	VEGETATION CLASSIFICATION
Austray	Village	Trees and grass	10%	<10%	50%	5-8m	1-1.5m	<0.5m	Short open woodland
	Edge	Shrubs and grass	5%	20%	50%	4-6m	1.5-2m	<0.5m	Low thicket
	Natural	Trees and shrubs	10%	30%	45%	5-8m	1-2m	<0.5m	Short bushland
Mmagabue	Village	Trees and grass	<10%	<10%	40%	6-8m	1-2m	<0.5m	Short open woodland
	Edge	Trees and grass	<1%	5%	60%	5-8m	1.5-2m	<0.5m	Short sparse woodland
	Natural	Shrubs and grass	<1%	20%	55%	6-8m	1-2m	<0.5m	Short open shrubland
Southey	Village	Trees and grass	10%	<5%	30%	4-10m	1-2m	<0.5m	Short open woodland
	Edge	Shrubs and grass	<1%	10%	45%	5-6m	1.5-2m	<0.5m	Tall open shrubland
	Natural	Shrubs and grass	<5%	10%	60%	5-8m	1-2m	<0.5m	Low closed grassland

4.1.4.2 SPECIES RICHNESS

The aggregated species richness at each village is represented graphically in Figure 4.4. Austray and Southey had very similar total species richness, with 80 and 79 species, respectively. Mmagabue, being the smallest village, had the lowest species richness with 66. Figure 4.4 also indicates how many of the species occurred in the natural, village, and edge habitats. In the natural habitat, Austray and Southey once again had very similar species richness of 74 and 71, respectively. Mmagabue's natural habitat supported 62 of its 66 species. In the village habitats, 57 species were recorded at Austray, 52 species at Southey, and 44 species at Mmagabue. The species richness within the edge habitats at all three villages were almost identical to those of the village habitat. Austray's edge habitat had two species less than its village habitat and the other two villages each had one species less.

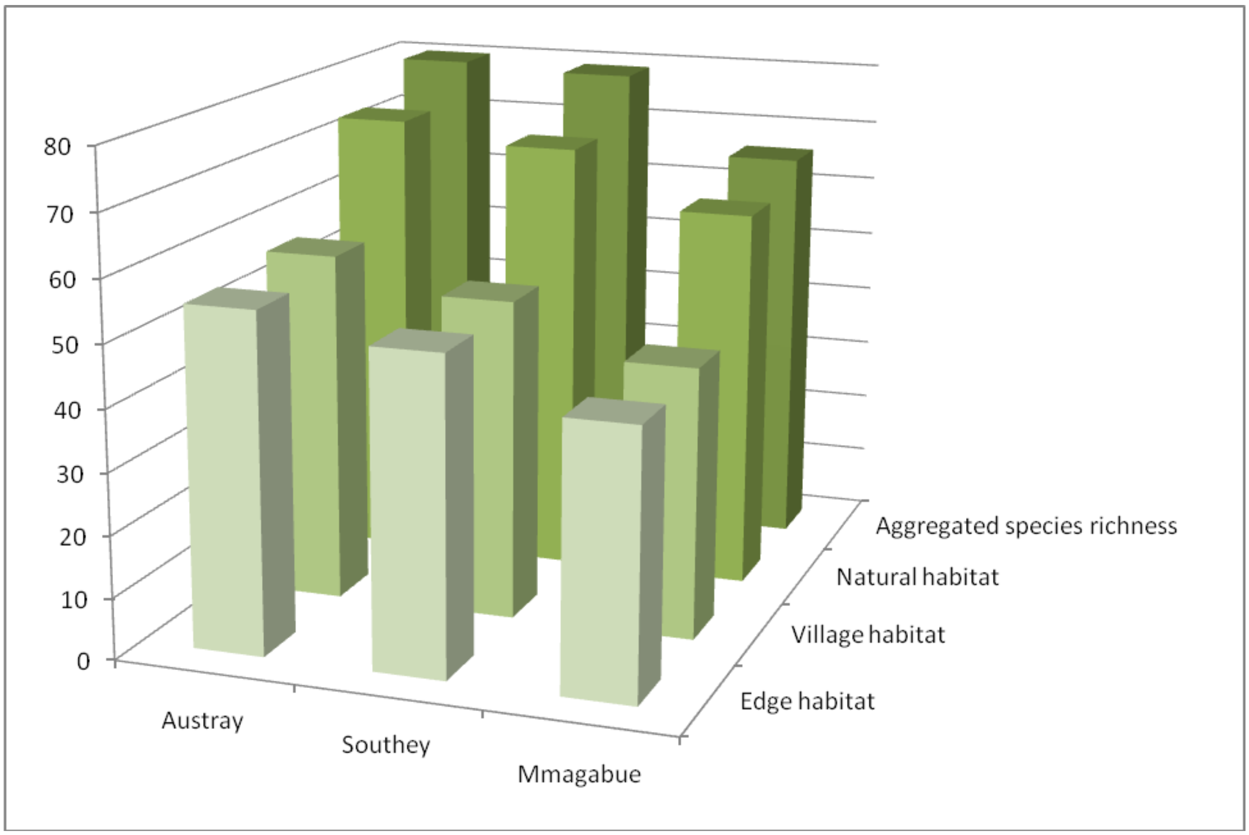

Figure 4.4: Aggregated species richness at each village

4.1.4.2 BIRD NUMBERS

Figure 4.5 represents the total bird numbers at each village. Austray, the largest village, had the highest count (4806 birds). This was followed by the second largest village which is Southey (3488 birds). Mmagabue once again had the lowest count (1967 birds). Austray supported more than double the number of birds than Mmagabue. The figure also shows the bird counts within the three respective habitats. Bird numbers were higher in the village habitat than in the natural habitat. At Austray, 2816 birds were recorded inside the village and 2007 birds were recorded in the natural habitat. Southey had 2185 birds in the village and 1303 birds in the natural habitat. At Mmagabue, 1088 birds were counted in the village habitat and only 920 in the surrounding natural habitat. The lowest bird counts were found in the edge habitats. 1346 birds were counted in Austray's edge habitat while Southey and Mmagabue's edges supported only 373 and 441 birds, respectively.

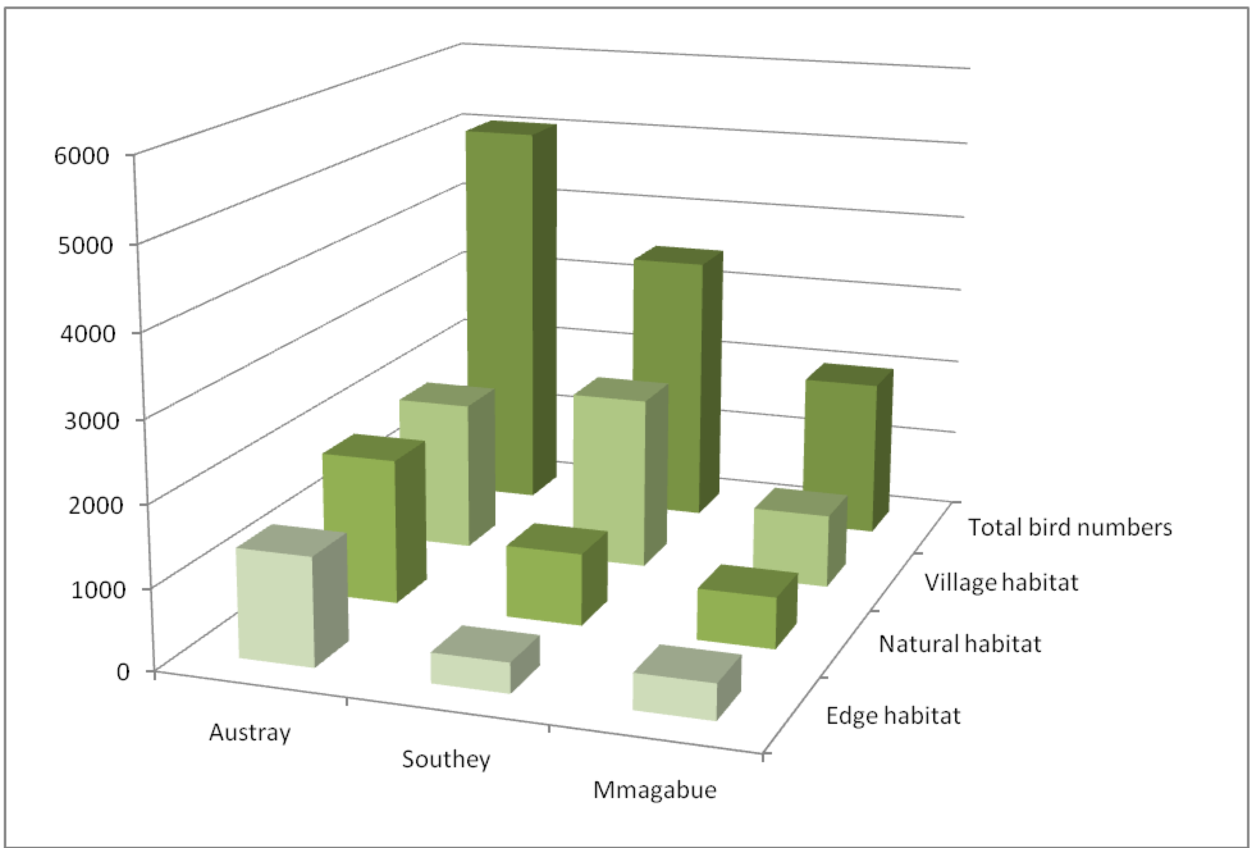

Figure 4.5: Total bird numbers at each village

4.1.4.3 MEAN SPECIES RICHNESS AND BIRD NUMBERS

The mean species richness and number of birds, as well as the standard deviation (SD) of each, was calculated for each habitat type at each village. The common trend for species richness and number of birds was that there was an increase from natural habitat to edge habitat and a further increase from edge habitat to village habitat, whereas the aggregated species richness often showed the opposite. Mean species richness and bird numbers were calculated to give an indication of what the average number of birds per point count site was in each habitat type. Aggregated species richness can be misleading since more species may have been recorded in the natural habitat, many of which were only seen once at a single point count site. Mean species richness and bird numbers gives a better indication of the typical number of species and birds found per point count site. The results are listed in Table 4.14, along with the aggregated species richness and bird numbers.

Table 4.14: Mean and aggregated species richness and bird numbers at each village

VILLAGE	HABITAT	NUMBER OF SITES	AGGREGATED SPECIES RICHNESS	MEAN SPECIES RICHNESS*	SD	AGGREGATED BIRD NUMBERS	MEAN NUMBER OF BIRDS*	SD
Southey	Natural	40	74	15.5	4.6	1819	45.5	16.2
	Edge	16	55	19	3.4	1346	84.1	34.2
	Village	19	57	21.2	2.6	1893	99.6	19.1
Austray	Natural	26	71	12.7	2.9	901	34.7	12.7
	Edge	8	51	16.5	2.4	373	46.6	15
	Village	26	52	20.9	1.8	2181	83.9	18.9
Mmagabue	Natural	17	62	12.1	2.6	641	37.7	9.6
	Edge	6	43	18	5.2	441	56.8	20.4
	Village	12	44	20.8	3.7	923	76.9	12.8

*****per point count site

4.1.4.4 SPECIES OCCURRENCES

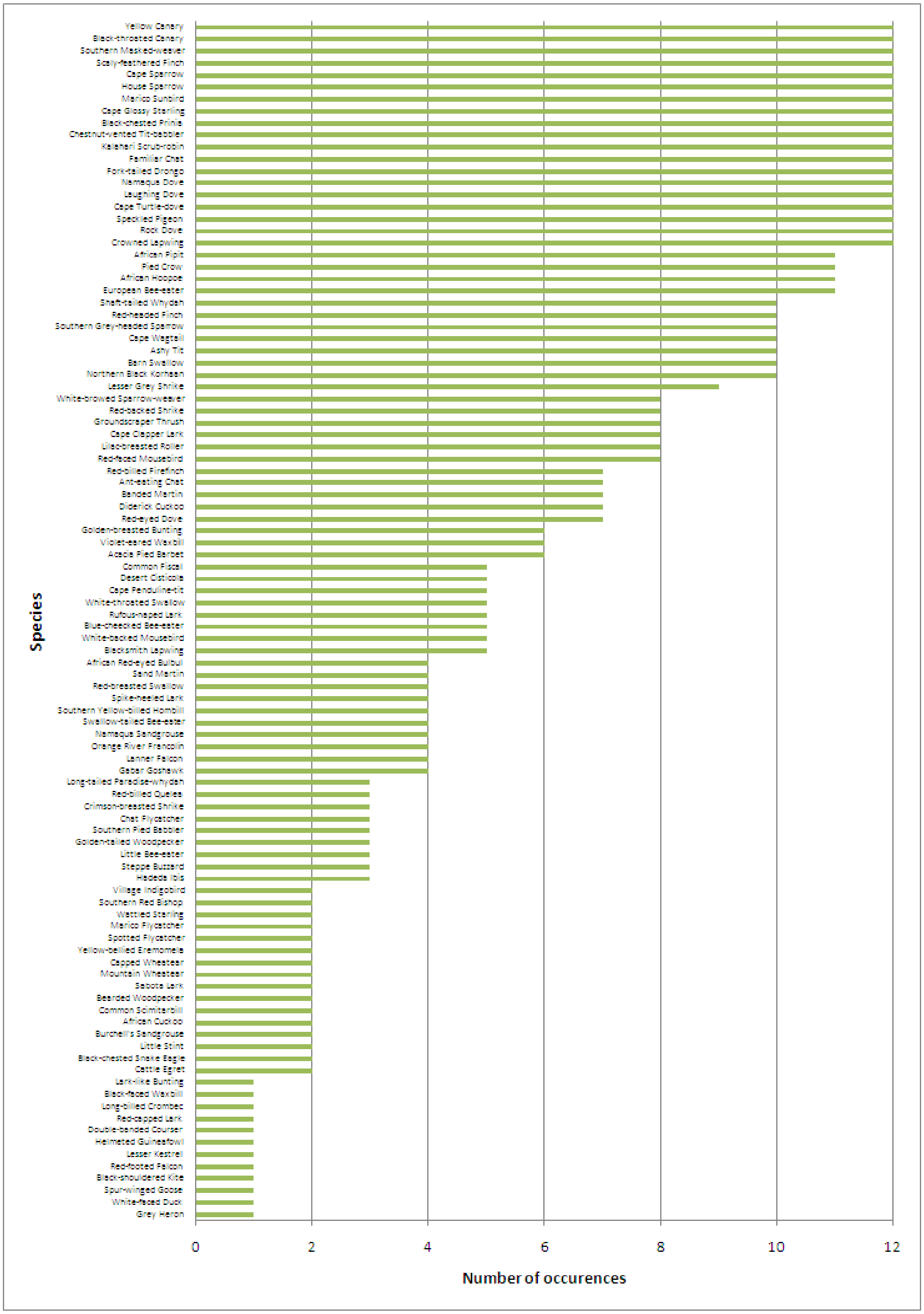

Figure 4.6: Number of times each species occurred during the 12 surveys (4 surveys x 3 villages)

Figure 4.6 indicates the number of times each species occurred during the 12 surveys done throughout the course of the study. Species varied in their presence at the different villages. Some species were very common and occurred during each survey while others were uncommon and were only found during one or two surveys.

4.1.4.5 GUILD ANALYSIS

In the feeding guild analysis, guilds that represented less than 3% of the total species at a village were left out. An interesting observation was that the basic composition of feeding guilds was the same for each village. Insectivore species were dominant at each of the villages, with just over 50% of the total species composition. At each village, granivore species came second, with just under 30% of the species composition. Carnivores represented 7-9% of the species found at each village, while frugivores and omnivores made up almost 4% of the species in each village, except at Southey, where omnivores represented less than 3% of the total species and were thus left out of the graphical analysis of feeding guilds for that village. Nectarivores and scavengers were present in each village, but consisted only of one species each, representing less than 3% of the total species composition.

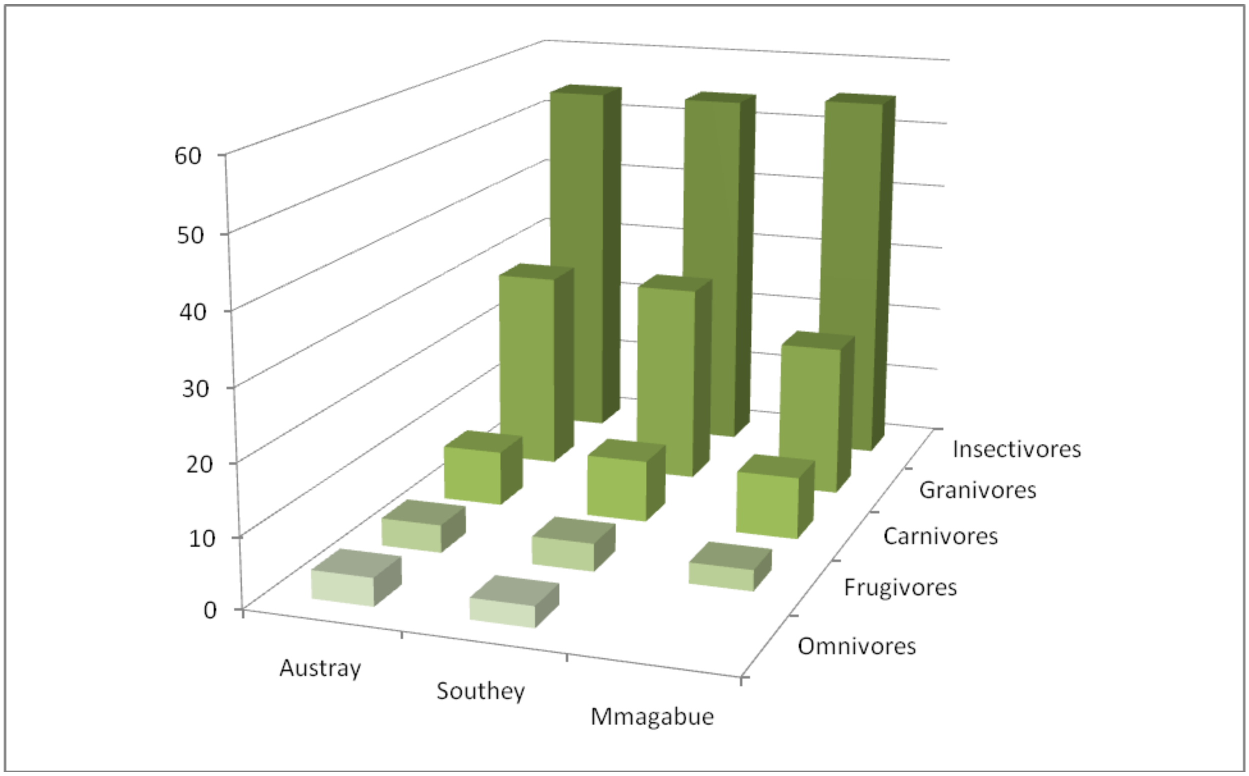

Figure 4.7: Percentage composition of bird species by feeding guild at each village

A summary of the species composition at each village according to feeding guilds is given in Table 4.15.

Table 4.15: Feeding guild composition at each village

VILLAGE	INSECTIVORE SPECIES	GRANIVORE SPECIES	CARNIVORE SPECIES	FRUGIVORE SPECIES	OMNIVORE SPECIES	NECTARIVORE SPECIES	SCAVENGER SPECIES	TOTAL
Austray	43	23	6	3	3	1	1	**80**
Southey	43	23	7	3	1	1	1	**79**
Mmagabue	36	18	6	2	2	1	1	**66**

In the nesting guild analysis, it was found that there was once again quite some variation between the different guilds found at each village, although the basic composition was more or less the same at each village. The dominant nesting guild at all three villages was tree-nesters, ranging between 35 - 40% of the total species composition. Ground-nesters had the second highest numbers at Southey, but overall, ground-nesters, shrub-nesters and structure-nesters had very similar counts at all three villages, ranging between 10 - 15%. Mmagabue had the highest number of extralimital breeders at 12%. At all three villages, brood parasites and grass-nesters made up the smallest percentage of the total species composition.

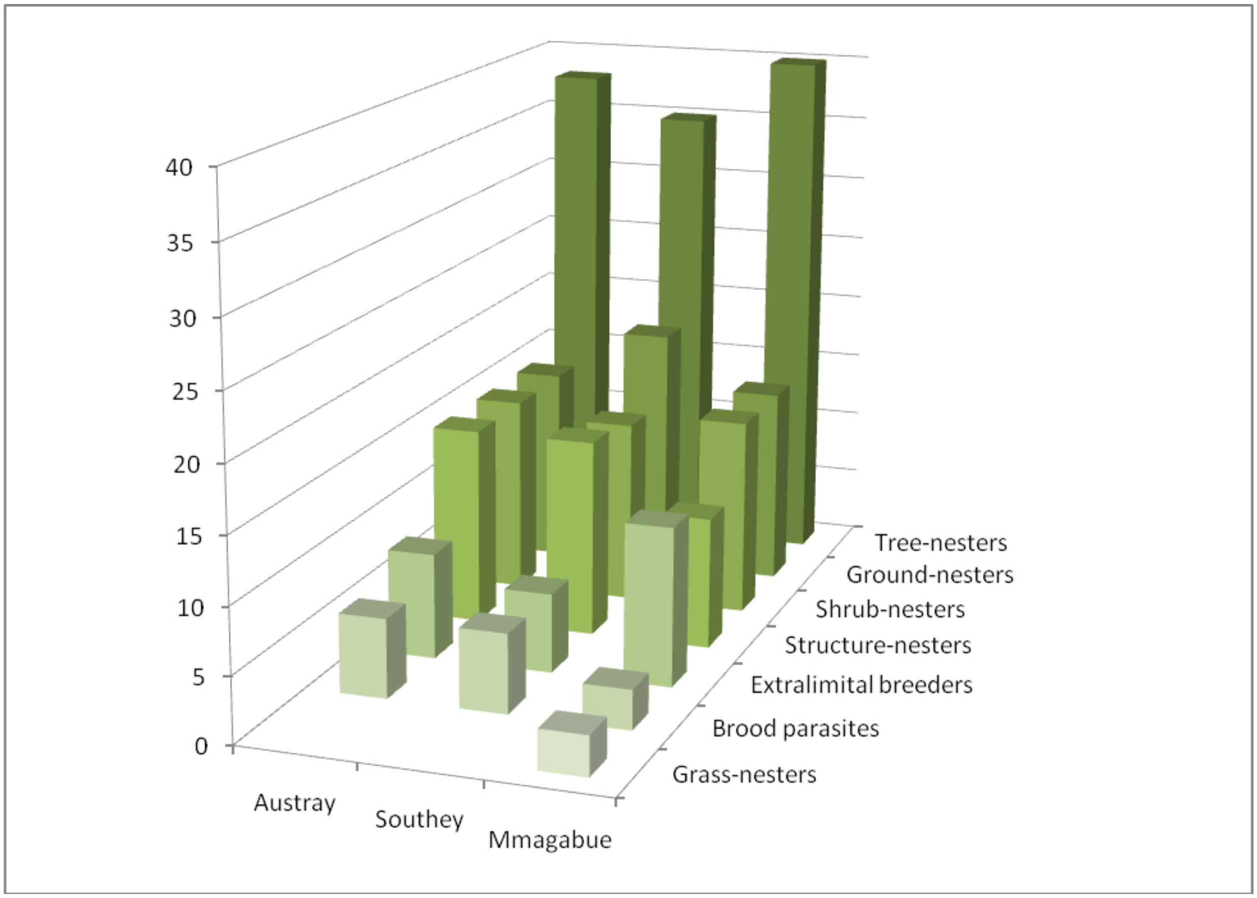

Figure 4.8: Percentage composition of bird species by nesting guild at each village

A summary of the species composition at each village according to nesting guilds is given in Table 4.16.

Table 4.16: Nesting guild composition at each village

VILLAGE	TREE-NESTING SPECIES	SHRUB-NESTING SPECIES	GROUND-NESTING SPECIES	STRUCTURE/CLIFF-NESTING SPECIES	EXTRALIMITAL BREEDERS	GRASS-NESTING SPECIES	REED-NESTING SPECIES	BROOD-PARASITES	TOTAL
Austray	31	12	12	12	7	1	0	5	**80**
Southey	28	11	15	12	5	2	1	5	**79**
Mmagabue	27	13	10	7	8	2	0	2	**66**

Statistical analyses are presented in the following section.

4.2 STATISTICAL ANALYSES

4.2.1 GEOSTATISTICAL ANALYSIS

A geostatistical analysis of the collected data was done using the GS+^{TM} programme. MapViewer^{TM} was then used to overlay each map with an outline of its respective village. In the following section, maps are given for the total number of birds over all four counting events, the aggregated species richness over all four counting surveys, the aggregated species richness of insectivores, granivores and carnivores over all four surveys, and the total numbers of ground-, tree-, shrub- and structure-nesting birds over all four counting events for each village. Other feeding and nesting guilds were left out of this analysis since their numbers were very low and not very intuitive or instructive. North in all distribution maps is oriented towards the top of the page.

4.2.1.1 SPECIES RICHNESS

The interpolation of aggregated species richness per point count site is presented in Figures 4.9 - 4.11. The common trend at each village was that the aggregated species richness was higher within the village, with a decrease toward the village edges and a further decrease in the natural habitat surrounding the village.

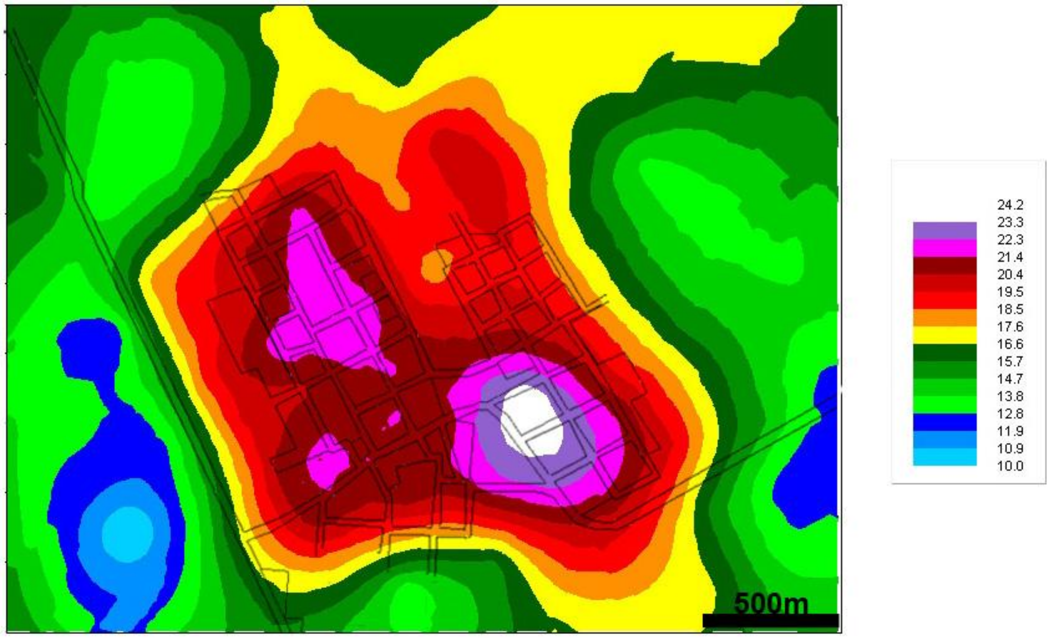

Figure 4.9: Interpolation of aggregated (per point count site) species richness at Austray

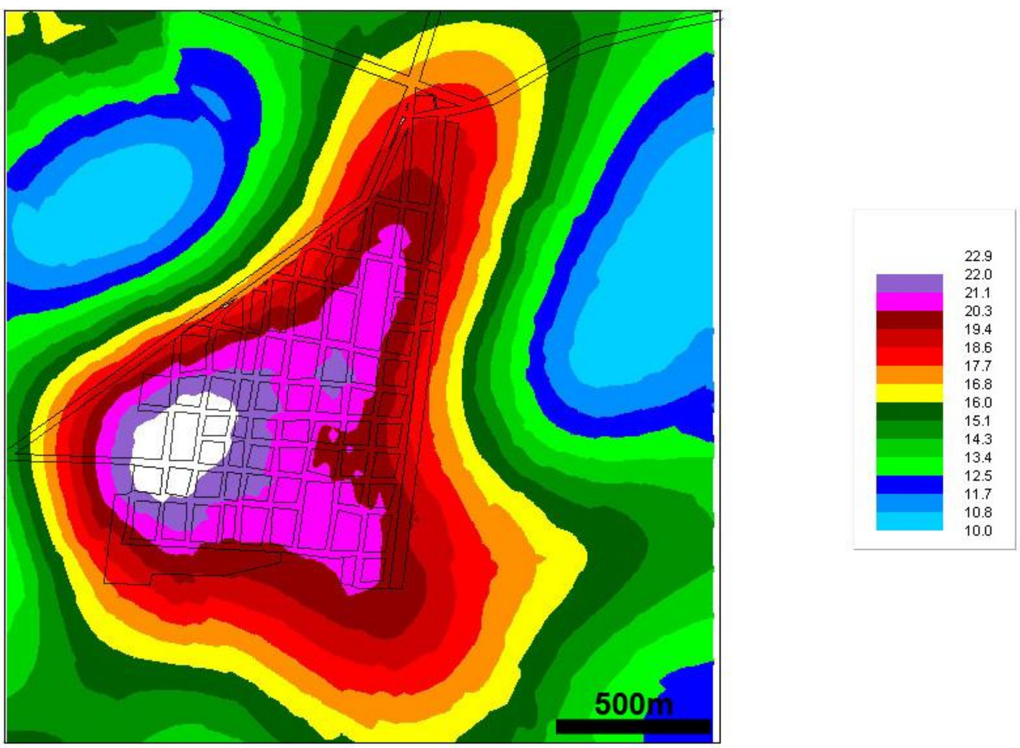

Figure 4.10: Interpolation of aggregated (per point count site) species richness at Southey

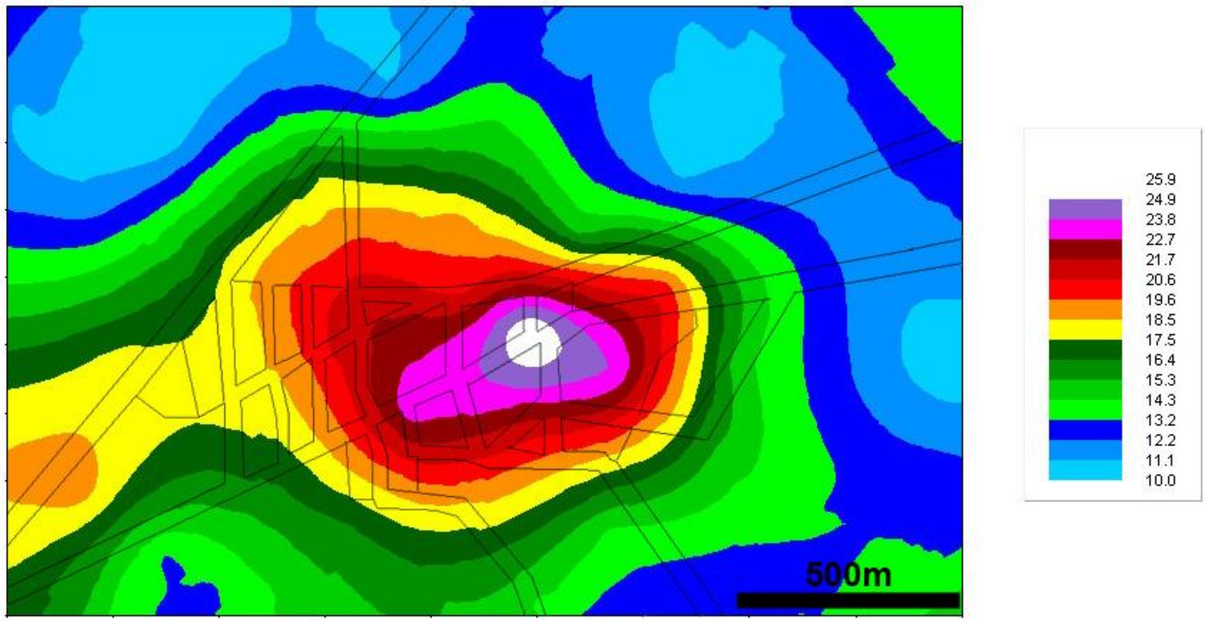

Figure 4.11: Interpolation of aggregated (per point count site) species richness at Mmagabue

4.2.1.2 NUMBER OF BIRDS

The interpolation of the distribution of bird numbers at each village is indicated in Figures 4.12 - 4.14. All three villages showed the same pattern, with the number of birds highest inside the village, with a decrease toward the edges and the natural vegetation surrounding the villages.

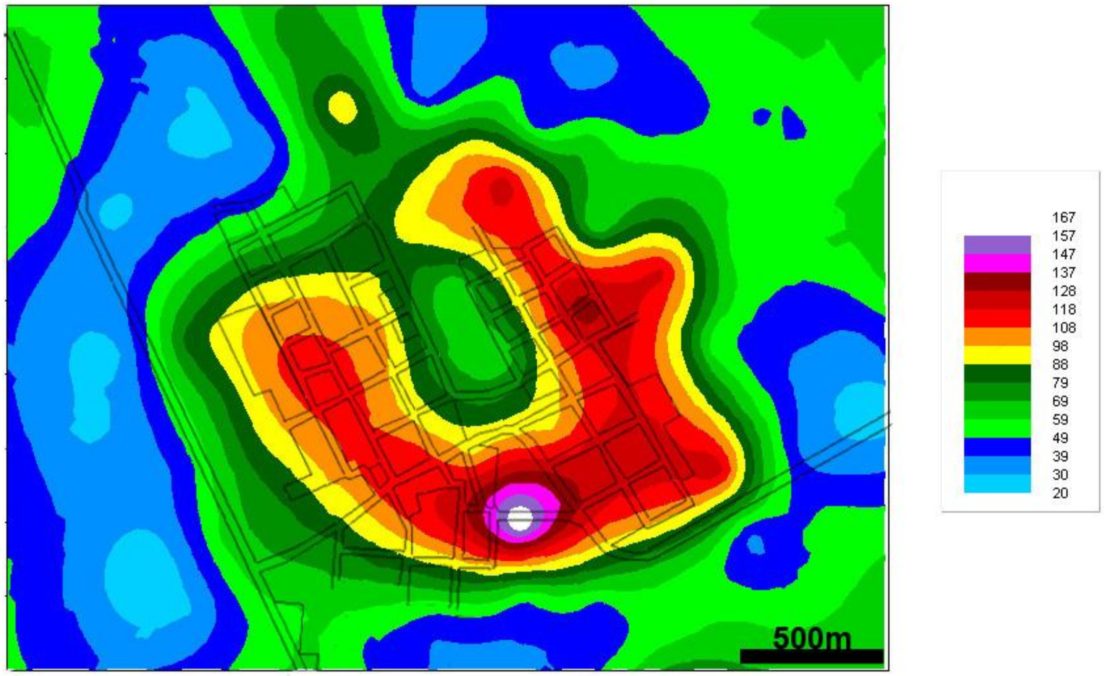

Figure 4.12: Interpolation of numbers of birds at Austray

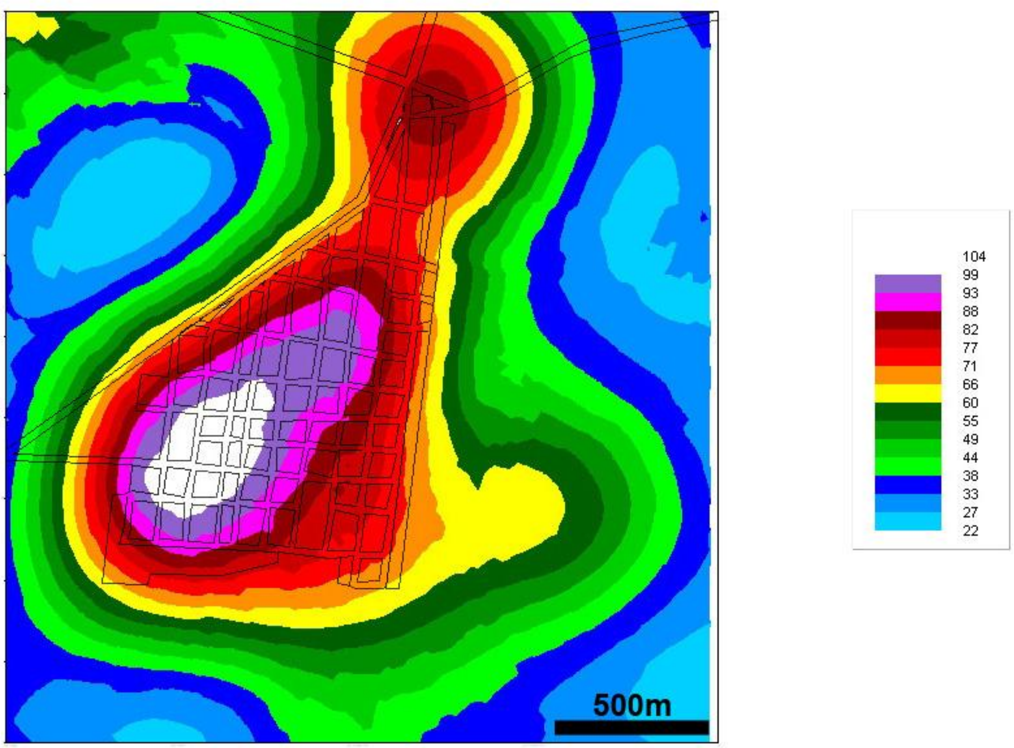

Figure 4.13: Interpolation of numbers of birds at Southey

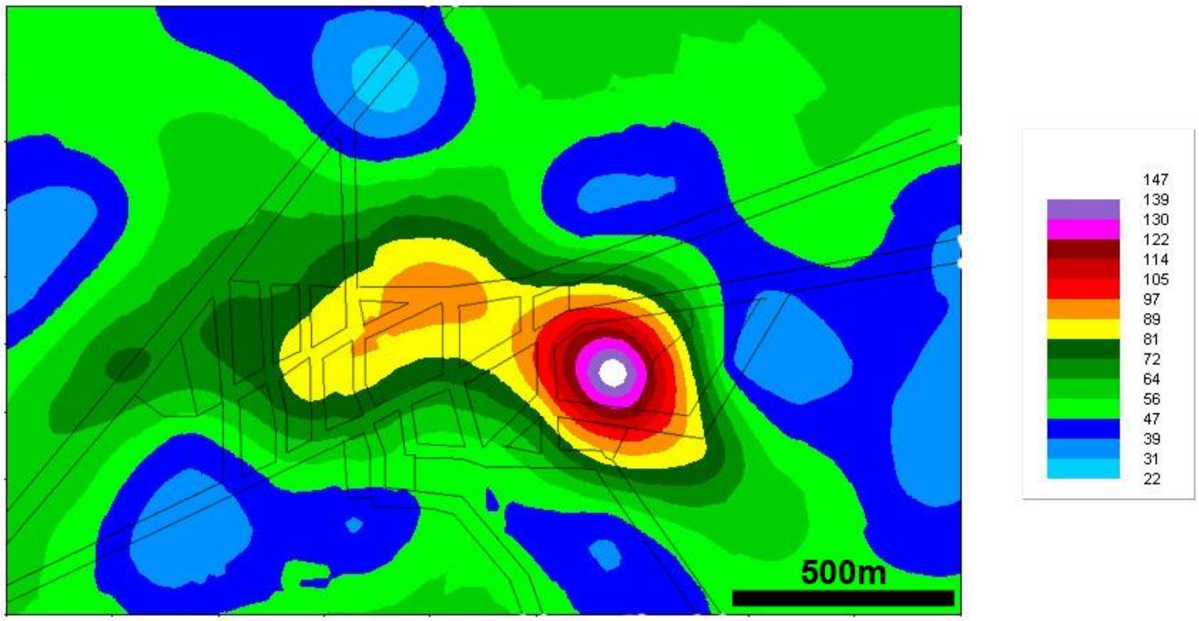

Figure 4.14: Interpolation of numbers of birds at Mmagabue

4.2.1.3 INSECTIVORES

For each feeding and nesting guild, two distribution maps were drawn for each village: one indicating the total number of species for the particular guild, and the second showing the total number of individual birds classified under the guild. The geostatistical analysis for insectivores is represented by Figures 4.15 - 4.20.

At Austray (Figures 4.15 and 4.16) and Southey (Figures 4.17 and 4.18), there was clearly a higher number of insectivorous species and individual insectivores in the natural habitat surrounding the two villages. At Mmagabue (Figures 4.19 and 4.20), there is not a very definitive pattern, with high insectivore numbers at certain patches in and around the village. However, the sites with the lowest insectivore numbers fell within the village interior.

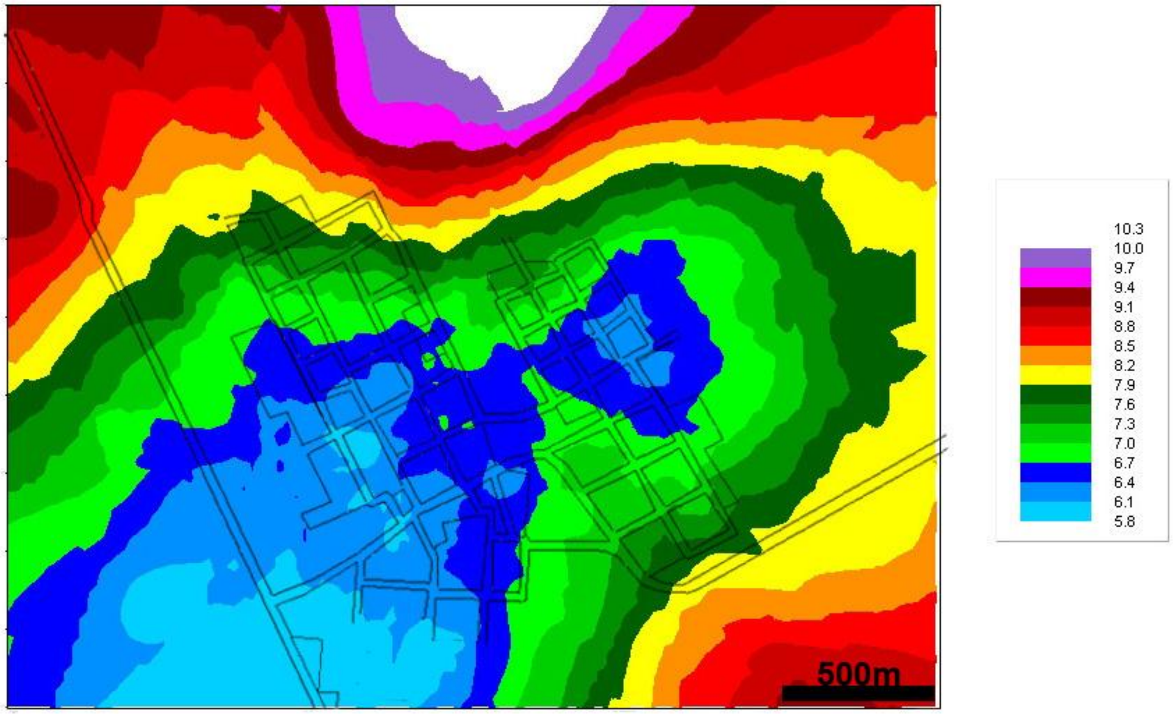

Figure 4.15: Interpolation of insectivorous species richness at Austray

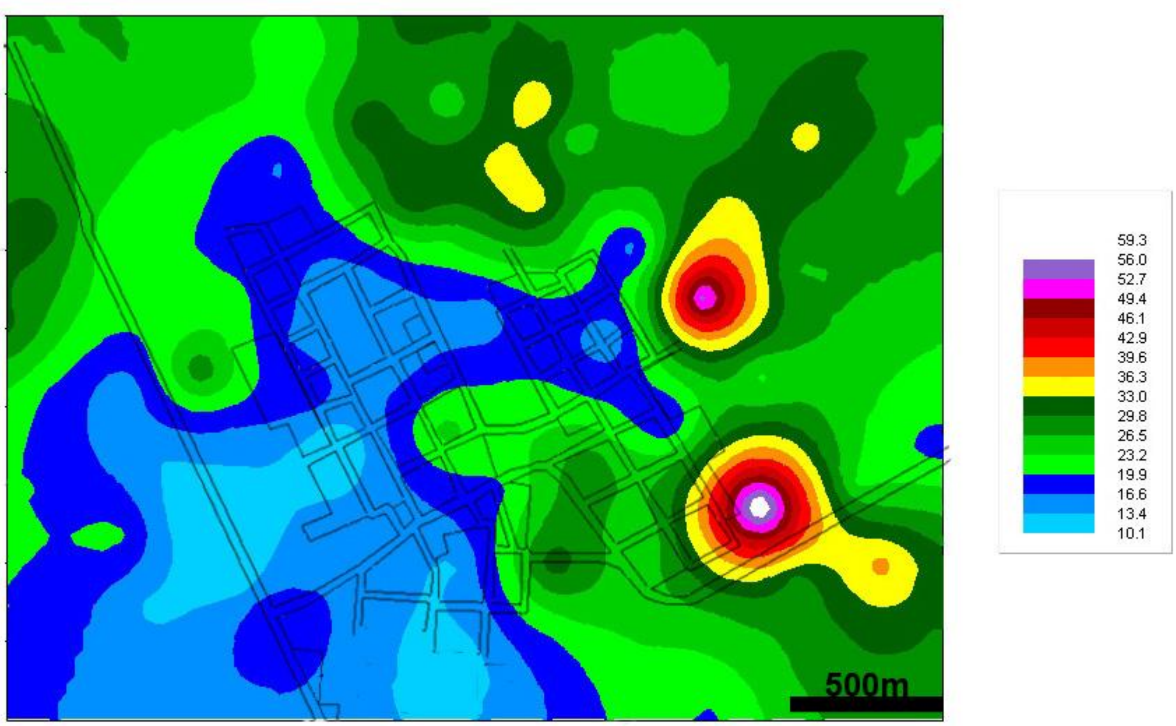

Figure 4.16: Interpolation of insectivore numbers at Austray

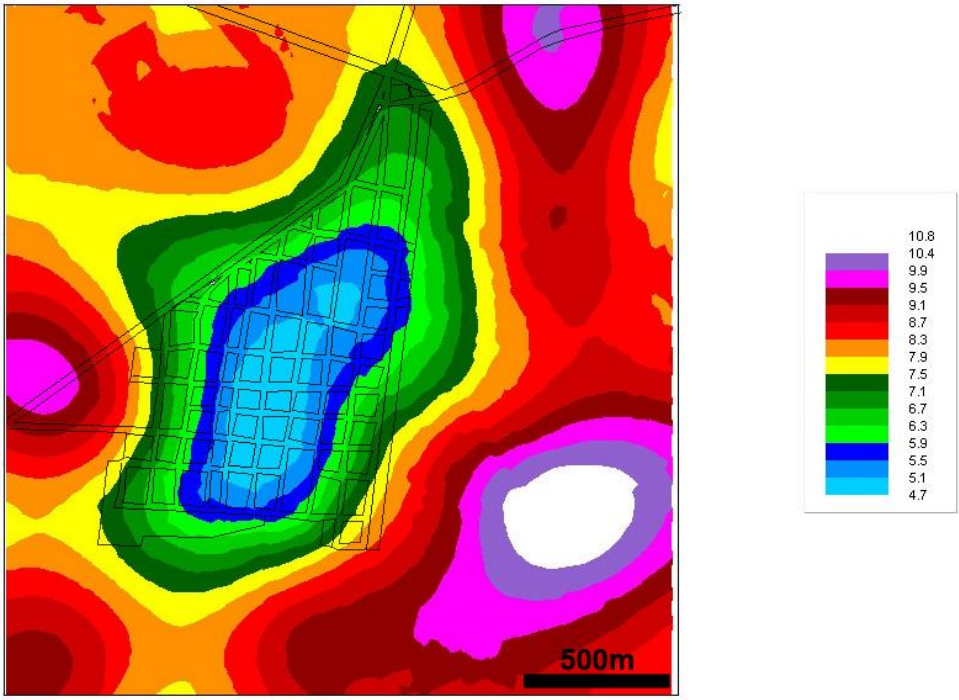

Figure 4.17: Interpolation of insectivorous species richness at Southey

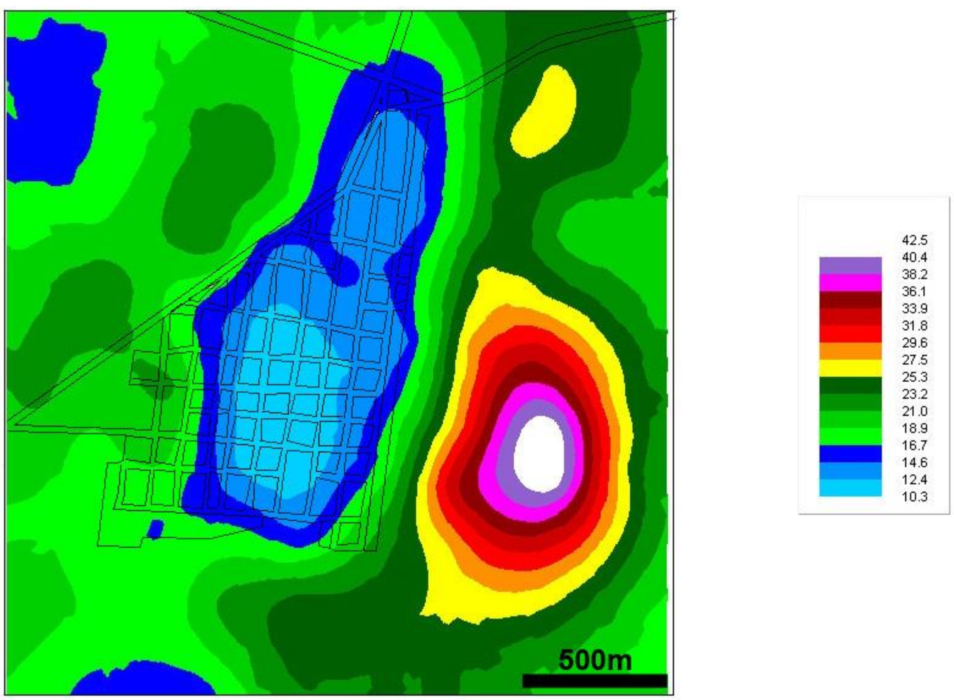

Figure 4.18: Interpolation of insectivore numbers at Southey

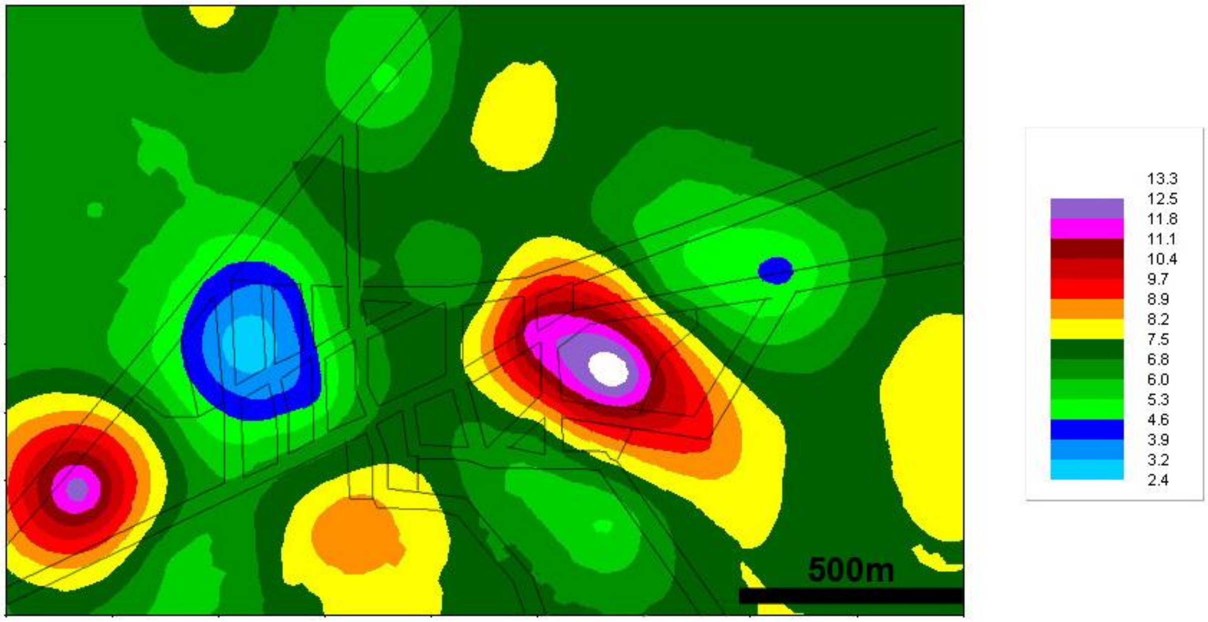

Figure 4.19: Interpolation of insectivorous species richness at Mmagabue

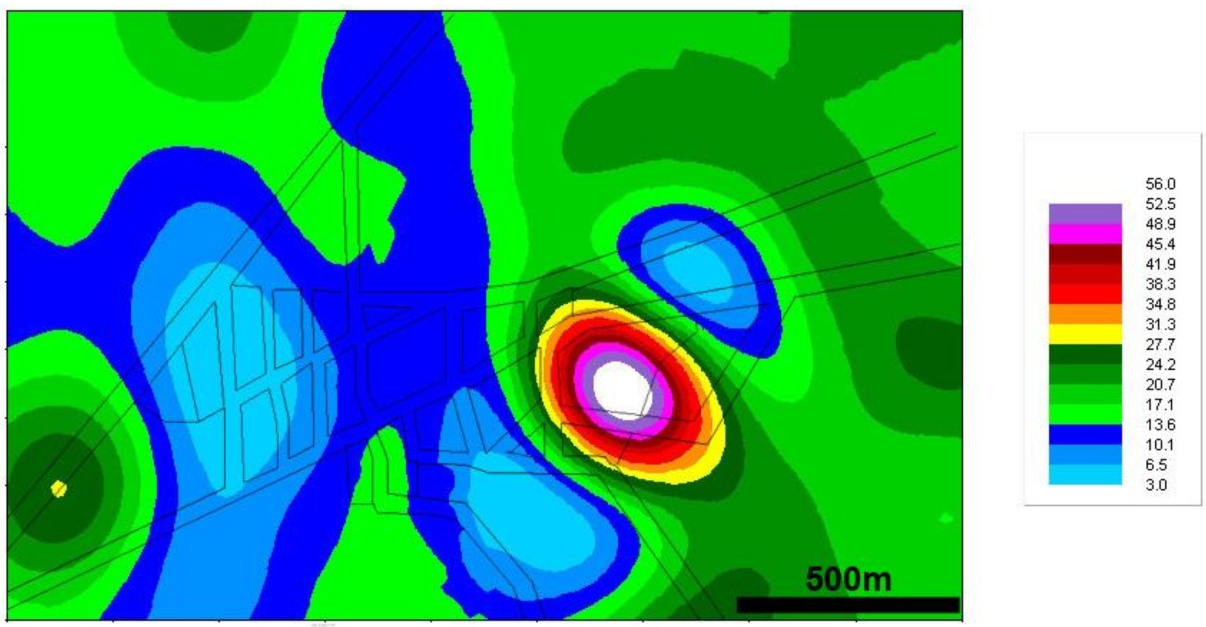

Figure 4.20: Interpolation of insectivore numbers at Mmagabue

4.2.1.4 GRANIVORES

Granivorous birds showed consistent distribution patterns for each village, with the number of species and individual birds high within the village and considerably lower in the natural habitats. Figures 4.21 - 4.26 represent the interpolated distribution of granivore numbers at each village.

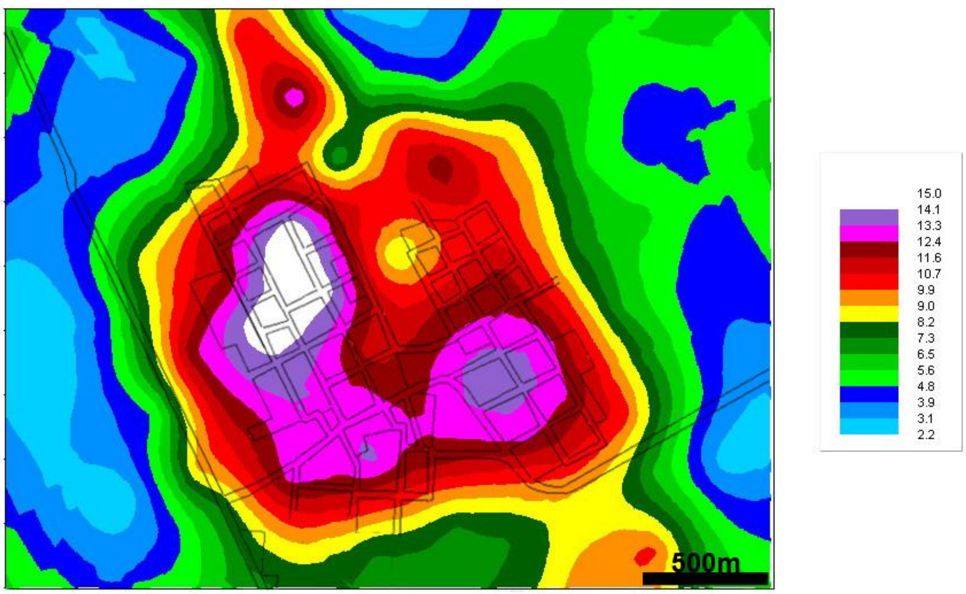

Figure 4.21: Interpolation of granivorous species richness at Austray

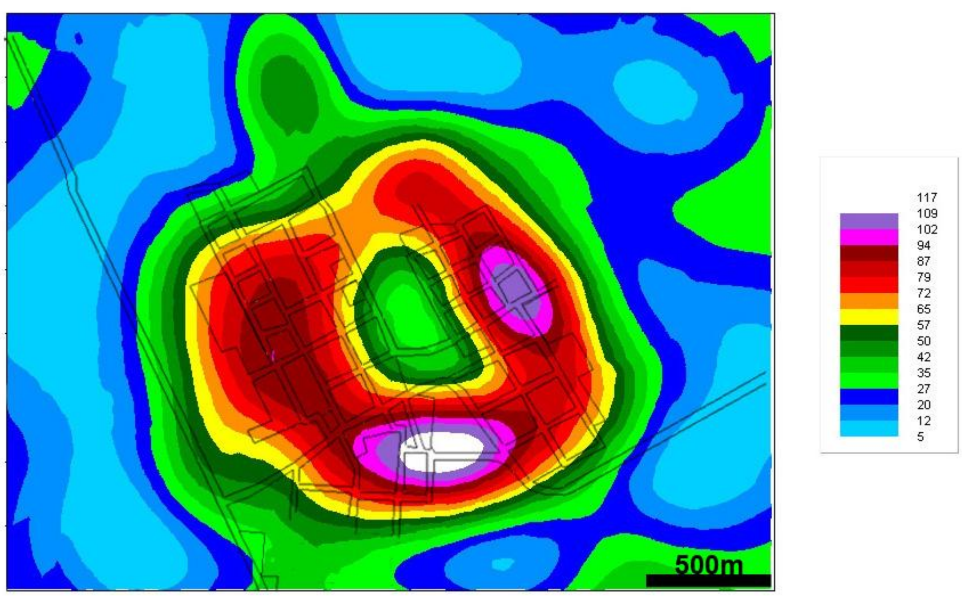

Figure 4.22: Interpolation of granivore numbers at Austray

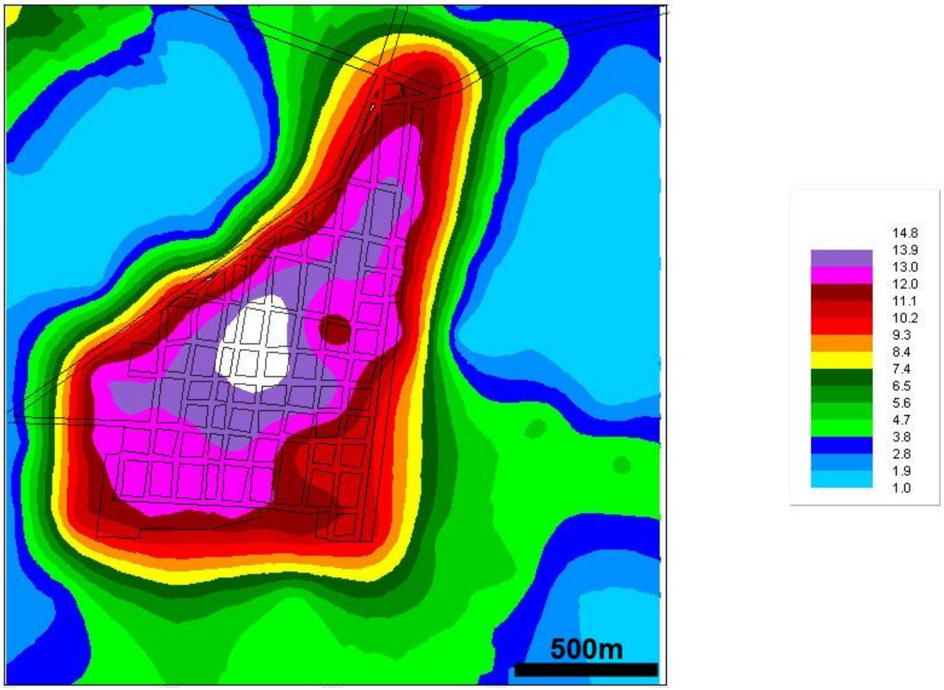

Figure 4.23: Interpolation of granivorous species richness at Southey

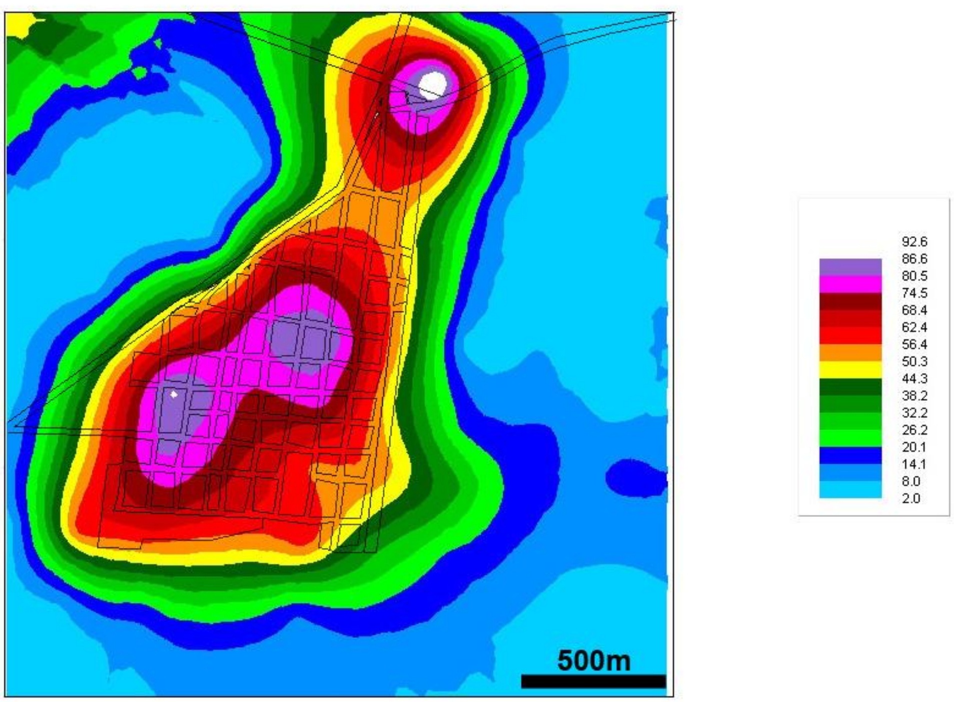

Figure 4.24: Interpolation of granivore numbers at Southey

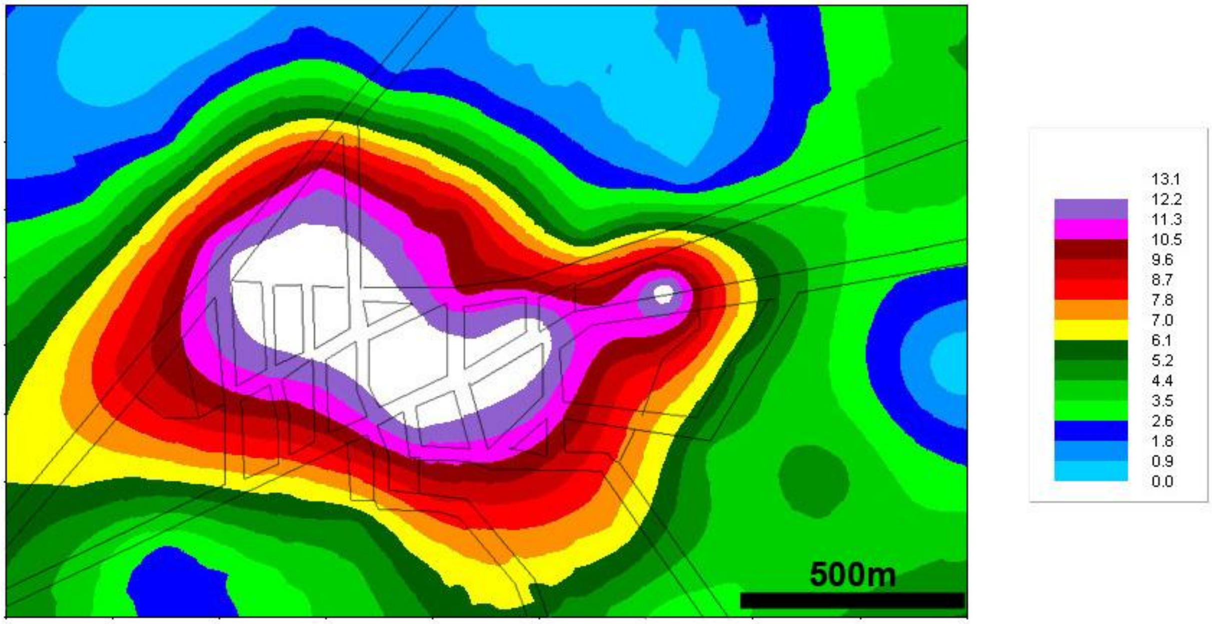

Figure 4.25: Interpolation of granivorous species richness at Mmagabue

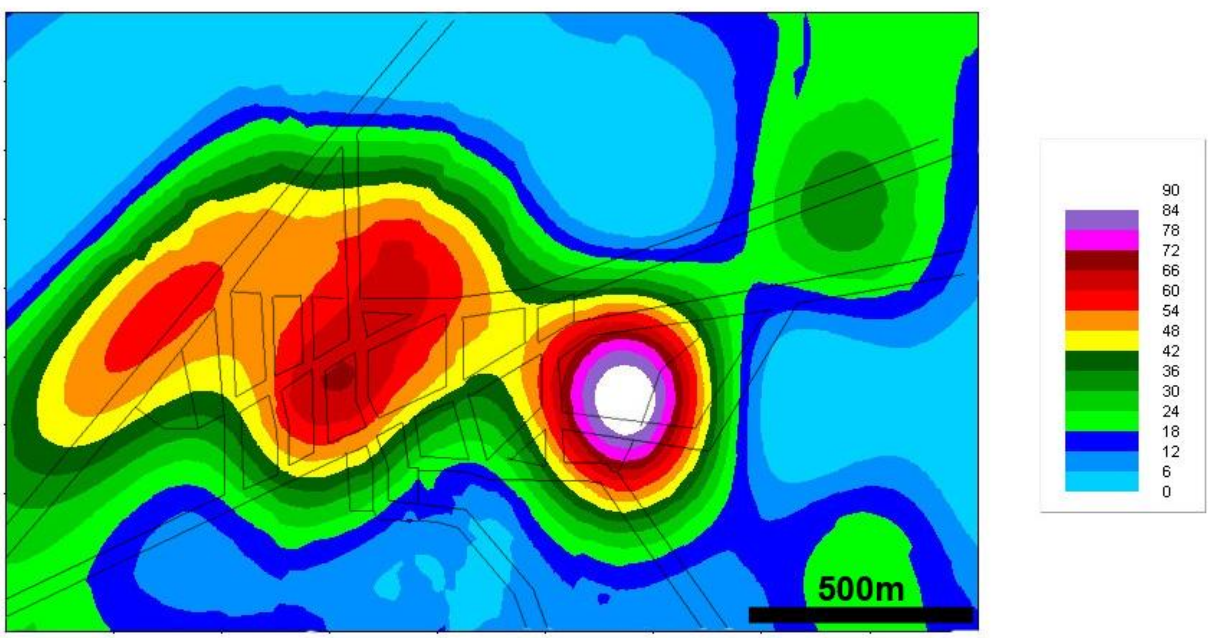

Figure 4.26: Interpolation of granivore numbers at Mmagabue

4.2.1.5 CARNIVORES

Carnivore species and numbers were consistently higher in the natural habitats surrounding each village, as shown in Figures 4.27 - 4.32, but note should be taken of the low values for each variable.

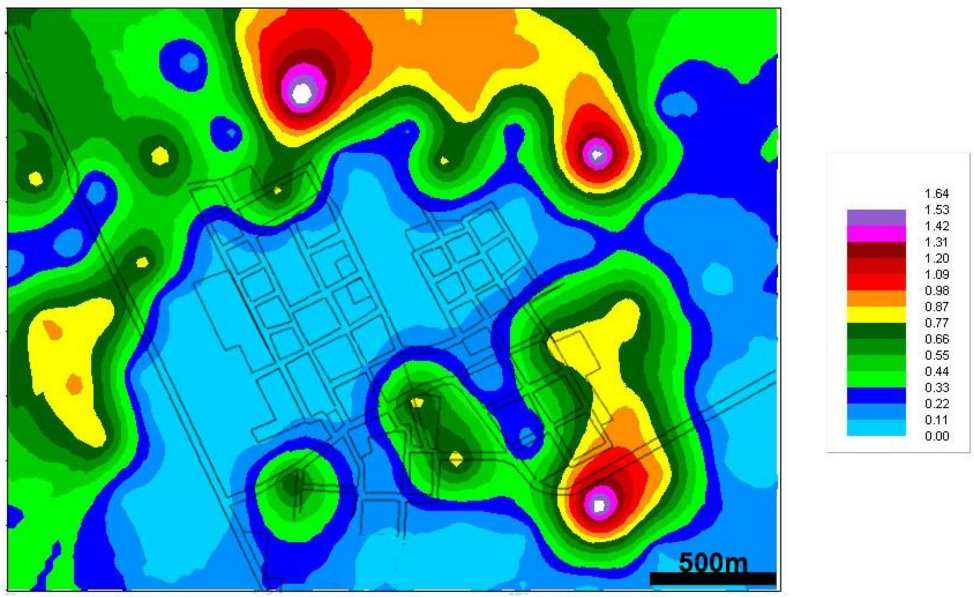

Figure 4.27: Interpolation of carnivorous species richness at Austray

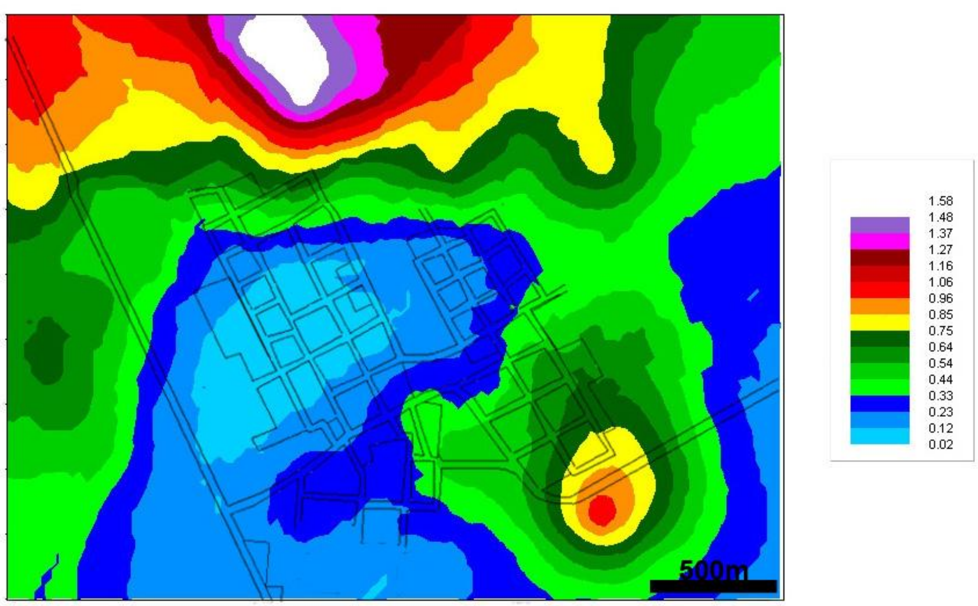

Figure 4.28: Interpolation of carnivore numbers at Austray

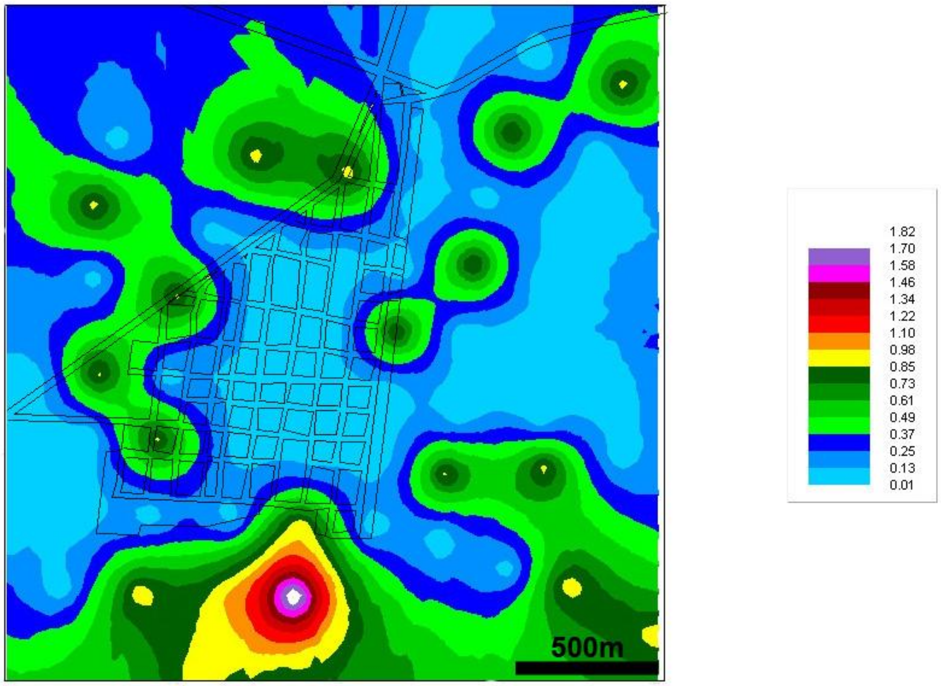

Figure 4.29: Interpolation of carnivorous species richness at Southey

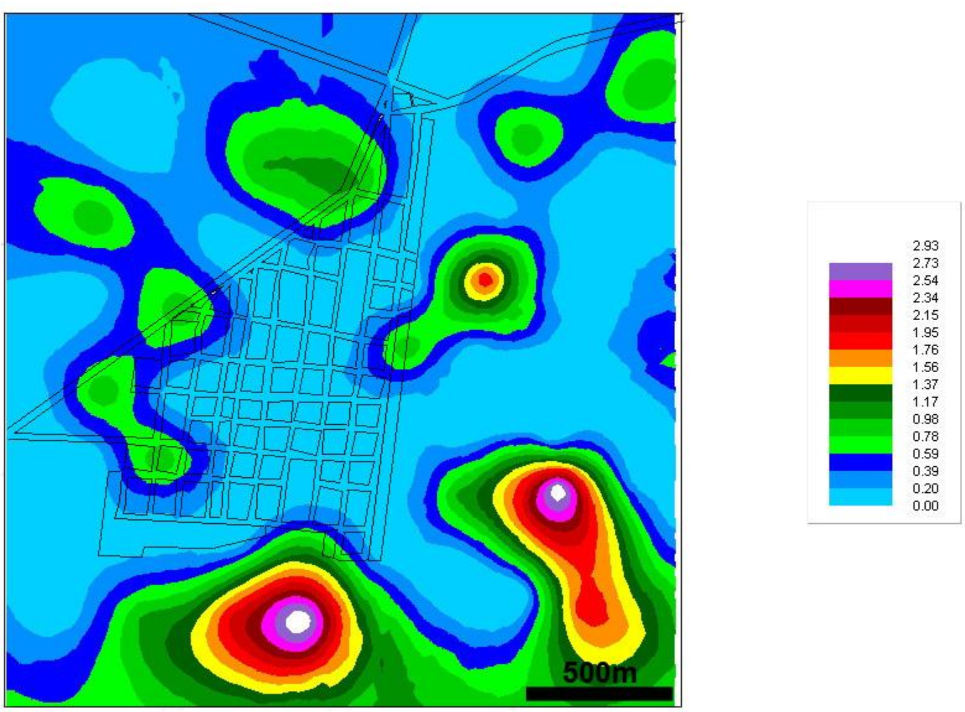

Figure 4.30: Interpolation of carnivore numbers at Southey

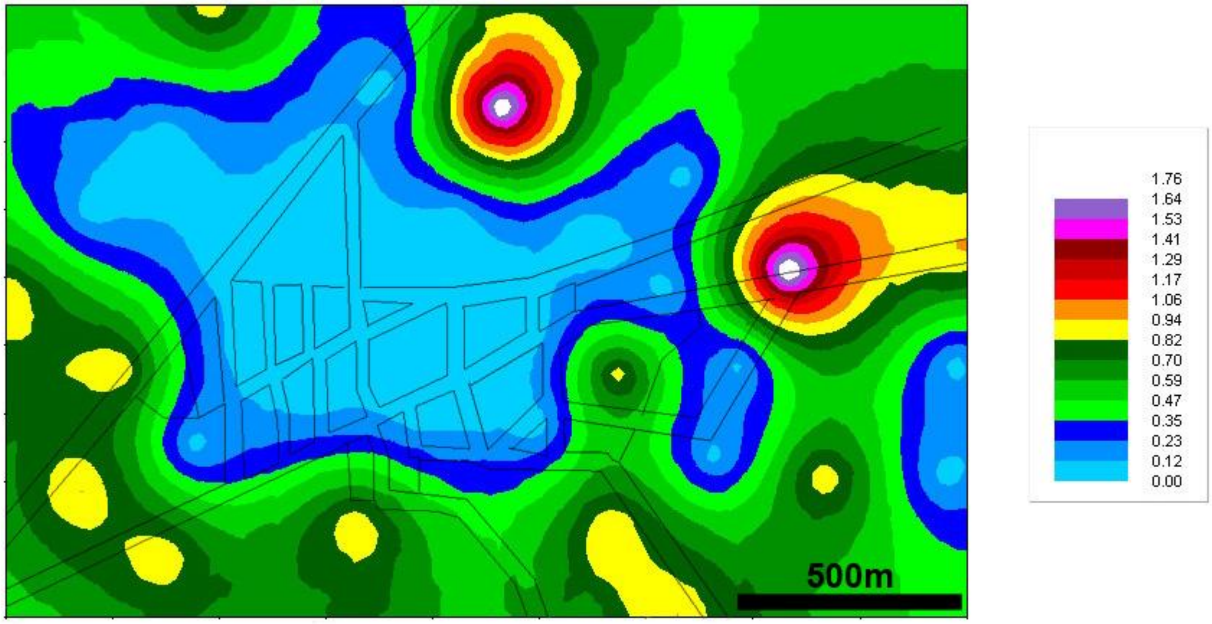

Figure 4.31: Interpolation of carnivorous species richness at Mmagabue

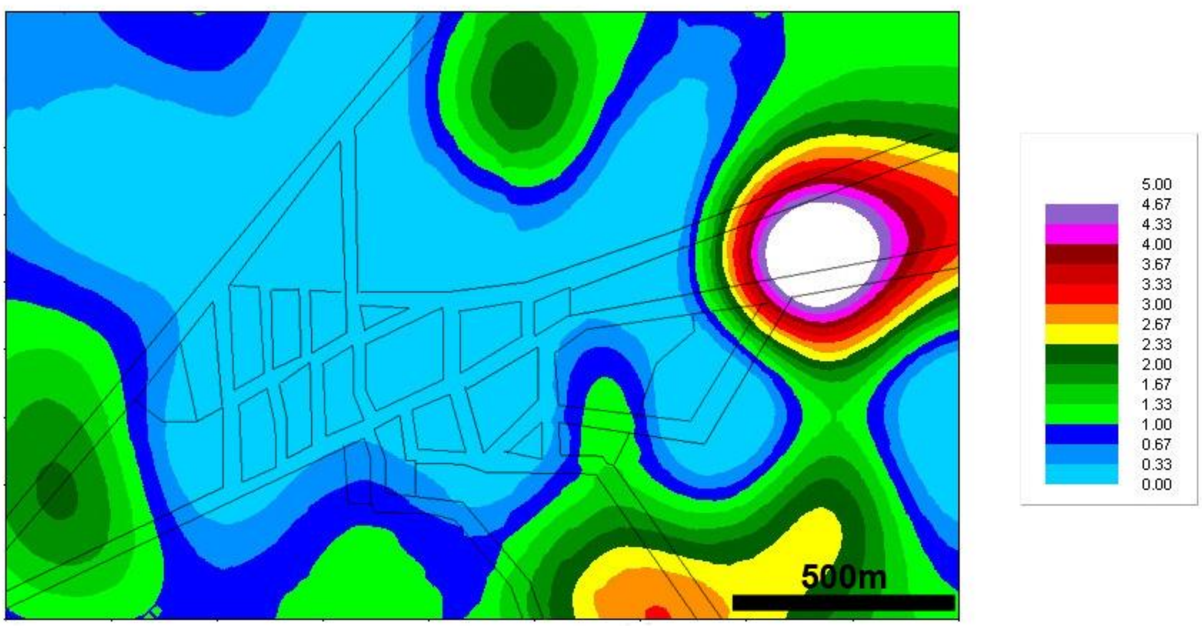

Figure 4.32: Interpolation of carnivore numbers at Mmagabue

4.2.1.6 GROUND-NESTERS

The numbers of ground-nesting species and individual birds tended to be higher in the natural areas surrounding the village. Mmagabue (Figures 3.37 and 3.38), had many open areas and bare ground within the village, resulting in patches inside the village with high numbers of ground-nesters. These results are shown in Figures 3.33 - 4.38 but note should be taken of the low values for each variable.

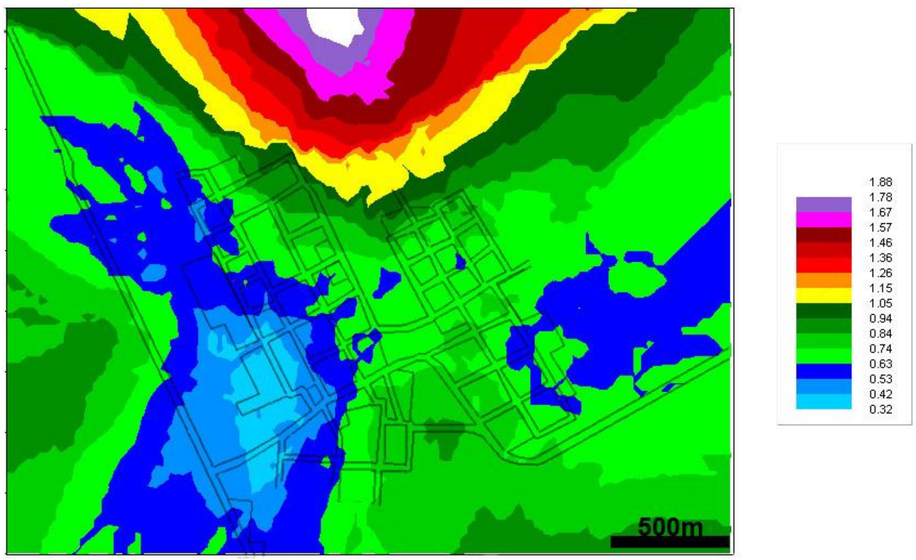

Figure 4.33: Interpolation of ground-nesting species richness at Austray

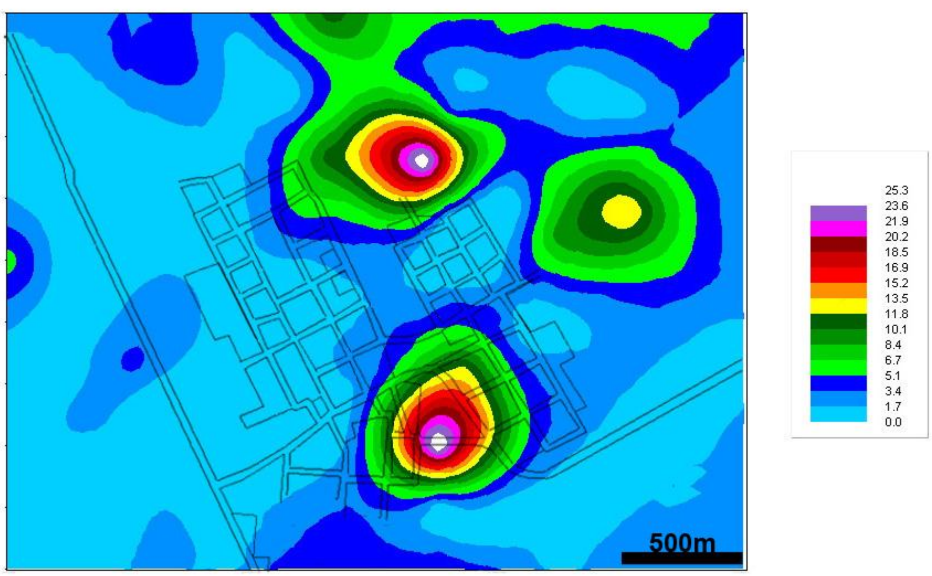

Figure 4.34: Interpolation of number of ground-nesters at Austray

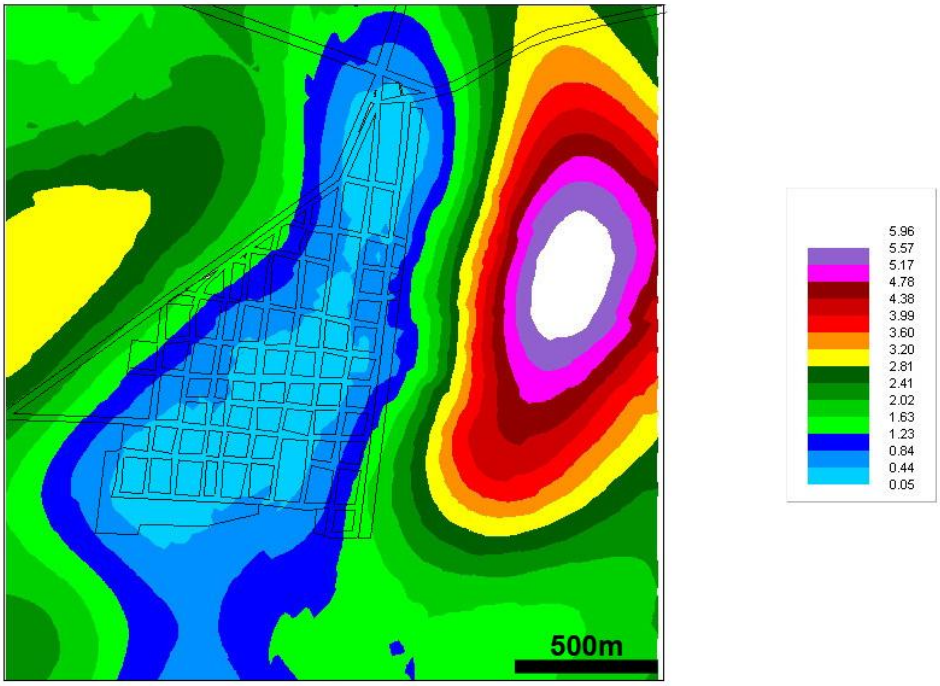

Figure 4.35: Interpolation of ground-nesting species richness at Southey

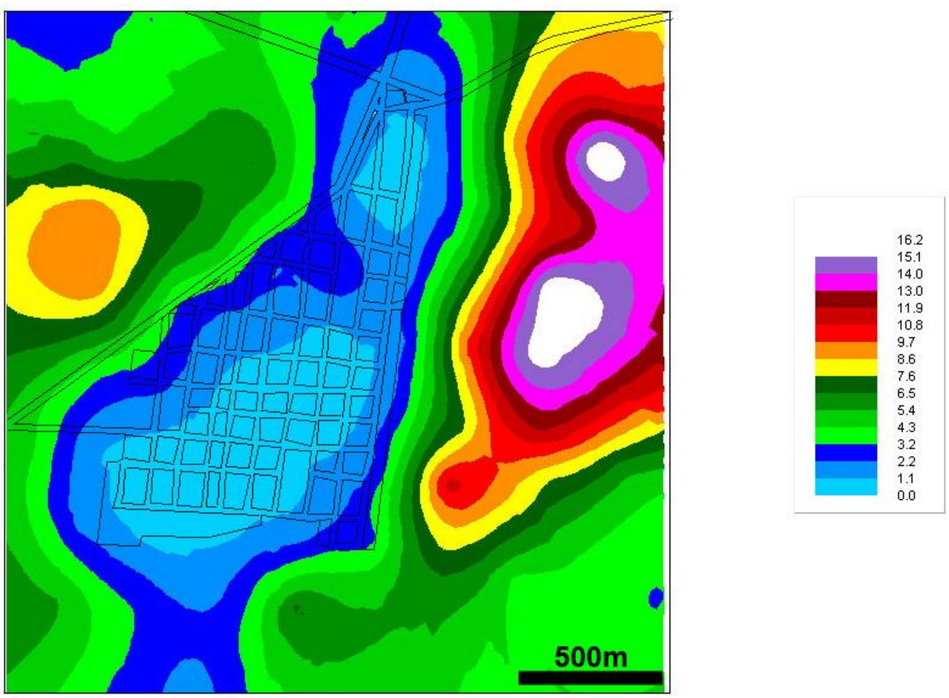

Figure 4.36: Interpolation of number of ground-nesters at Southey

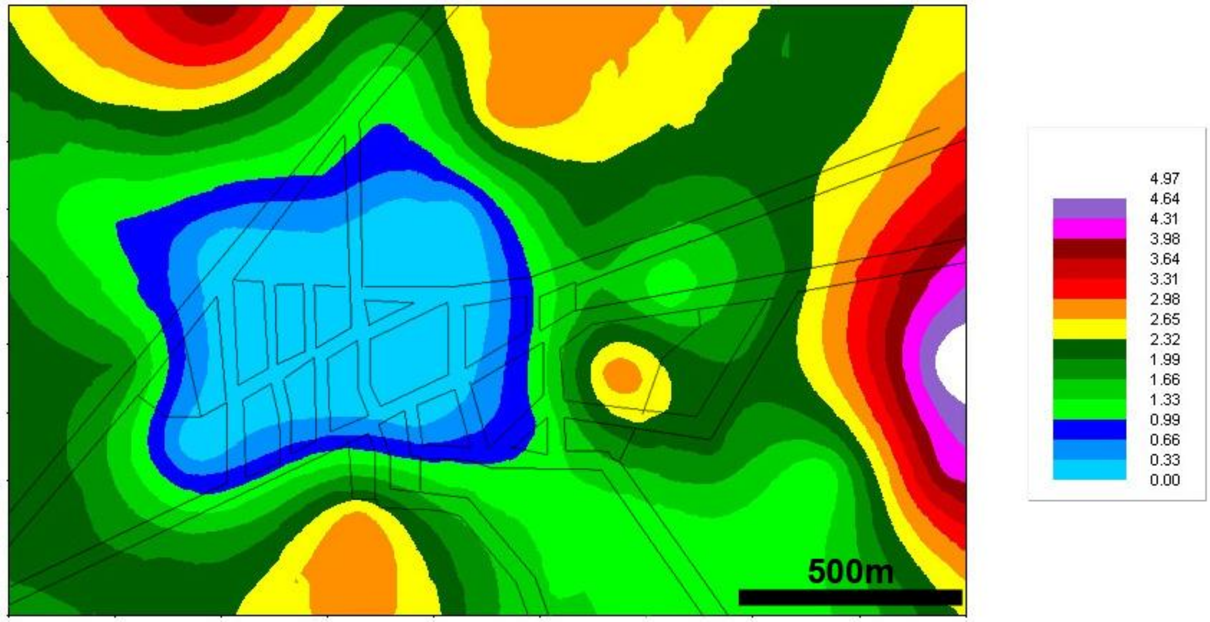

Figure 4.37: Interpolation of ground-nesting species richness at Mmagabue

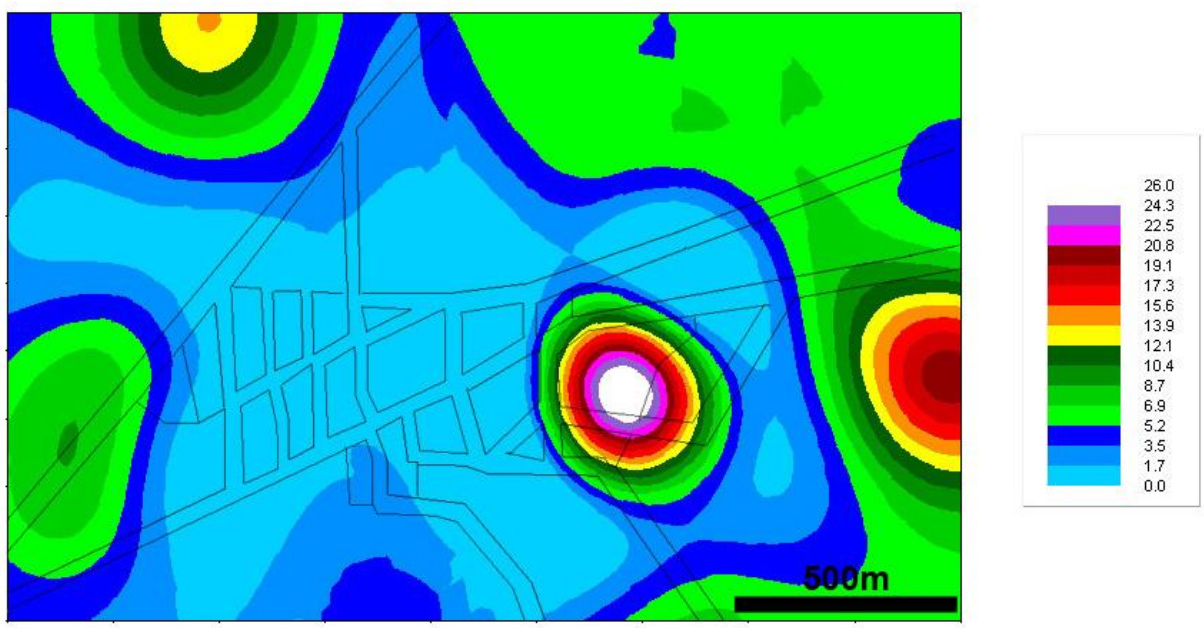

Figure 4.38: Interpolation of number of ground-nesters at Mmagabue

4.2.1.7 TREE-NESTERS

The village interiors supported a much higher diversity and abundance of tree-nesters at all three villages. This data is shown in Figures 4.39 - 4.44.

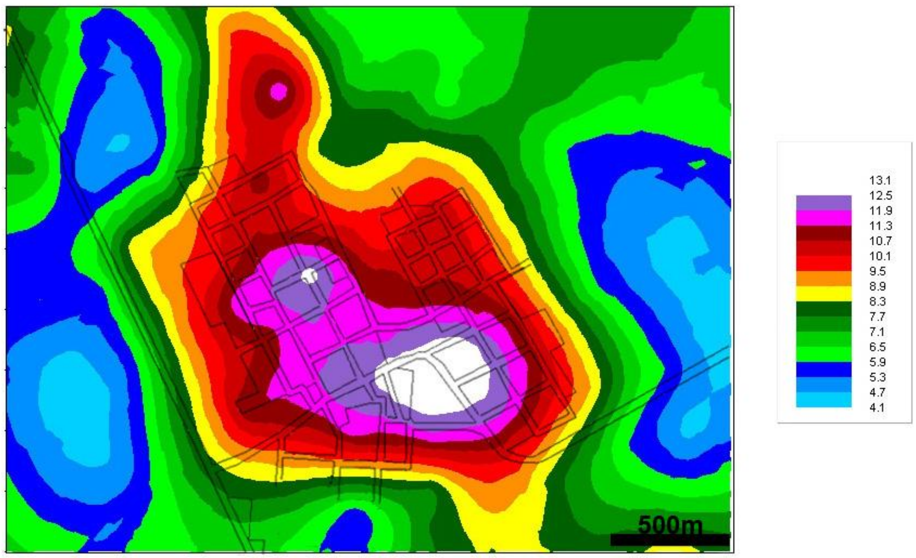

Figure 4.39: Interpolation of tree-nesting species richness at Austray

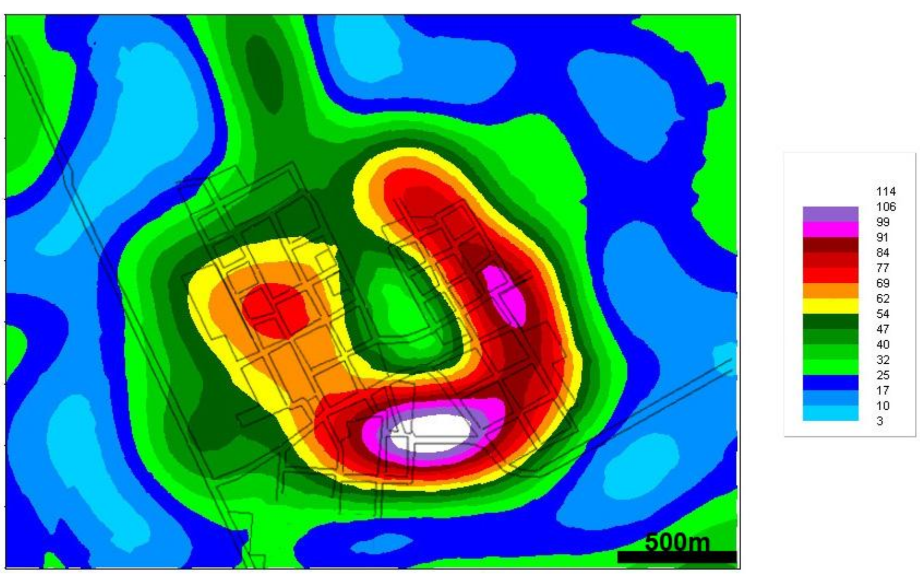

Figure 4.40: Interpolation of number of tree-nesters at Austray

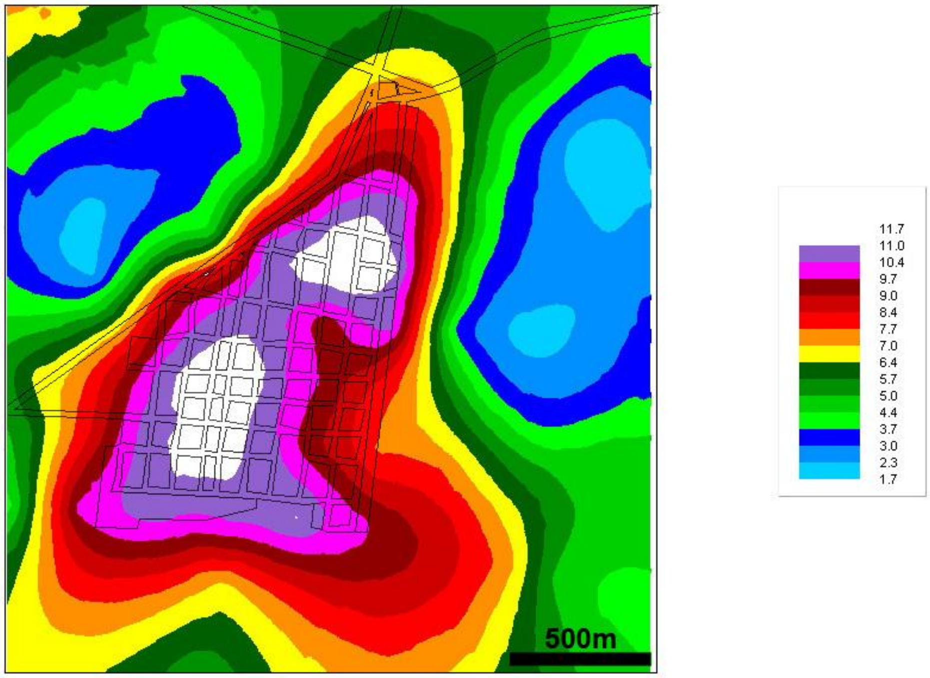

Figure 4.41: Interpolation of tree-nesting species richness at Southey

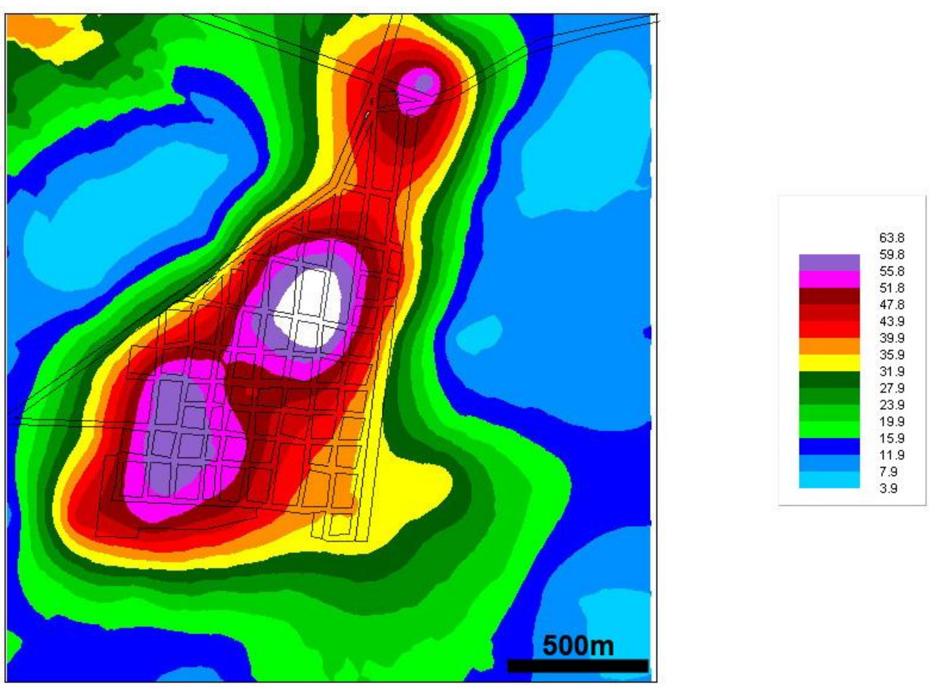

Figure 4.42: Interpolation of number of tree-nesters at Southey

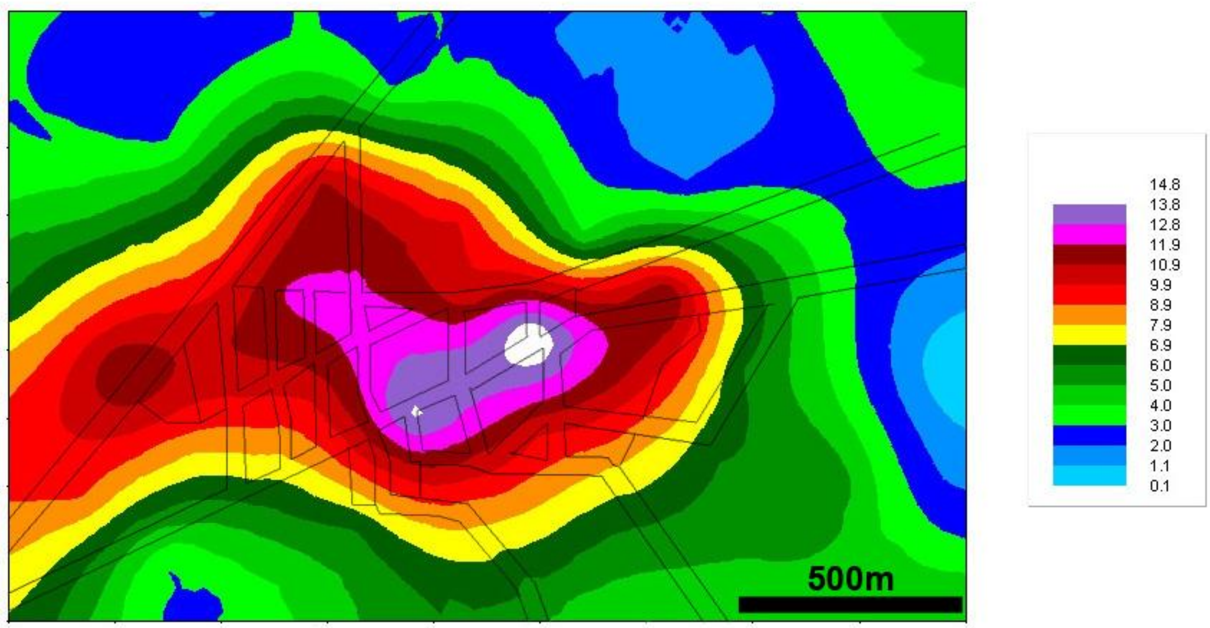

Figure 4.43: Interpolation of tree-nesting species richness at Mmagabue

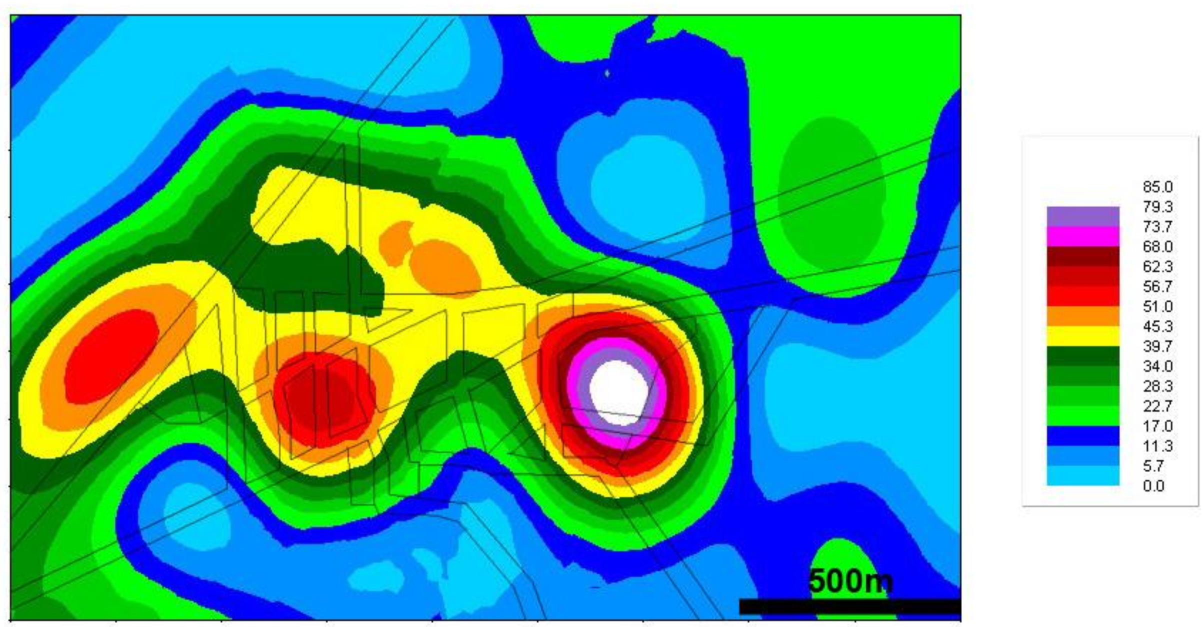

Figure 4.44: Interpolation of number of tree-nesters at Mmagabue

4.2.1.8 SHRUB-NESTERS

Inconsistent patterns for shrub-nesters were found between villages. Austray (Figures 4.45 and 4.46) and Mmagabue (Figures 4.49 and 4.50), had more shrub-nesters outside the village, although Mmagabue did have patches with high numbers inside the village. At Southey (Figures 4.47 and 4.48), shrub-nesters seemed to have occurred at higher levels within the village. This data is shown in Figures 4.45 – 50.

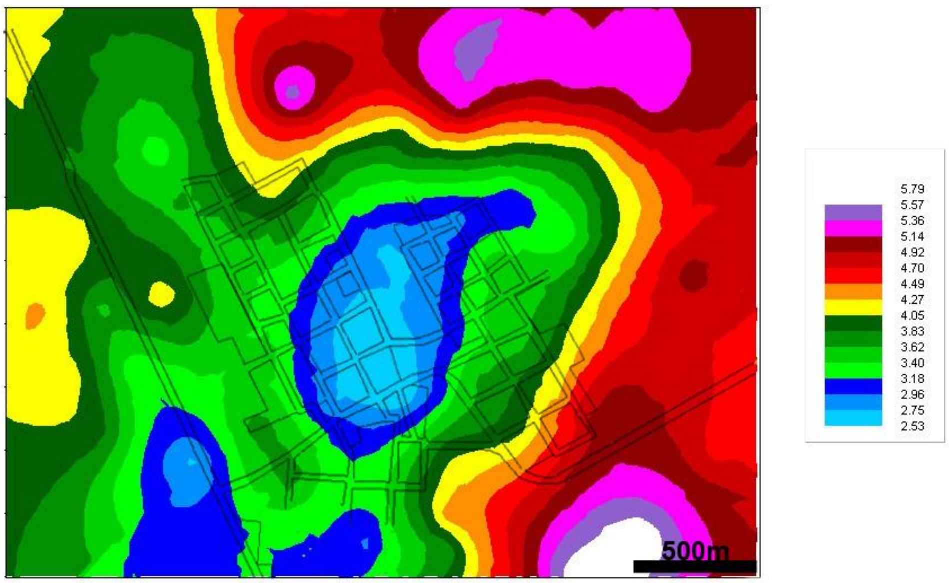

Figure 4.45: Interpolation of shrub-nesting species richness at Austray

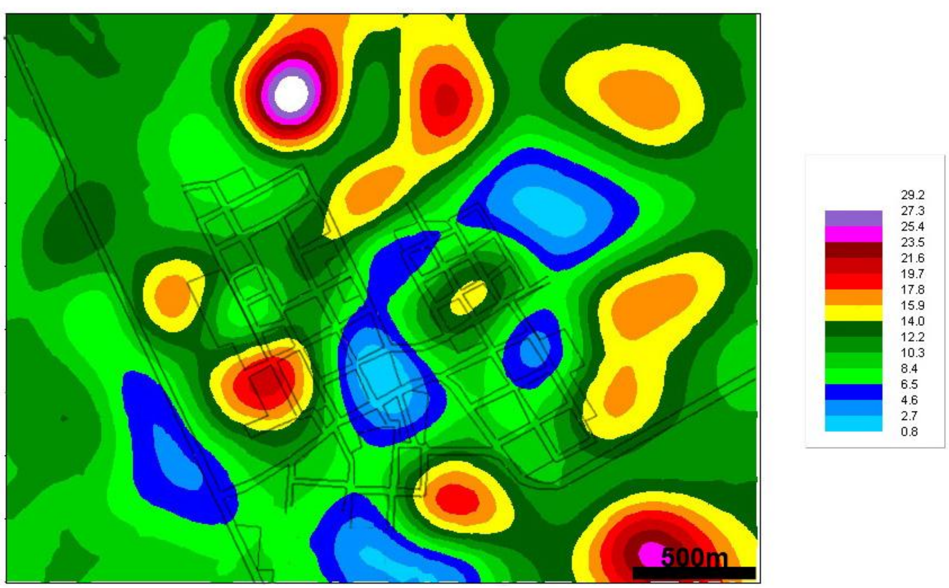

Figure 4.46: Interpolation of number of shrub-nesters at Austray

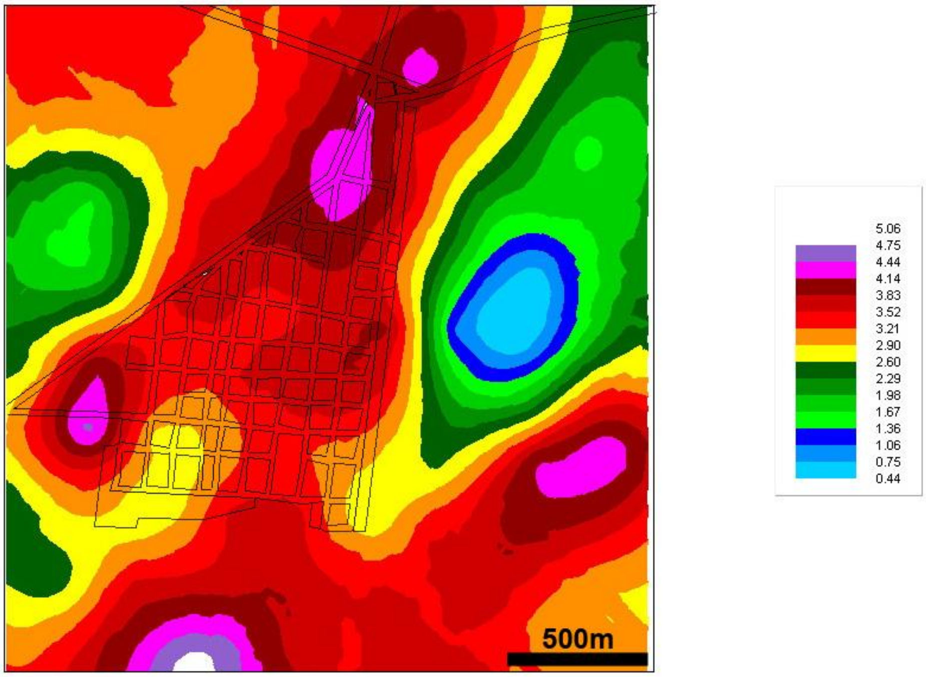

Figure 4.47: Interpolation of shrub-nesting species richness at Southey

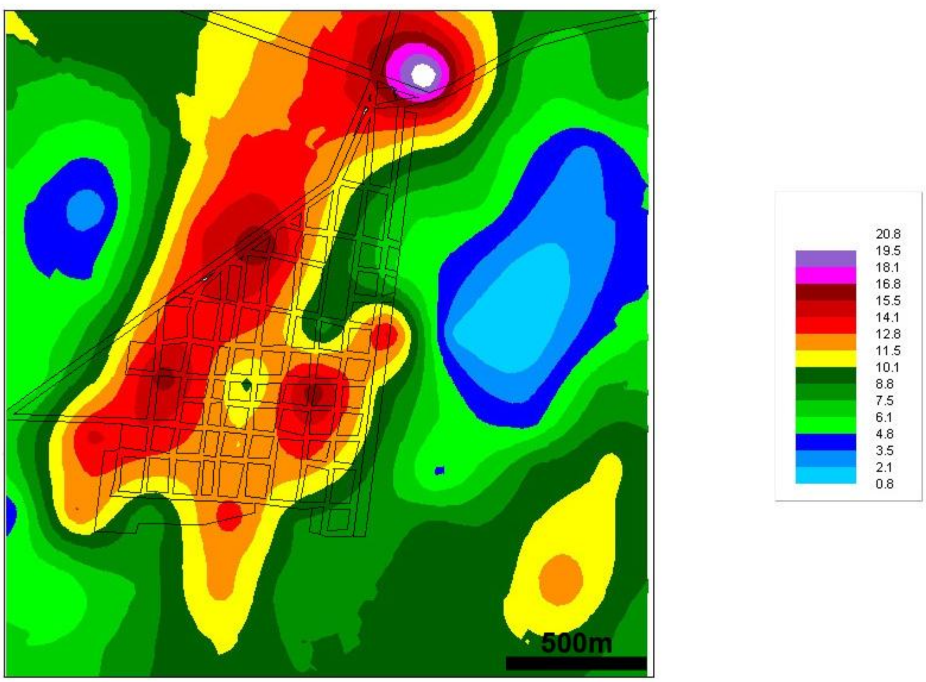

Figure 4.48: Interpolation of number of shrub-nesters at Southey

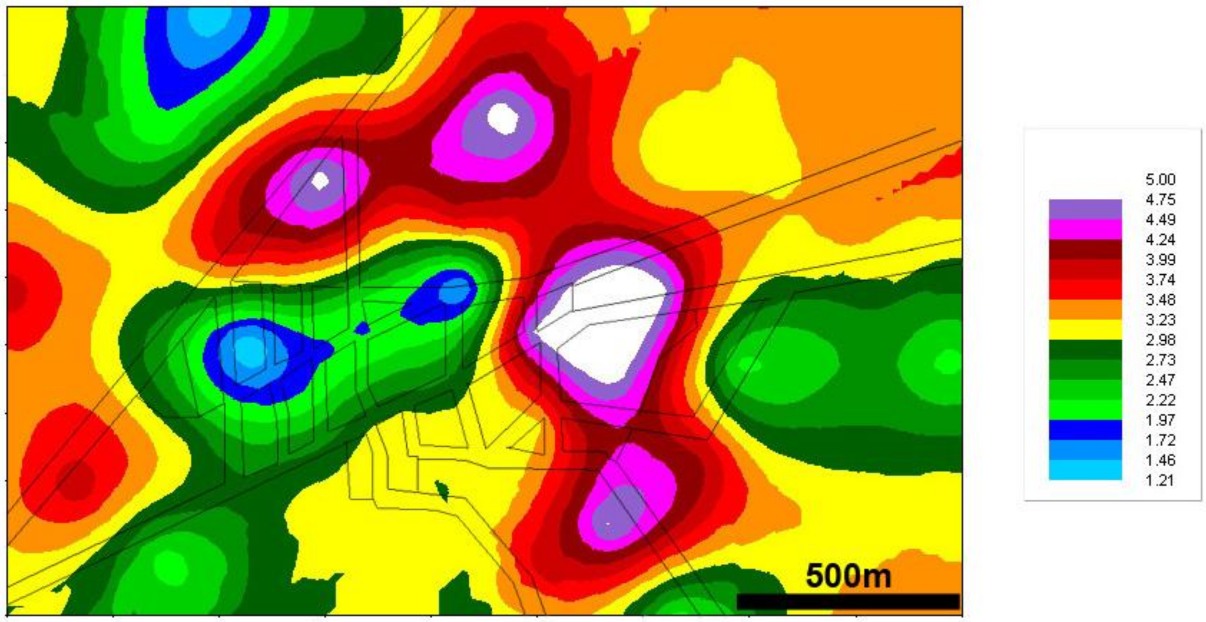

Figure 4.49: Interpolation of shrub-nesting species richness at Mmagabue

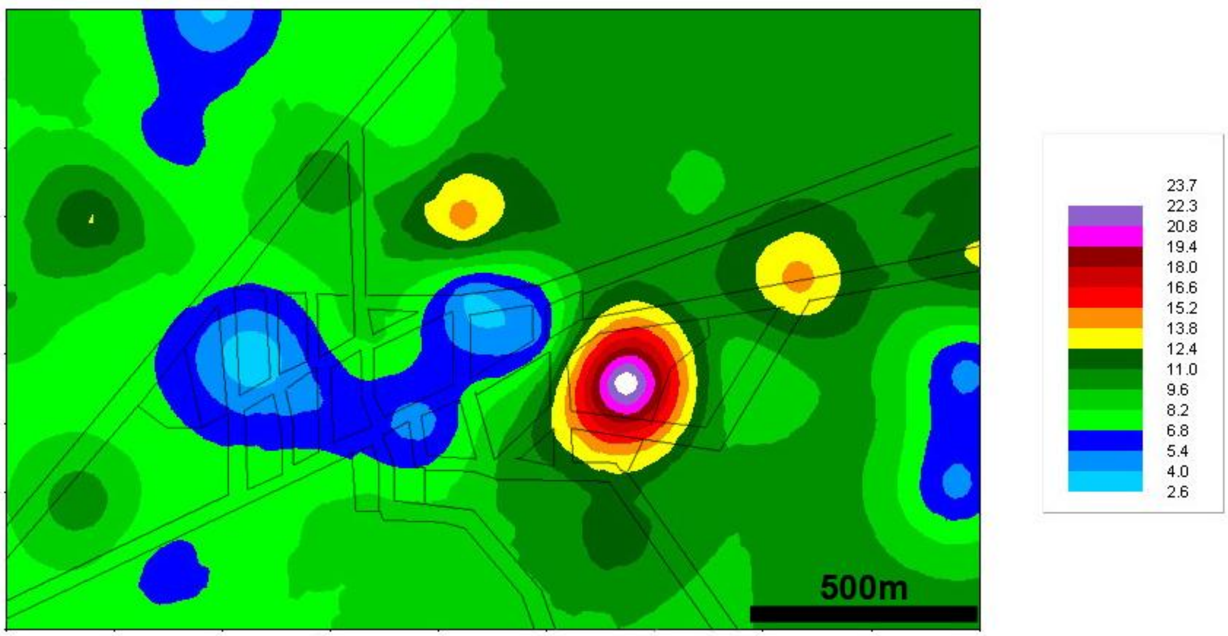

Figure 4.50: Interpolation of number of shrub-nesters at Mmagabue

4.2.1.9 STRUCTURE-NESTERS

At all three villages, the interior parts of the village supported much higher levels of structure-nesting birds. These results are shown in Figures 4.51 - 4.56.

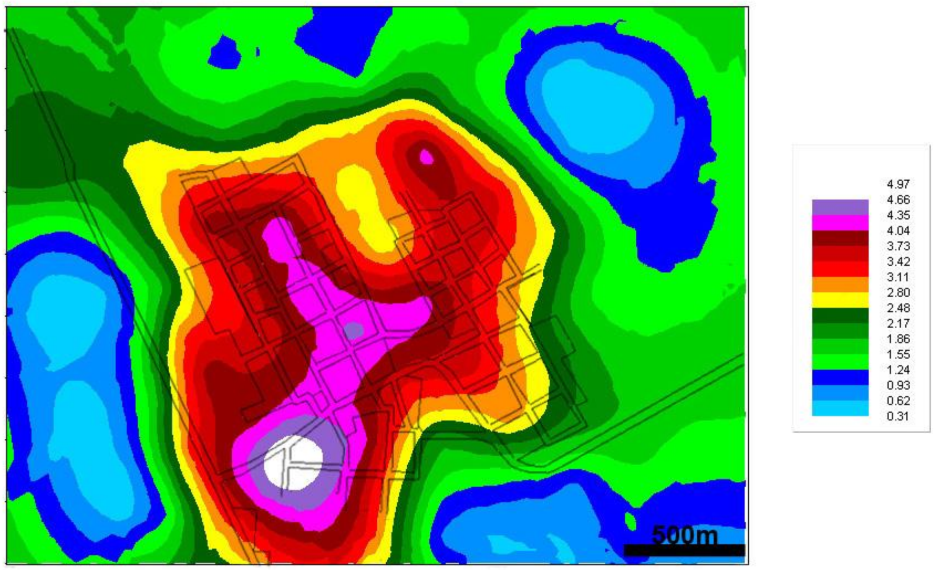

Figure 4.51: Interpolation of structure-nesting species richness at Austray

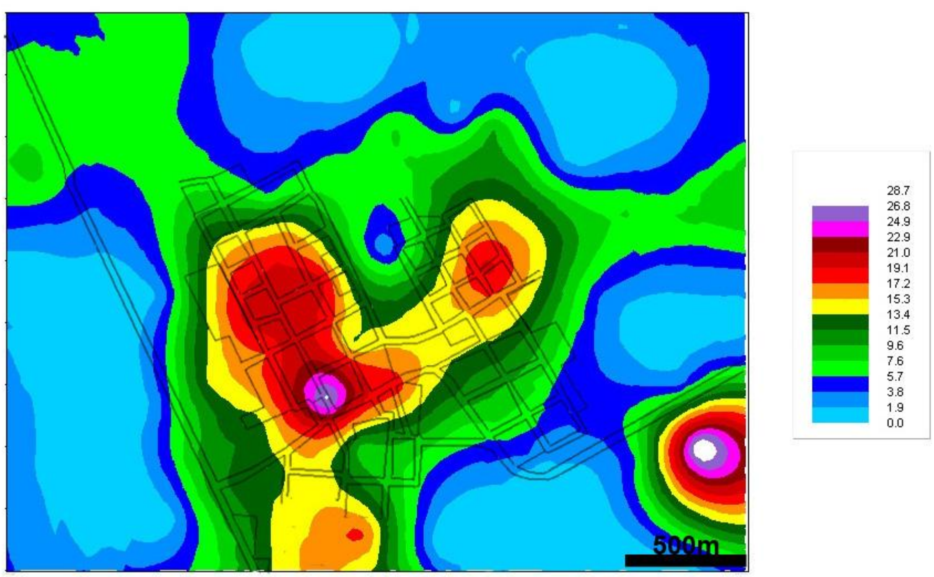

Figure 4.52: Interpolation of number of structure-nesters at Austray

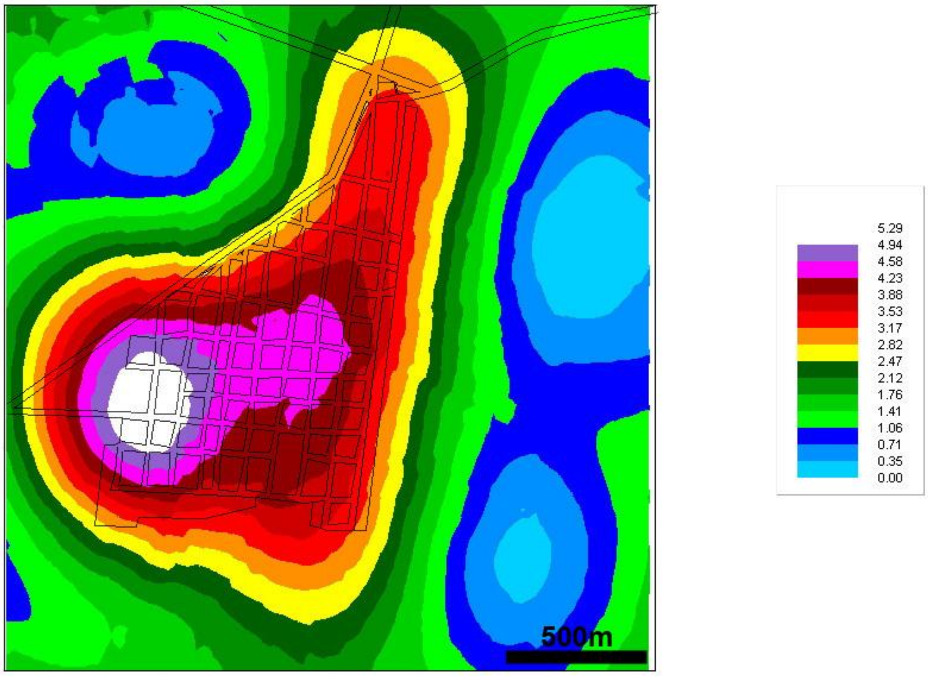

Figure 4.53: Interpolation of structure-nesting species richness at Southey

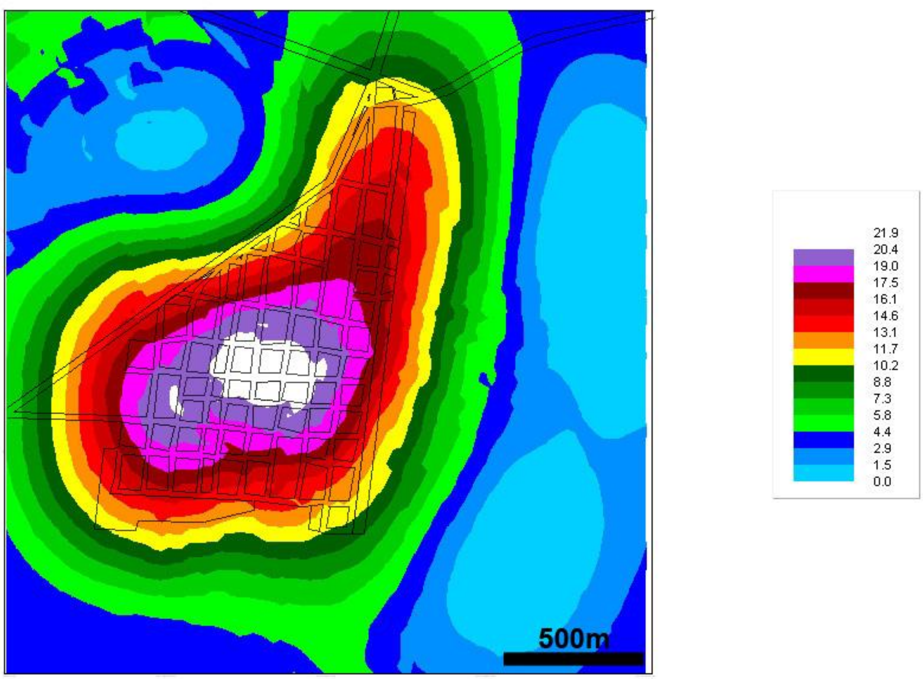

Figure 4.54: Interpolation of number of structure-nesters at Southey

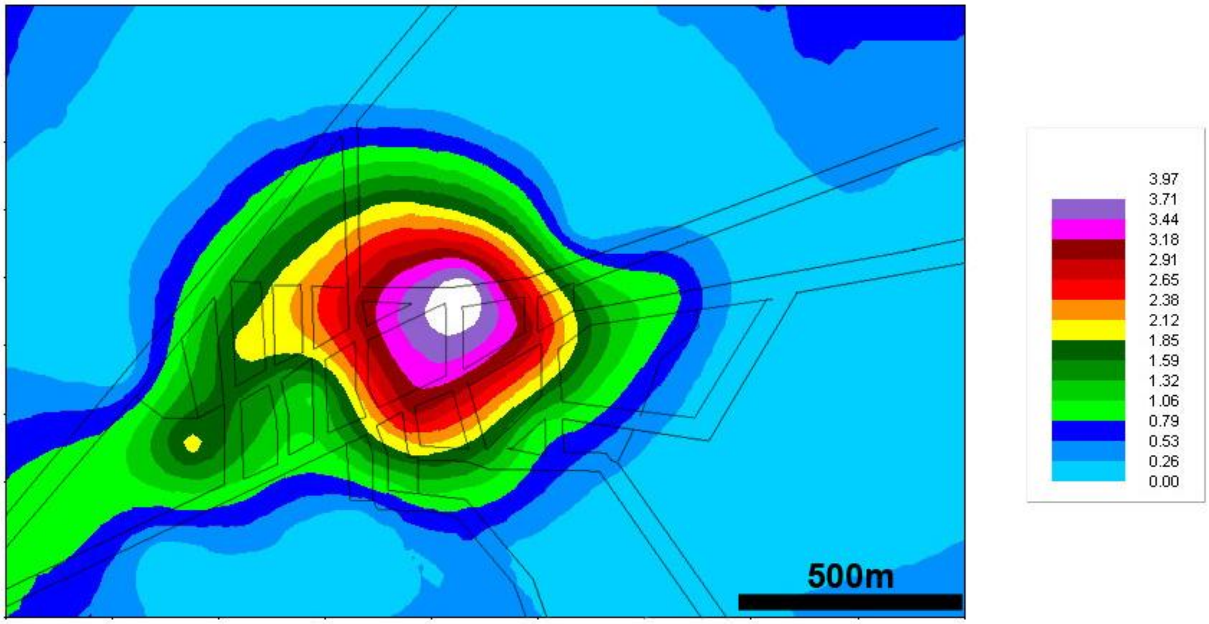

Figure 4.55: Interpolation of structure-nesting species richness at Mmagabue

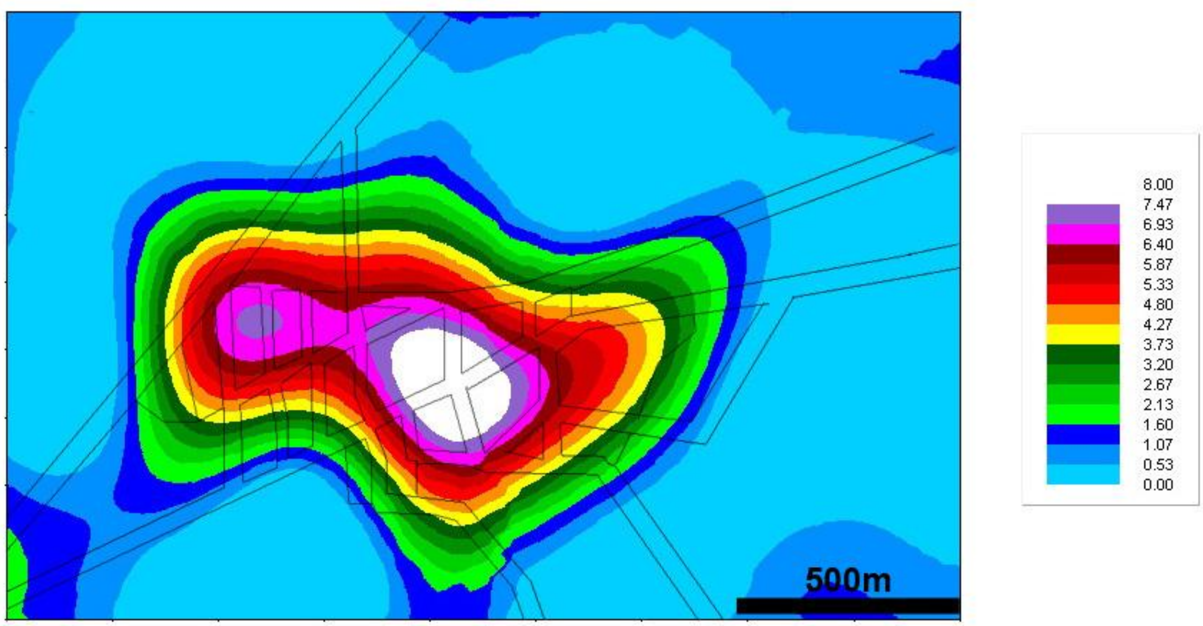

Figure 4.56: Interpolation of number of structure-nesters at Mmagabue

4.2.2 DIVERSITY INDICES

Primer 5™ and PC-ORD™ were used to calculate diversity indices for the collected data. Diversity indices were calculated for each site surveyed at each village. The mean diversity indices and the evenness for each village are given in Table 4.17.

Table 4.17: Mean diversity indices for all villages

	AUSTRAY	STANDARD DEVIATION	MMAGABUE	STANDARD DEVIATION	SOUTHEY	STANDARD DEVIATION
Evenness	0.87	±0.06	0.87	±0.07	0.90	±0.04
Shannon	2.48	±0.31	2.39	±0.35	2.49	±0.30
Simpson	0.90	±0.05	0.89	±0.07	0.91	±0.04
Margalef	4.03	±0.84	3.76	±0.99	3.89	±0.80

The results in Table 4.17 show that there were only relatively small differences in diversity between the three villages. The evenness for each village is quite low, indicating a small number of common species and a large number of uncommon species at the different sites. This may lead to higher similarity between diversity indices, since they would have been even less similar had the evenness been higher. The Shannon, Simpson, and Margalef indices indicate some difference in diversity between the three villages. The Shannon diversity for each habitat type is shown in Table 4.18.

Table 4.18: Mean Shannon diversity for each habitat type

	NATURAL HABITAT	EDGE HABITAT	VILLAGE HABITAT
Austray	2.417	2.464	2.619
Southey	2.253	2.483	2.733
Mmagabue	2.143	2.477	2.689

To see the distribution of Shannon diversity within each village, GS+™ was once again used and the results are shown in Figures 4.57 - 4.59. Shannon was used as the other indices gave counter intuitive distributions.

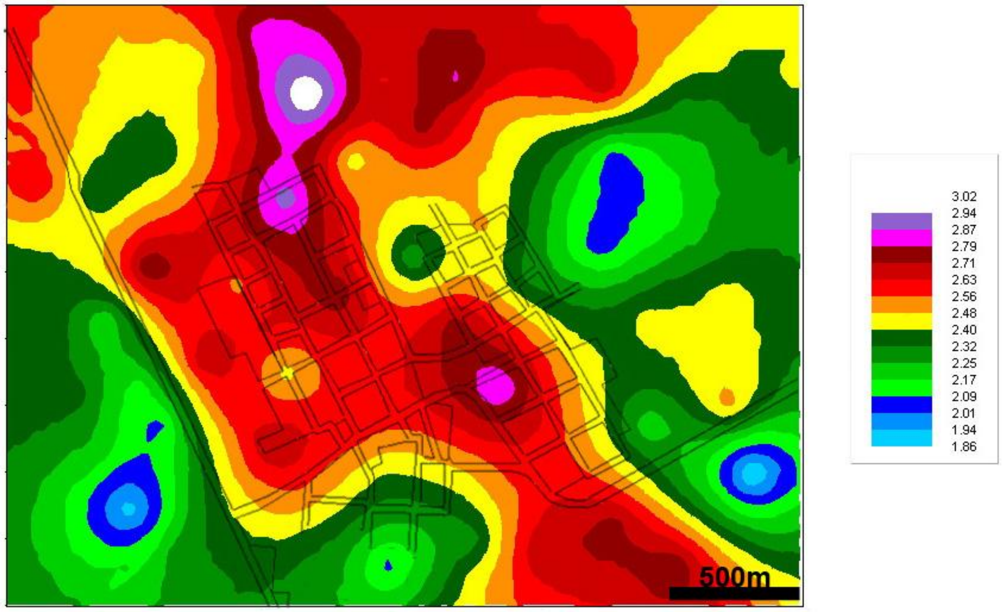

Figure 4.57: Interpolated Shannon index distribution for Austray

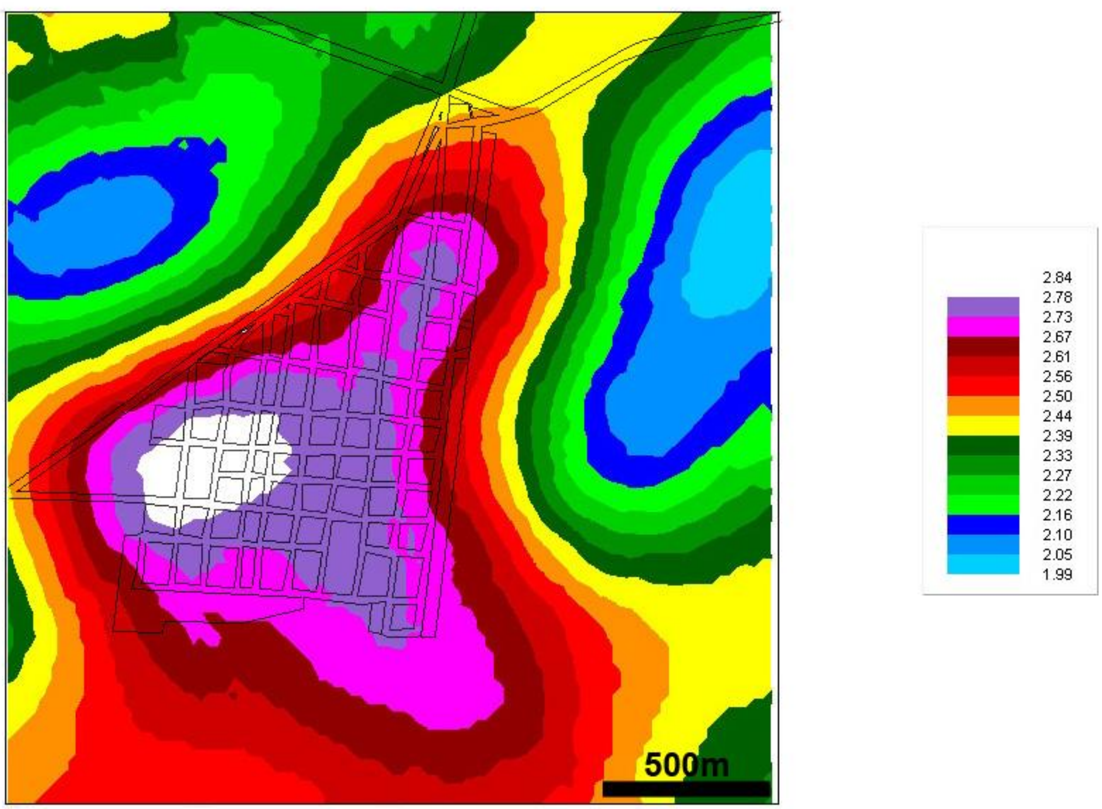

Figure 4.58: Interpolated Shannon index distribution for Southey

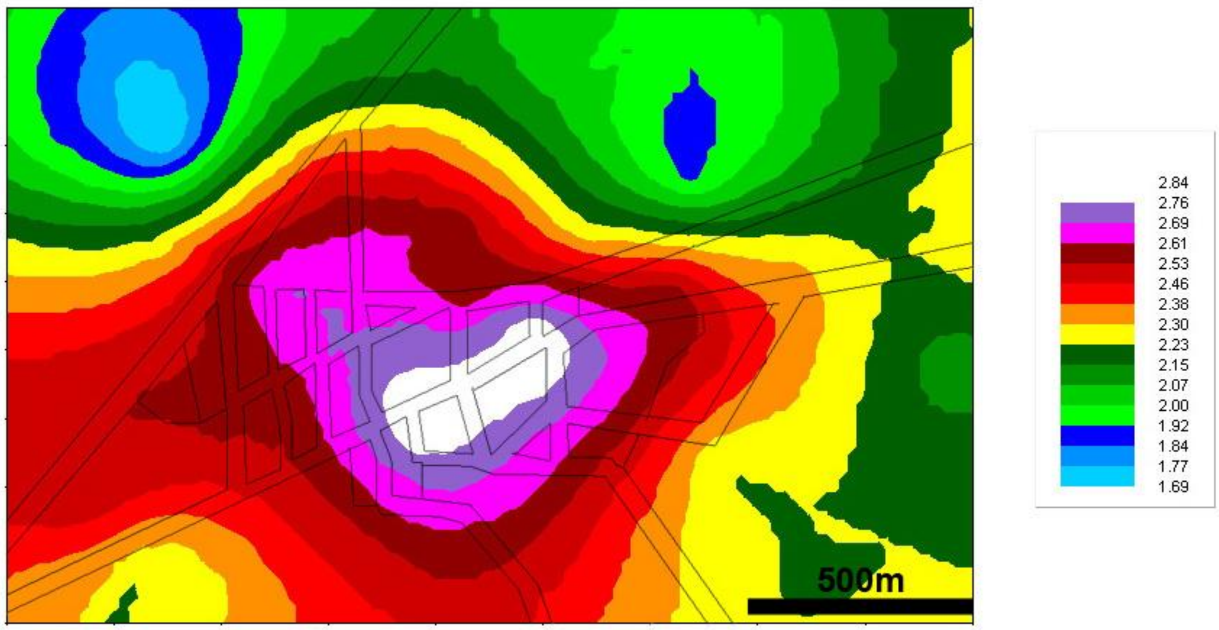

Figure 4.59: Interpolated Shannon index distribution for Mmagabue

4.2.3 NON-METRIC MULTIDIMENSIONAL SCALING (NMS)

Non-metric Multidimensional Scaling (NMS) was done using PC-ORD^{TM}.
At Austray (Figure 4.60), only two dimensions were derived. The final stress after 200 iterations was 19.793 and the final instability was 0.00616. The Monte Carlo tests were significant for both axes ($p = 0.0196$). Axis 1 explained 31% of the variation and axis 2 explained 42.1%, for a cumulative explanation of 73.1%. Natural habitat point count sites were located mostly to the top, and village habitat point count sites were clustered together at the bottom. Edge habitat point count sites were scattered around the village habitat sites, indicating that they resembled the village habitat sites more closely that the natural habitat sites in terms of species composition. Species closely associated with the natural habitat were the Kalahari Scrub-robin, Chestnut-vented Tit-babbler, Fork-tailed Drongo, and Barn Swallow. Species associated with the edge and village habitats were the Speckled Pigeon, Laughing Dove, Namaqua Dove, African Hoopoe, House Sparrow, Cape Sparrow, Southern Grey-headed Sparrow, Red-headed Finch and Black-throated Canary.

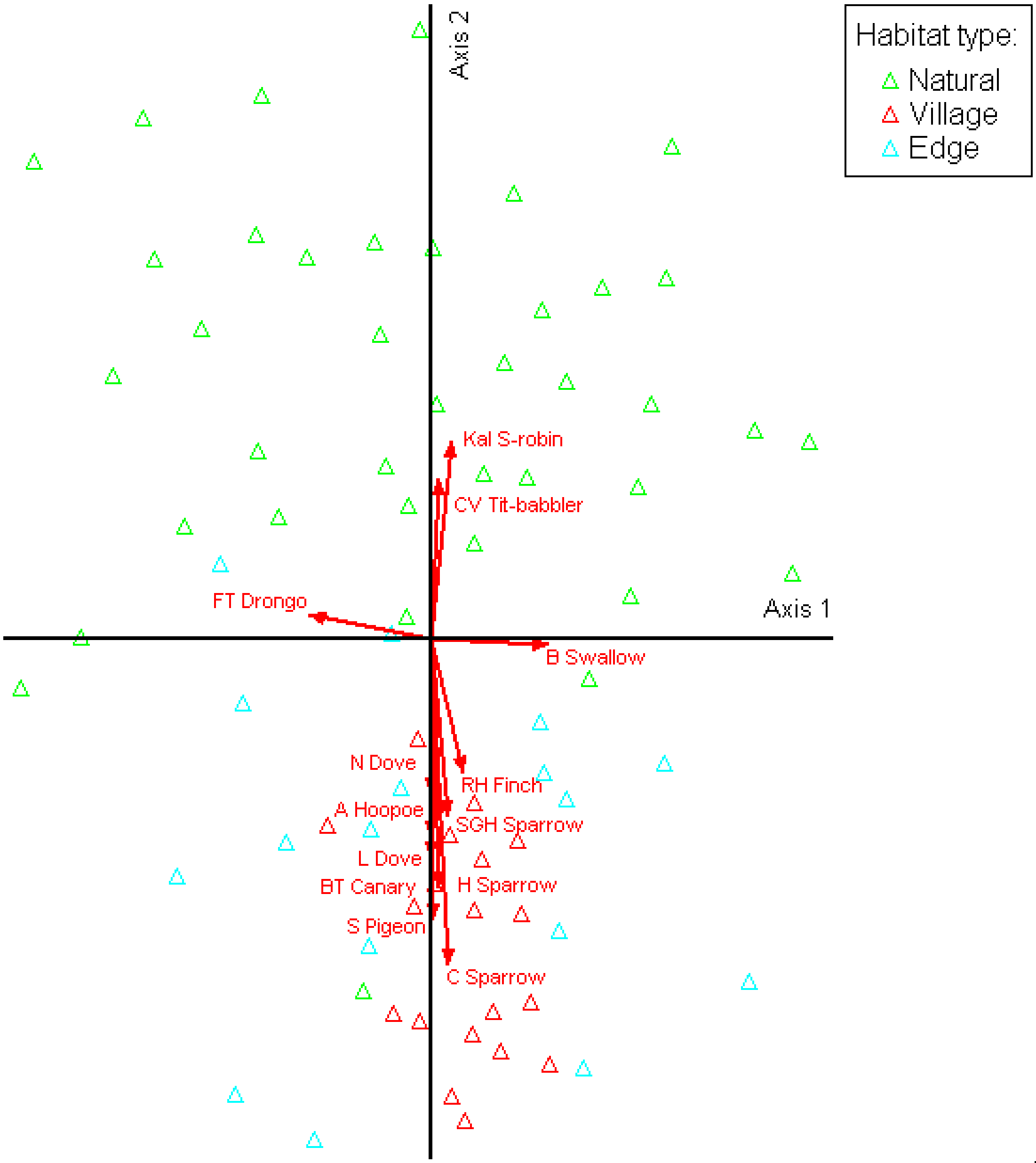

Figure 4.60: NMS bi-plot for Austray

At Southey (Figure 4.61), two dimensions were derived. The final stress reached after 200 iterations was 19.455. Final instability was 0.00374. The Monte Carlo tests were significant for both axes ($p = 0.0196$). Axis 1 explained 61.3% of the variation and Axis 2, 15.1%, for a cumulative explanation of 76.4%. Natural habitat point count sites were located at the top, and village habitat sites at the bottom. Edge habitat sites were located between the natural and village sites, but resembled the natural habitat sites more closely. Species closely associated with the natural habitat were the Spike-heeled Lark, Cape Clapper Lark, Barn Swallow, Ashy Tit, Kalahari Scrub-robin, Chestnut-vented Tit-babbler, Black-chested Prinia, Lesser Grey Shrike, African Pipit and White-browed Sparrow-weaver. Species associated with the village habitat included the Speckled Pigeon, Laughing Dove, Namaqua Dove, African Hoopoe, Familiar Chat, Cape Glossy Starling, Marico Sunbird, House Sparrow, Cape Sparrow, Southern Grey-headed Sparrow, Southern Masked-weaver, and Yellow Canary.

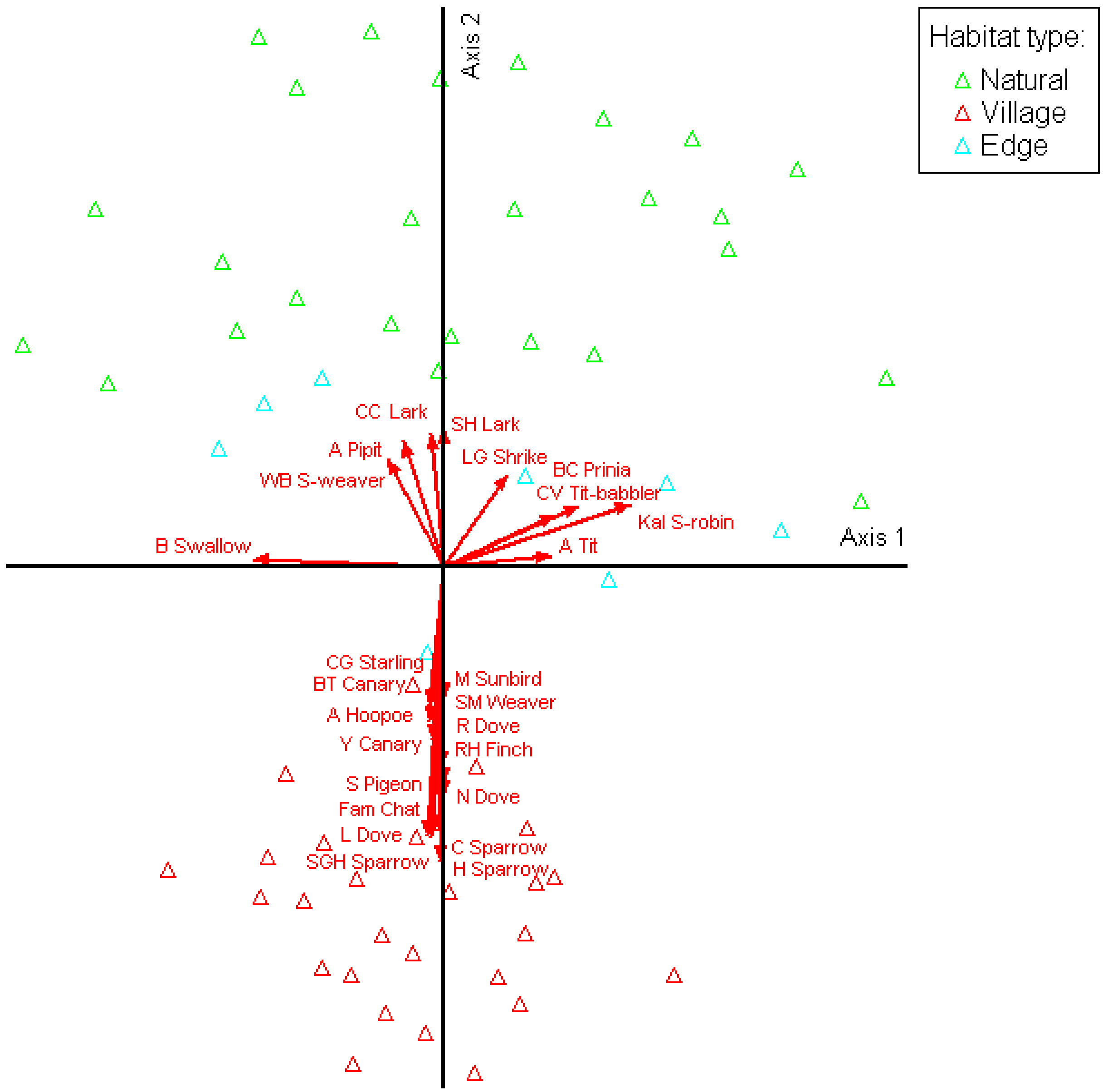

Figure 4.61: NMS bi-plot for Southey

At Mmagabue (Figure 4.62), three dimensions were derived. The final stress reached after 200 iterations was 12.669 and final instability was 0.00029. The Monte Carlo tests were significant for Axes 1 and 2 (p = 0.0196). Axis 1 explained 32.4% of the variation and Axis 2, 36.2%, for a cumulative explanation of 68.2%. The third axis explained 15.6%. Natural habitat point count sites were located mostly to the left, and village habitat sites to the right. Edge habitat sites were located roughly between the natural and village sites. Species closely associated with the natural habitat were the Northern Black Korhaan, Spike-heeled Lark, Cape Clapper Lark, Barn Swallow, Kalahari Scrub-robin, Black-chested Prinia and Red-backed Shrike. Species associated with the village habitat included the Speckled Pigeon, Laughing Dove, Familiar Chat, Cape Glossy Starling, Marico Sunbird, House Sparrow, Southern Grey-headed Sparrow, Southern Masked-weaver, Red-headed Finch and Black-throated Canary.

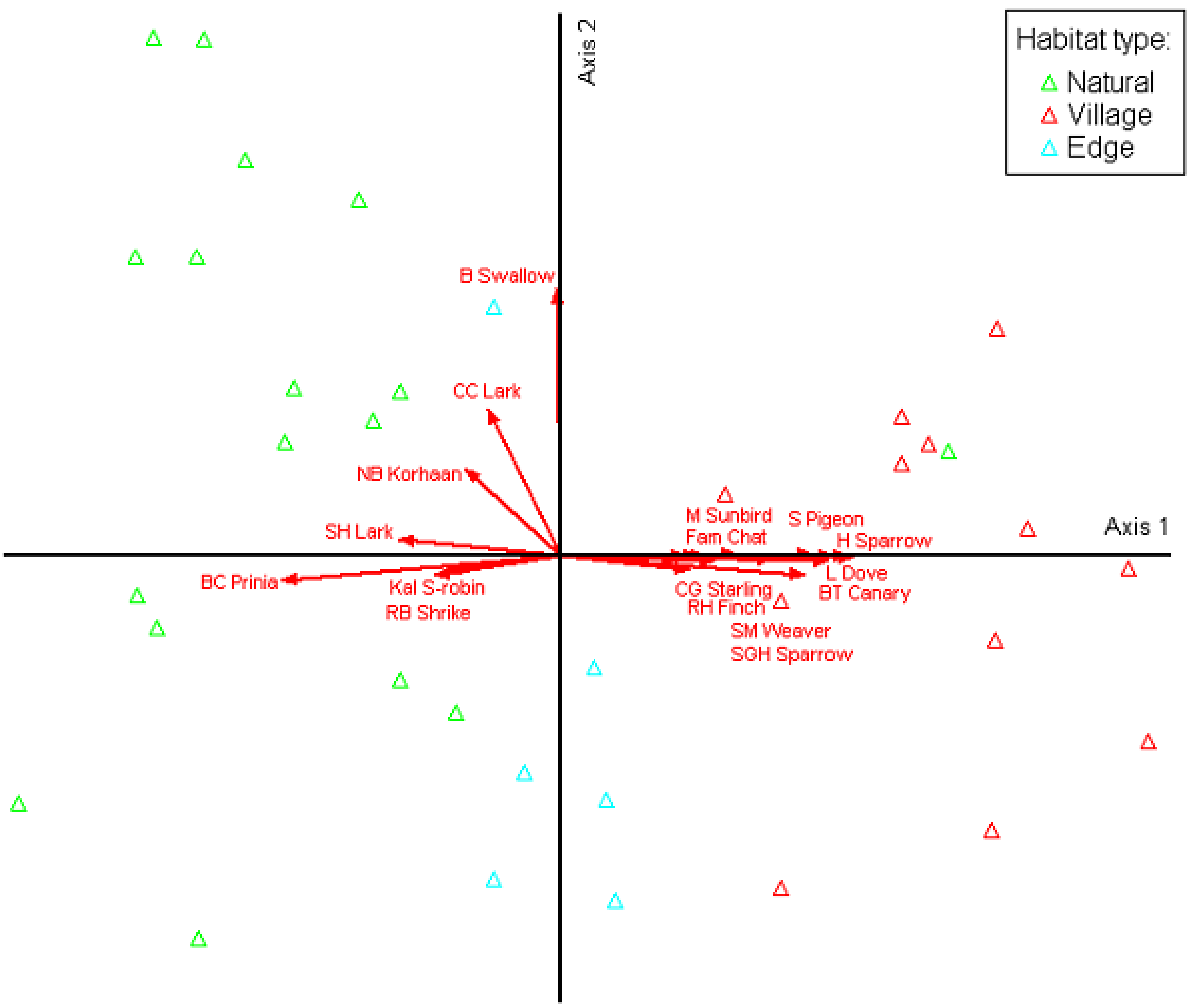

Figure 4.62: NMS bi-plot for Mmagabue

4.2.4 ANALYSIS OF VARIANCE (ANOVA)

An analysis of variance (ANOVA) was done with the use of GraphPad Prism™. Non-parametric Kruskal-Wallis tests and Dunn's post tests were performed for the aggregated number of species per point count site at each village, as well as for the total number of birds per point count site at each village. The p-value for each test is indicated on the top right of each scatter plot. A further post test to determine the linear trend and significance of the slope was also performed.

In terms of species richness, village habitats showed a higher number of species than the natural habitats. In terms of bird numbers, all three villages had the highest counts within the village habitats. For species richness, the most significant difference was found between the natural and village habitats at all three villages. Village and edge habitats were shown to be the most similar in terms of their species richness. For bird numbers, the most significant difference at each village was also between the natural and village habitats. However, at Austray, a significant difference was also found between the natural and edge habitats.

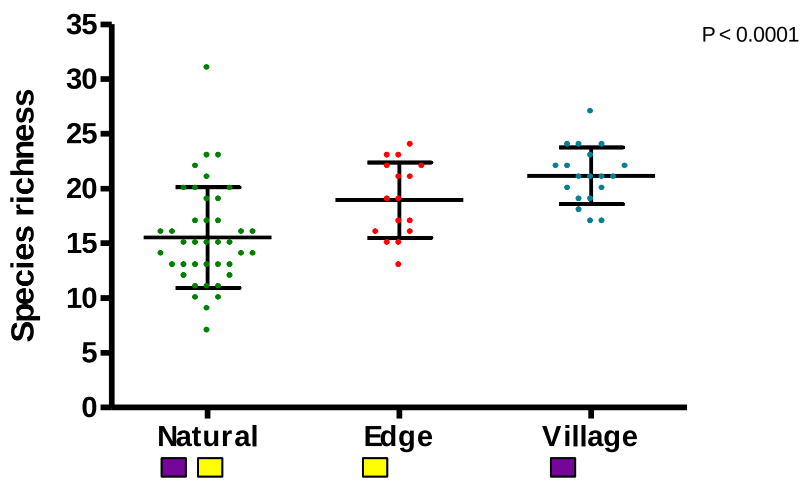

Figure 4.63: Scatter plot of species richness at Austray. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.001$. The difference between Natural and Edge was $p < 0.05$. The post test for linear trend showed a positive slope of 2.816 with $p < 0.05$. Mean and standard deviations are indicated.

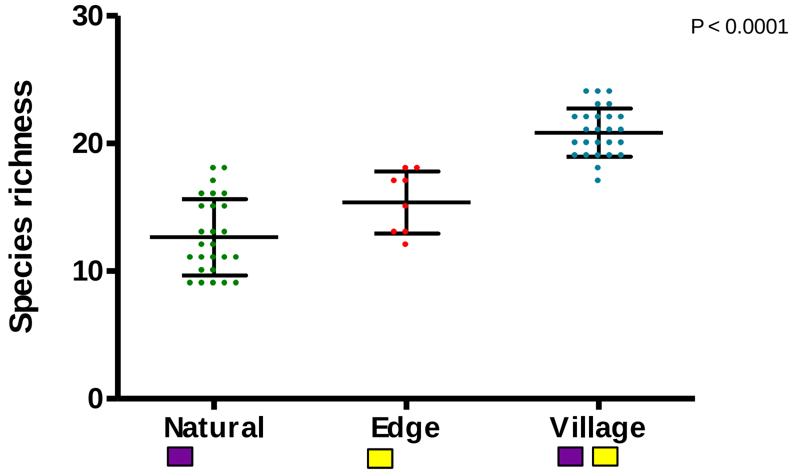

Figure 4.64: Scatter plot of species richness at Southey. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.001$. The difference between Village and Edge was $p < 0.05$. The post test for linear trend showed a positive slope of 4.096 with $p < 0.05$. Mean and standard deviations are indicated.

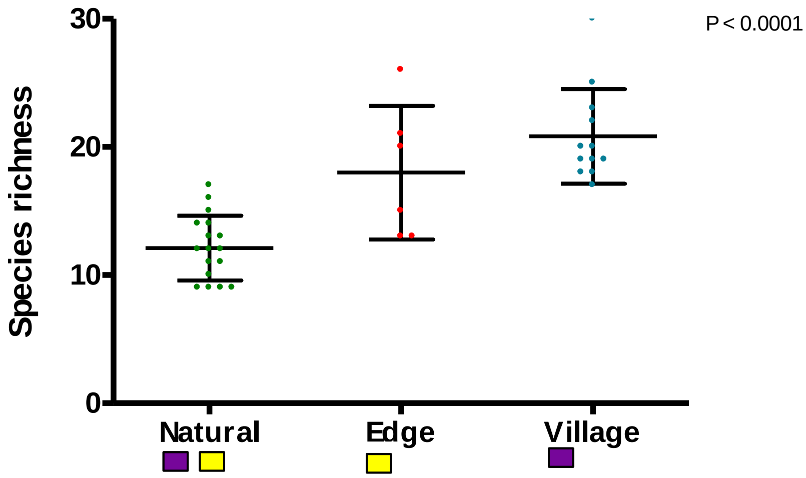

Figure 4.65: Scatter plot of species richness at Mmagabue. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.001$. The difference between Natural and Edge was $p < 0.05$. The post test for linear trend showed a positive slope of 4.358 with $p < 0.05$. Mean and standard deviations are indicated.

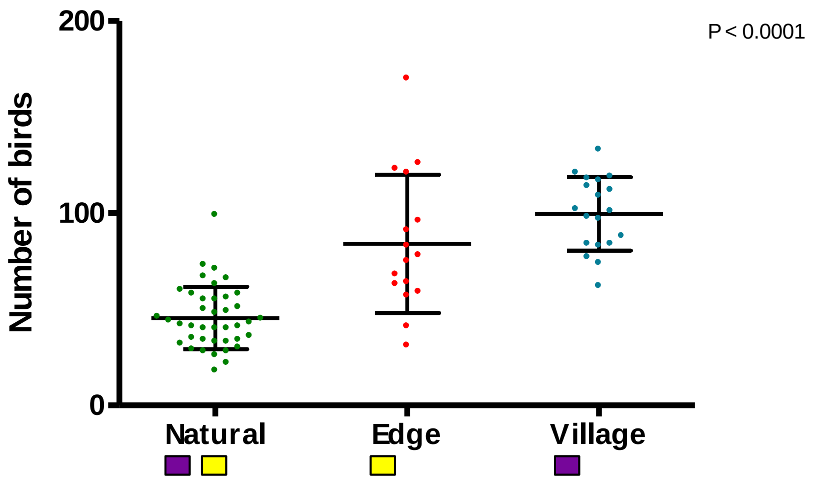

Figure 4.66: Scatter plot of number of birds at Austray. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.001$. The difference between Natural and Edge was $p < 0.001$. The post test for linear trend showed a positive slope of 27.08 with $p < 0.05$. Mean and standard deviations are indicated.

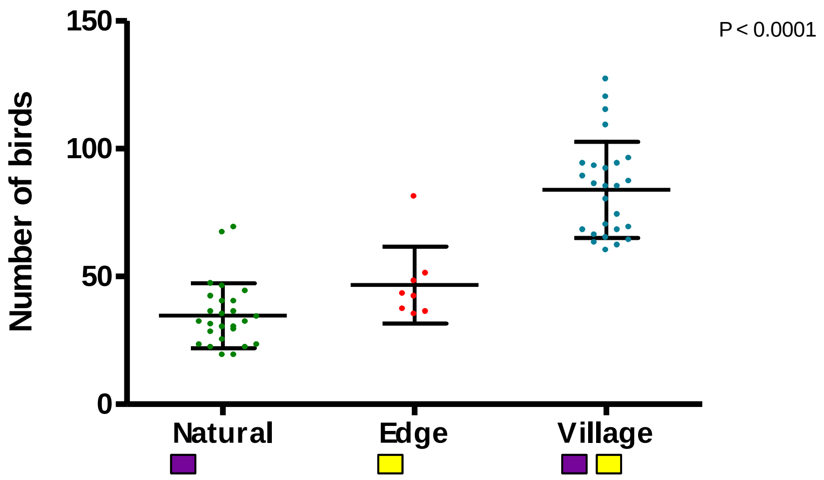

Figure 4.67: Scatter plot of number of birds at Southey. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.001$. The difference between Village and Edge was $p < 0.05$. The post test for linear trend showed a positive slope of 24.62 with $p < 0.05$. Mean and standard deviations are indicated.

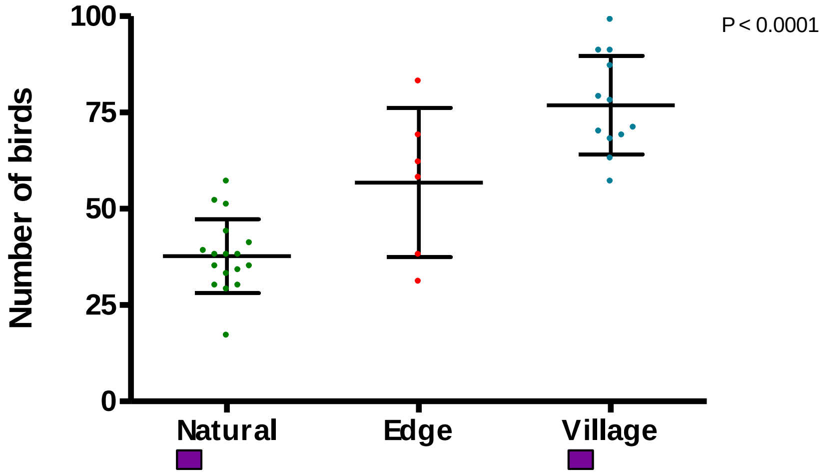

Figure 4.68: Scatter plot of number of birds at Mmagabue. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.001$. The post test for linear trend showed a positive slope of 19.61 with $p < 0.05$. Mean and standard deviations are indicated.

Kruskal-Wallis tests and Dunn's post tests were also conducted for the aggregate Shannon diversity (combined species and numbers over four surveys per point count site) at each village. The results are shown in Figures 4.69 - 4.71.

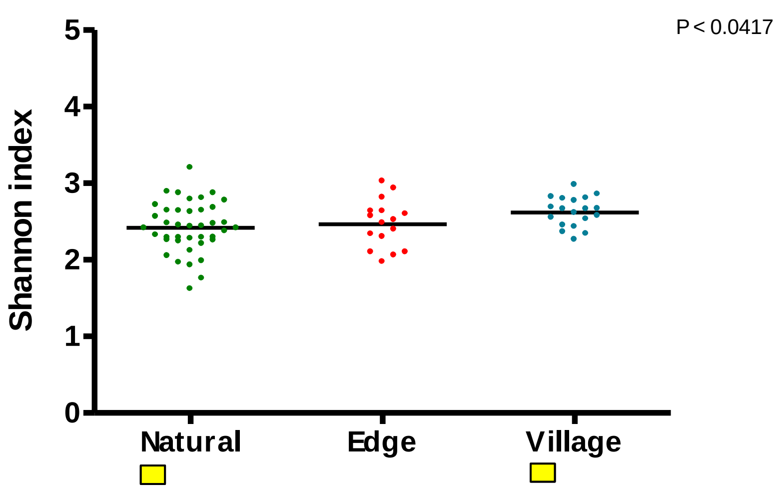

Figure 4.69: Scatter plot of Shannon diversity at Austray. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.05$. The post test for linear trend showed a positive slope of 0.1011 with $p < 0.05$.

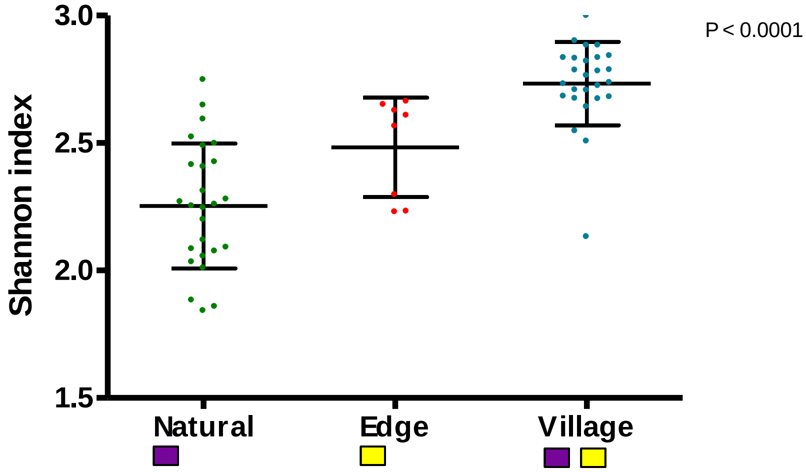

Figure 4.70: Scatter plot of Shannon diversity at Southey. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.001$. The difference between Village and Edge was $p < 0.05$. The post test for linear trend showed a positive slope of 0.2399 with $p < 0.05$. Mean and standard deviations are indicated.

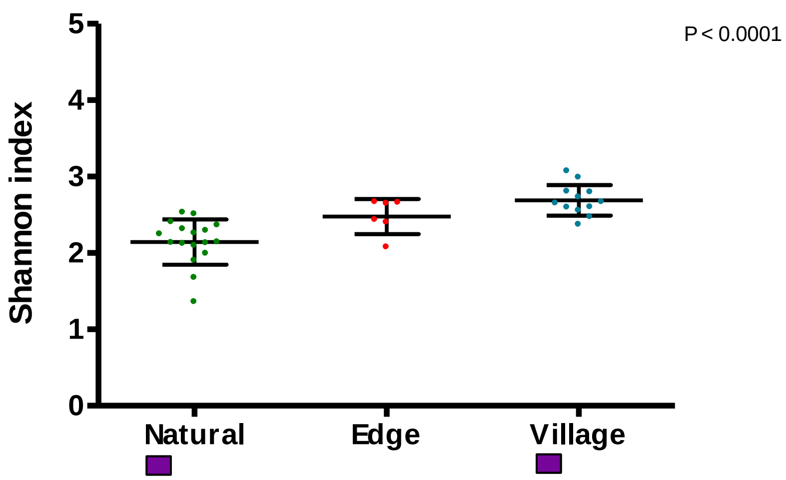

Figure 4.71: Scatter plot of Shannon diversity at Mmagabue. Habitats with the same colour codes are significantly different (Dunn's Multiple Comparison test). The difference between Natural and Village was $p < 0.001$. The post test for linear trend showed a positive slope of 0.2732 with $p < 0.05$. Mean and standard deviations are indicated.

A two-way ANOVA was conducted using the mean aggregate species richness and standard deviation per point count site for each habitat type. Interaction between villages and habitat type accounted for only 2.17% of the total variance ($p = 0.8603$). Variability among villages accounted for only 3.47% of the total variance ($p = 0.3690$), indicating that the variance between the three villages was not significant. Variability among habitat types, however, was responsible for 49.02% of the total variance ($p < 0.0001$) and was highly significant. The results are plotted in Figure 4.72.

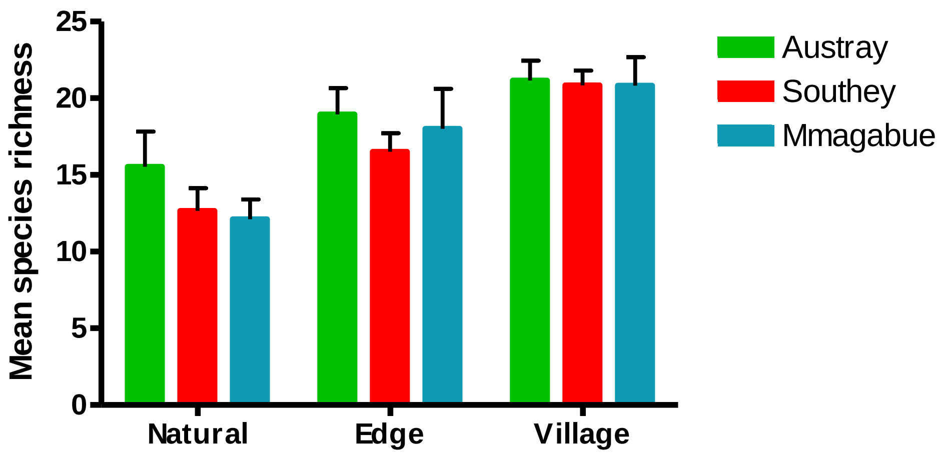

Figure 4.72: Mean species richness among the three villages.

A second two-way ANOVA was performed using the mean number of birds found in each habitat type at each village (Figure 4.73). Interaction between villages and habitats was responsible for only 3.68% of the total variance and had a non-significant p-value of 0.5930. There was a slightly larger variance between the villages, possibly because the villages differed in size and with the larger villages having more point count sites, the chances of encountering a larger number of birds were higher. The variability among villages accounted for 12.08% of the total variance ($p = 0.0183$). Variability among habitat types once again was responsible most of the variance. Habitat type accounted for 49.21% of the total variance ($p < 0.0001$).

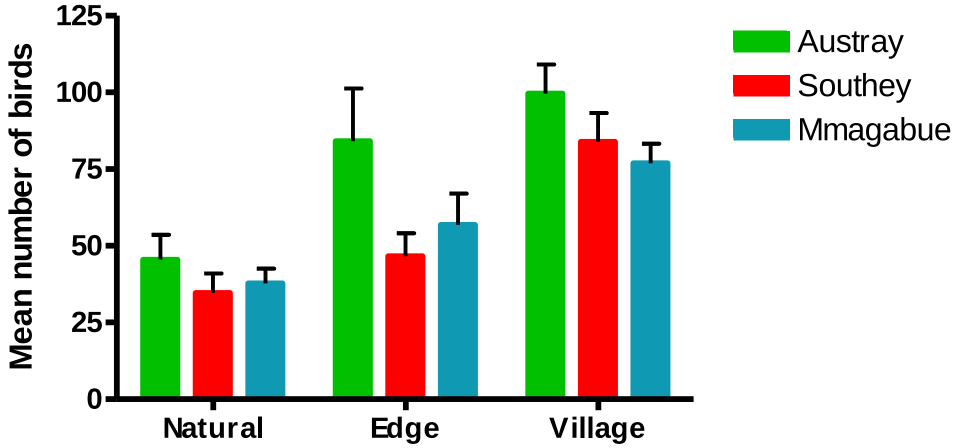

Figure 4.73: Mean number of birds among the three villages

The mean Shannon diversity per habitat type was also used to conduct a two-way ANOVA (Figure 4.74). The variance among the three villages was very low, accounting for only 0.98% of the total variance ($p = 0.7979$). Habitat type was responsible for 35.32% of the total variance ($p = 0.0017$).

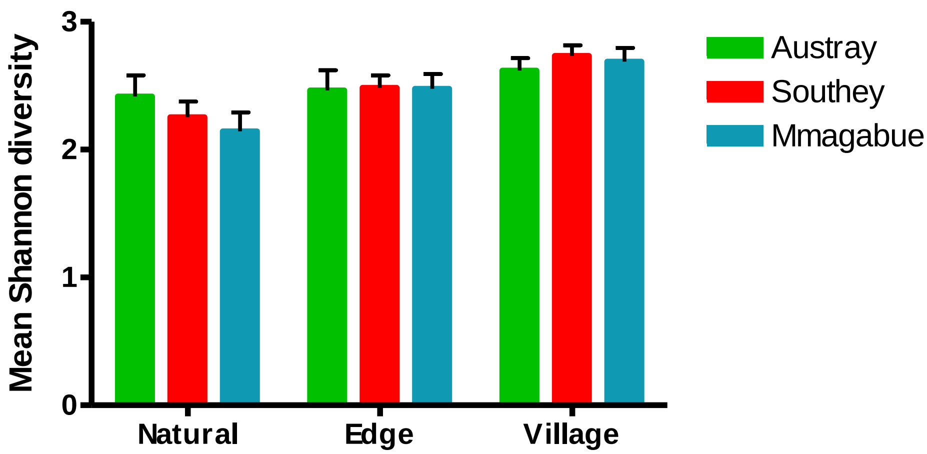

Figure 4.74: Mean Shannon diversity among the three villages

A final set of two-way ANOVA was conducted for the different feeding and nesting guilds to determine how each of the guilds is affected by the different habitat types. For granivores (Figure 4.75), the variability among villages accounted for 8.19% of the total variance ($p = 0.0060$), which indicates a significant variance in granivore species richness among the three villages. Variability among habitats accounted for 71.37% of the total variance ($p < 0.0001$), indicating a highly significant variance between habitat types. Figure 4.75 shows that granivore species richness was highest in the village habitats and lowest in the natural habitats.

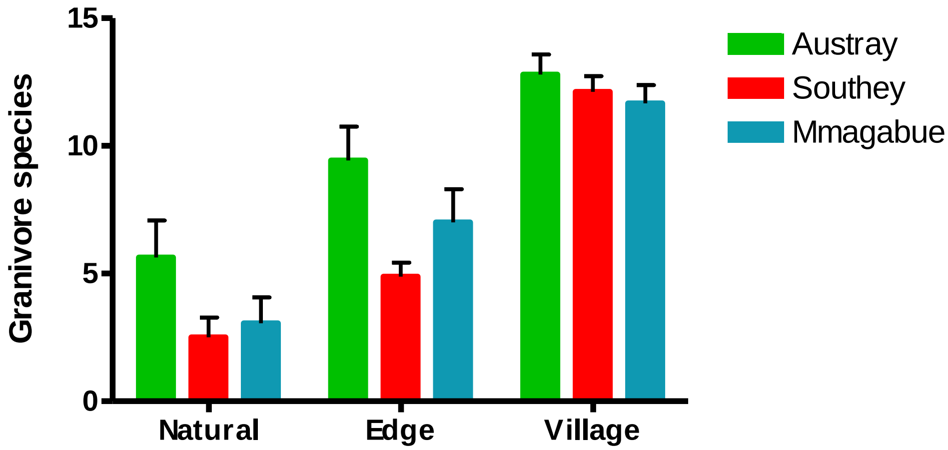

Figure 4.75: Mean granivore species richness among the three villages

For insectivores (Figure 4.76), the variability among villages was responsible for only 5.63% of the total variance ($p = 0.3758$). Variability among habitat types was responsible for 16.54% of the total variance ($p = 0.0677$). This indicates that there was no truly significant variance in insectivore species richness between villages or habitat types. Even though the variance is low, the graph does indicate that insectivore species richness was highest in the natural habitats and lowest in the village habitats.

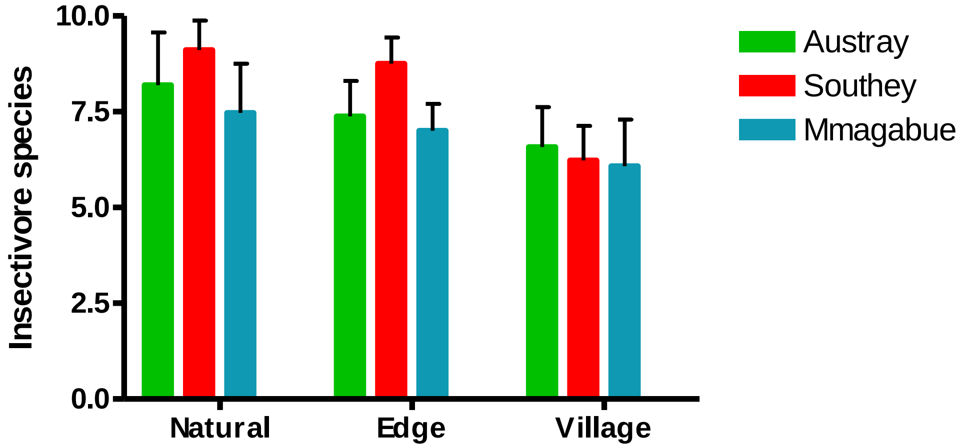

Figure 4.76: Mean insectivore species richness among the three villages

In terms of carnivore species richness (Figure 4.77), variability among villages accounted for a mere 0.46% of the total variance ($p = 0.9298$). Variability among habitats only accounted for 13.03% of the total variance ($p = 0.1444$). Thus, there was no significant variance in carnivore species richness between villages or habitat types. Despite there not being a significant variance, the graph shows that carnivore species richness was highest in the natural habitats and lowest in the village habitats.

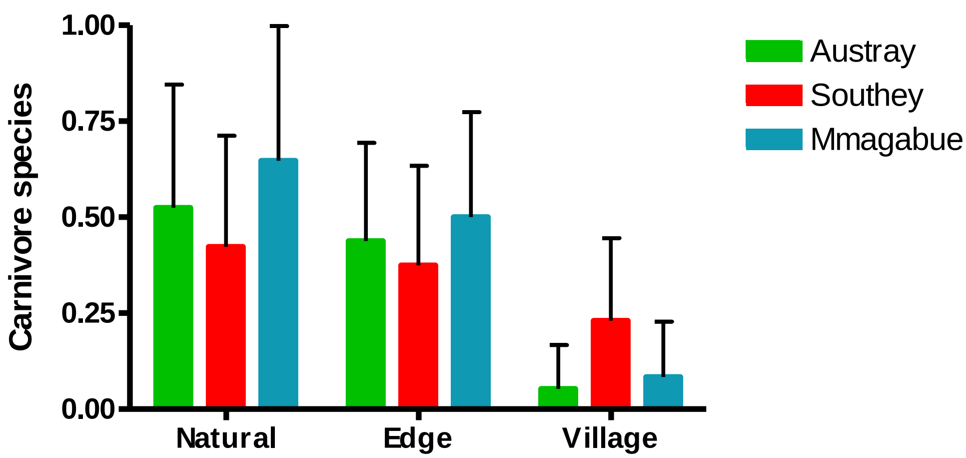

Figure 4.77: Mean carnivore species richness among the three villages

For ground-nesters (Figure 4.78), the variability among villages accounted for 12.9% of the total variance (p = 0.0402), indicating that there was a significant difference in ground-nesting species richness between the three villages. Variability among habitats accounted for 32.01% of the total variance (p = 0.0010), which is very significant. The graph clearly indicates that ground-nesting species richness was highest in the natural habitats and lowest in the village habitats.

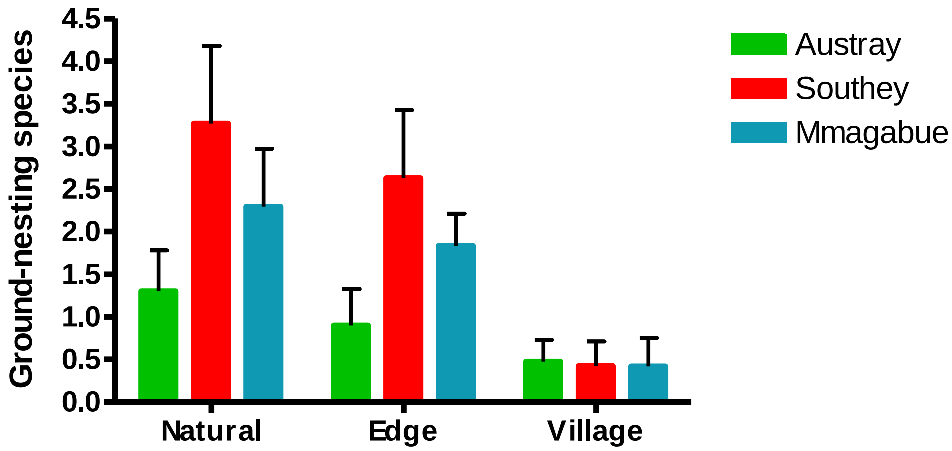

Figure 4.78: Mean ground-nesting species richness among the three villages

The ANOVA for shrub-nesting species richness (Figure 4.79) showed that the variability among villages accounted for 3.64% of the total variance (p = 0.3811). Variance among habitat types accounted for 14.62% of the total variance (p = 0.2257). Thus, there was no significant variance in shrub-nesting species richness between villages or habitat types. The graph shows that the natural habitats had the highest shrub-nesting species richness, and villages had the lowest.

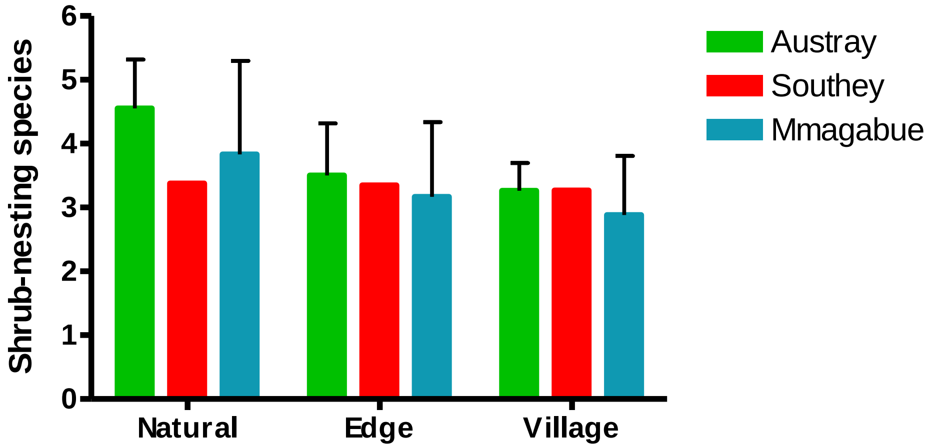

Figure 4.79: Mean shrub-nesting species richness among the three villages

For tree-nesters (Figure 4.80), the variance among villages accounted for 2.56% of the total variance (p = 0.6956), which is not significant. Variance among habitats was responsible for 60.2% of the total variance (p < 0.0001), which is highly significant. Tree-nesting species richness was highest within the village habitats and lowest in the natural habitat.

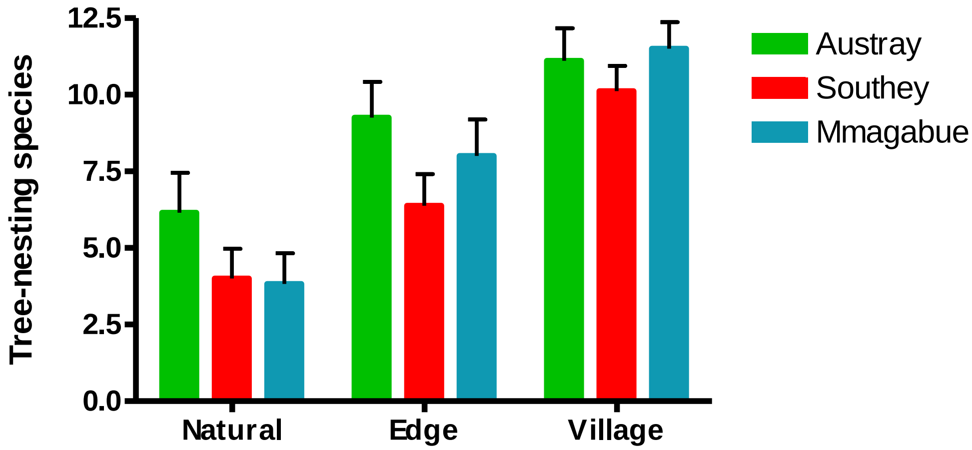

Figure 4.80: Mean tree-nesting species richness among the three villages

The final two-way ANOVA was conducted for structure nesting species richness (Figure 4.81). For this guild, variability among villages accounted for 19.76% of the total variance ($p = 0.0011$). The variance among habitats accounted for 42.9% of the total variance ($p < 0.0001$). Village habitats had the highest structure-nesting species richness, and natural habitats had the lowest.

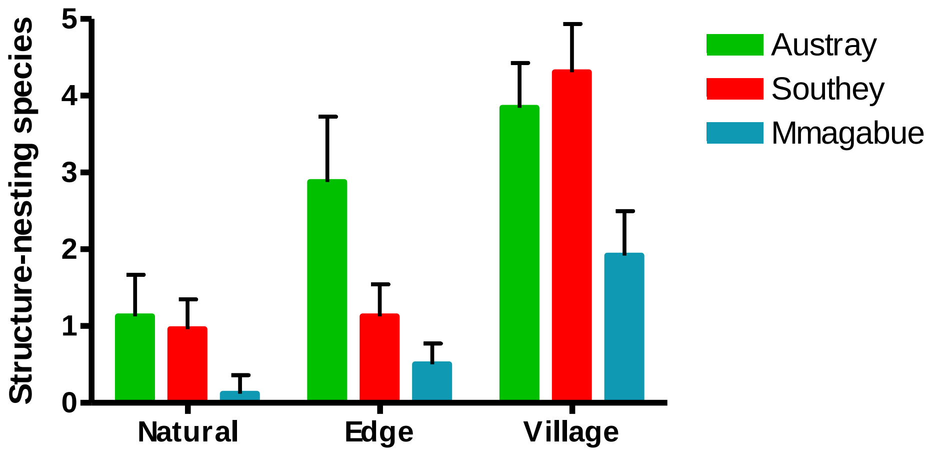

Figure 4.81: Mean structure-nesting species richness among the three villages

4.2.5 INDICATOR SPECIES ANALYSIS

PC-ORD™ was used to do an indicator species analysis for each village in order to determine whether certain species could be classified as indicators for a certain habitat type. The following tables list the species which were considered indicators for the different habitats at each village. The tables include each species' feeding and nesting guild, observed indicator value (OIV), p-value and the habitat for which it is classified as an indicator.

Table 4.19: Indicator species at Austray **(OIV = Observed Indicator Value)**

COMMON NAME	FEEDING GUILD	NESTING GUILD	OIV	P-VALUE	HABITAT
Southern Masked-weaver	Granivore	Tree	63.0	0.0002	**Village**
House Sparrow	Granivore	Structure	62.1	0.0002	**Village**
Namaqua Dove	Granivore	Shrub	61.8	0.0002	**Village**
Speckled Pigeon	Granivore	Structure	58.2	0.0002	**Village**
Cape Sparrow	Granivore	Tree	56.4	0.0004	**Village**
Black-throated Canary	Granivore	Tree	55.2	0.0002	**Village**
Laughing Dove	Granivore	Tree	51.2	0.0006	**Village**
Yellow Canary	Granivore	Shrub	49.5	0.0020	**Village**
Red-headed Finch	Granivore	Tree	49.0	0.0008	**Village**
Rock Dove	Granivore	Structure	42.9	0.0002	**Village**
African Hoopoe	Granivore	Tree	41.7	0.0012	**Village**
Familiar Chat	Insectivore	Structure	35.6	0.0040	**Village**
Marico Sunbird	Nectarivore	Tree	32.3	0.0222	**Village**
Southern Grey-headed Sparrow	Granivore	Tree	30.8	0.0028	**Village**
Kalahari Scrub-robin	Insectivore	Shrub	71.7	0.0002	**Natural**
Chestnut-vented Tit-babbler	Insectivore	Shrub	55.9	0.0002	**Natural**
Black-chested Prinia	Insectivore	Shrub	45.0	0.0054	**Natural**
Lesser Grey Shrike	Insectivore	Extralimital	43.5	0.0012	**Natural**
Red-backed Shrike	Carnivore	Extralimital	31.6	0.0064	**Natural**
Southern Yellow-billed Hornbill	Omnivore	Tree	27.1	0.0066	**Natural**
Violet-eared Waxbill	Granivore	Tree	26.8	0.0096	**Natural**
Southern Pied Babbler	Insectivore	Tree	17.9	0.0288	**Natural**
Crowned Lapwing	Insectivore	Ground	40.7	0.0094	**Edge**

Table 4.20: Indicator species at Mmagabue **(OIV = Observed Indicator Value)**

COMMON NAME	FEEDING GUILD	NESTING GUILD	OIV	P-VALUE	HABITAT
Rock Dove	Granivore	Structure	83.3	0.0002	**Village**
House Sparrow	Granivore	Structure	79.6	0.0002	**Village**
Speckled Pigeon	Granivore	Structure	75.8	0.0002	**Village**
Black-throated Canary	Granivore	Tree	67.2	0.0004	**Village**
Cape Glossy Starling	Omnivore	Tree	66.3	0.0028	**Village**
Southern Masked-weaver	Granivore	Tree	59.5	0.0028	**Village**
Laughing Dove	Granivore	Tree	58.7	0.0044	**Village**
Red-headed Finch	Granivore	Tree	56.4	0.0048	**Village**
Marico Sunbird	Nectarivore	Tree	55.1	0.0018	**Village**
Familiar Chat	Insectivore	Structure	51.9	0.0042	**Village**
Southern Grey-headed Sparrow	Granivore	Tree	50.0	0.0056	**Village**
African Pipit	Insectivore	Ground	52.1	0.0176	**Natural**
Red-backed Shrike	Insectivore	Extralimital	41.2	0.0156	**Natural**
Cape Clapper Lark	Insectivore	Ground	41.2	0.0248	**Natural**
Black-chested Prinia	Insectivore	Shrub	46.4	0.0336	**Natural**
Sand Martin	Insectivore	Extralimital	35.9	0.0492	**Natural**
Northern Black Korhaan	Insectivore	Ground	35.3	0.0436	**Natural**
Spike-heeled Lark	Insectivore	Ground	35.3	0.0442	**Natural**
Fork-tailed Drongo	Insectivore	Tree	51.6	0.0174	**Edge**
Red-billed Quelea	Granivore	Tree	47.2	0.0048	**Edge**
European Bee-eater	Insectivore	Structure	39.8	0.0178	**Edge**
Banded Martin	Insectivore	Structure	28.2	0.0370	**Edge**

Table 4.21: Indicator species at Southey **(OIV = Observed Indicator Value)**

COMMON NAME	FEEDING GUILD	NESTING GUILD	OIV	P-VALUE	HABITAT
House Sparrow	Granivore	Structure	92.3	0.0002	**Village**
Cape Sparrow	Granivore	Tree	90.4	0.0002	**Village**
Black-throated Canary	Granivore	Tree	88.9	0.0002	**Village**
Rock Dove	Granivore	Structure	76.9	0.0002	**Village**
Laughing Dove	Granivore	Tree	74.3	0.0002	**Village**
Speckled Pigeon	Granivore	Structure	73.2	0.0002	**Village**
Southern Masked-weaver	Granivore	Tree	73.1	0.0002	**Village**
Red-headed Finch	Granivore	Tree	71.4	0.0002	**Village**
Yellow Canary	Granivore	Shrub	63.7	0.0006	**Village**
Familiar Chat	Insectivore	Structure	63.5	0.0002	**Village**
Namaqua Dove	Granivore	Shrub	56.9	0.0008	**Village**
Southern Grey-headed Sparrow	Granivore	Tree	50.0	0.0010	**Village**
Marico Sunbird	Nectarivore	Tree	50.0	0.0030	**Village**
African Red-eyed Bulbul	Frugivore	Tree	49.1	0.0014	**Village**
Cape Wagtail	Insectivore	Shrub	36.1	0.0142	**Village**
Groundscraper Thrush	Insectivore	Tree	33.3	0.0418	**Village**
Red-billed Quelea	Granivore	Tree	30.8	0.0126	**Village**
Red-billed Firefinch	Granivore	Grass	30.3	0.0338	**Village**
Red-eyed Dove	Granivore	Tree	29.7	0.0262	**Village**
African Hoopoe	Insectivore	Tree	26.7	0.0482	**Village**
Spike-heeled Lark	Insectivore	Ground	42.3	0.0024	**Natural**
Cape Clapper Lark	Insectivore	Ground	40.0	0.0096	**Natural**
Pied Crow	Scavenger	Tree	34.8	0.0172	**Natural**
Northern Black Korhaan	Insectivore	Ground	19.2	0.0430	**Natural**
Black-chested Prinia	Insectivore	Shrub	44.5	0.0270	**Edge**
Scaly-feathered Finch	Granivore	Tree	38.0	0.0460	**Edge**
Crowned Lapwing	Insectivore	Ground	35.3	0.0238	**Edge**

As can be seen in the above data, the three villages had some indicator species in common. In terms of natural habitat, the Northern Black Korhaan, Cape Clapper Lark and Spike-heeled Lark were classified as indicator species at two of the villages. All three species are insectivores and ground-nesters. The shrub-nesting Black-chested Prinia is also an insectivore and was classified as an indicator for natural habitat at two villages, and so was the carnivorous Red-backed Shrike, which is an extralimital breeder. The Crowned Lapwing, which is a ground-nesting insectivore, was classified as an indicator for edge habitat at two of the villages. Ten species were classified as indicators for village habitat at all three villages. Note that among these species, 8 are granivores, 1 is an insectivore and 1 is a nectarivore. In terms of nesting guilds, 6 are tree-nesters and 4 are structure-nesters. These species are listed in Table 4.22.

Table 4.22: Indicator species common to all three villages

SPECIES	FEEDING GUILD	NESTING GUILD	HABITAT TYPE
Rock Dove	Granivore	Structure-nester	Village
Speckled Pigeon	Granivore	Structure-nester	Village
Laughing Dove	Granivore	Tree-nester	Village
Familiar Chat	Insectivore	Structure-nester	Village
Marico Sunbird	Nectarivore	Tree-nester	Village
House Sparrow	Granivore	Structure-nester	Village
Southern Grey-headed Sparrow	Granivore	Tree-nester	Village
Southern Masked-weaver	Granivore	Tree-nester	Village
Red-headed Finch	Granivore	Tree-nester	Village
Black-throated Canary	Granivore	Tree-nester	Village

The next chapter will provide a detailed discussion and conclusion of all the results given in this chapter.

CHAPTER 5: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

In order to understand the results given in the previous chapter, this chapter will present a detailed discussion of the results, as well as the importance thereof and their implications for biodiversity and conservation. From the results in Chapter 4, certain trends or patterns in bird diversity and distribution in villages in the Kalahari can be identified. This chapter will deal with the discussion of those trends or patterns, and will analyse the factors leading to them. Use will be made of text boxes to highlight certain species observations.

Following the discussion will be conclusions, recommendations for management, and possibilities for future research.

5.2 DISCUSSION

5.2.1 BIRD DISTRIBUTION PATTERNS

As mentioned in previous chapters, three habitat types were identified at each of the villages, namely village, edge, and natural habitat. The results presented in Chapter 4 showed interesting patterns regarding bird species richness, bird numbers, and guild distribution across these habitat types.

5.2.1.1 SPECIES RICHNESS

Species richness showed a common trend throughout all three villages surveyed. For the purposes of this discussion a distinction will be made between aggregated species richness and mean species richness. Aggregated species richness refers to the total number of species recorded in each habitat type during the duration of the study, but does not reflect the species richness of each point count site. Mean species richness was calculated by taking the aggregated number of species observed in each habitat and dividing it between the number of point count sites within that particular habitat type, thereby producing the mean number of birds per point count site. Table 4.14 (p. 73) listed the aggregate and mean species richness for each village.

The importance of this is that just using aggregated species richness may be somewhat misleading in that many species were recorded only once within the entire study, but were not necessarily representative or indicative to a particular habitat. For example, Table 4.14 indicated that the aggregate species richness was higher in the natural habitats than in the village habitats, whereas mean species richness showed the opposite. This is because a large number of uncommon species were recorded in the natural habitat over the course of the study, occurring only once or twice at single sites. Mean species richness therefore gave a clearer indication of the general species composition in each habitat type.

Figure 4.4 (p. 71) showed the aggregated species richness of each habitat type at each village. The graph showed that the edge and village habitats had the lowest species richness and were about the same, while species richness was much higher in the natural habitats. However, the geostatistical gave a clearer indication of the species richness observed per point count site. Figures 4.9 - 4.11 (pp. 79-80) showed the interpolated maps of species richness for each village. In each case, species richness (one could almost say ‘species density’) was clearly lower in the areas surrounding the villages (i.e. the natural habitats), higher at the village edges, and highest within the village habitat.

The one-way analysis of variance (ANOVA) for the mean number of species per point count site showed the same pattern. Figures 4.63 – 4.65 (pp. 110-111) showed a clear increase in mean species richness per point count site from the natural habitats towards the edge habitats, and a further increase into the village habitats. At all three villages, the ANOVA produced a p-value of < 0.001 for natural vs. village habitat - a very significant difference. The post tests for linear trend reported p-values of < 0.05, indicating significant linear trends as species richness increased from natural habitat to village habitat. The linear trend test is valid as any edge point count site is equidistant (250 m) between a natural and village point count site.

A two-way ANOVA comparing the mean species richness of each habitat of each village showed no significant differences for the three villages together as a source of variation; the villages therefore were comparable per habitat type. For habitat type, however, the biggest difference was between the natural and village habitats for all three villages. The results plotted in Figure 4.72 (p. 115) also showed that species richness increased from the natural habitats to the edge habitats and was highest in the village habitats. Habitat type as a source of variation was highly significant at $p < 0.0001$.

Shannon diversity distribution also showed an increase from natural habitat to village habitat, as was shown in Table 4.18 (p. 104). Figures 4.57 – 4.59 (pp. 105-106) showed the interpolated maps of Shannon diversity at the three villages. In each case, Shannon diversity increased from the natural to village habitats. Figures 4.69 – 4.71 (pp. 113-114) showed the scatter plots obtained from the one-way ANOVA of Shannon diversity. These figures also showed significant differences between habitat types, with $p < 0.05$ at Austray (Figure 4.69) and $p < 0.001$ at Southey (Figure 4.70) and Mmagabue (Figure 4.71). The two-way ANOVA showed that the difference in Shannon diversity between villages was not significant, with a p-value of 0.7979. Habitat type as a source of variation was significant with a p-value of 0.0017.

The conclusion that can be made is that species richness and diversity increased with urbanisation as represented by villages in the Kalahari. A number of studies, reviewed by Blair and Johnson (2008), found that urban land-uses that are represented by intermediate levels of development are often a point of extirpation for woodland birds as well as an entry point for invasive species into urban systems in regions where these studies have been done – mainly Europe and North America (Blair and Johnson, 2008). It has also been found that suburban habitats in naturally forested in the United States areas typically contain less than half of the native woodland bird species that would exist at these sites if they were not developed, but also contain more total bird species than if these sites were left in a natural state (Blair, 2004). In the current study, both invasive and many woodland species were present in the villages, although the numbers of the latter were mostly higher in the natural habitats (Tables 4.2, 4.7 and 4.12).

Woodland species occurring within villages
Golden-tailed Woodpecker, Diderick Cuckoo, Common Scimitarbill, Acacia Pied Barbet, Fork-tailed Drongo, Ashy Tit, Kalahari Scrub-robin, Chestnut-vented Tit-babbler, Spotted Flycatcher, Marico Flycatcher, Chat Flycatcher, Lesser Grey Shrike, Red-backed Shrike, Violet-eared Waxbill, and Golden-breasted Bunting

Research has shown that the introduction of new elements, such as tree or shrub plantings, buildings, lawns, and other anthropogenic structures often increases or maintains species richness in urban areas (Sodhi, 1992; Petit *et al.,* 1999; Crooks *et al.,* 2004). The village profiles shown in Figures 4.1 – 4.3 (pp. 54, 60, 66) show the increase in man-made structures at all three villages.

Several studies have found that species richness was higher at intermediate levels of urbanisation (Blair, 1996; Marzluff, 2001; Tratalos *et al.,* 2007) and the villages surveyed in this study probably epitomises urbanisation at intermediate levels. Even though these villages currently support a healthy richness of species, the danger lies in further development. Research elsewhere indicated that species richness initially increases with intermediate levels of urbanisation, but then decreases with increased levels of urbanisation (Blair, 1996; Tratalos *et al.,* 2007; Blair and Johnson, 2008). Betts *et al*. (2007) discovered that there were thresholds in suitable habitat amount within urban areas, below which the likelihood of bird species occurrence declined more rapidly. This may be the case in the Kalahari, but this is not apparent from the present data for small towns. In all figures, the villages are arranged left to right, from large to small. In Figure 4.72 (p. 115), no increase in species richness with an increase in village size can be seen inside the village. A decrease in species richness may become apparent in larger villages, such as in Ganyesa, where the village centre will be further away from the village edges and natural area.

A concept not frequently used in avian research is that of species density, which is an interesting approach to species richness. Species density could describe the relationship between aggregated and mean species richness. The term refers to the metric of species richness per point (or transect). For instance, Table 4.17 (p. 104) indicates that the aggregate species richness at Austray was higher in the natural habitat (74 species) than in the village habitat (57 species). But not all of those 74 species were present at each point count site within the natural habitat (low species density with a high species richness), whereas many of the 57 species in the village habitat occurred at most of the point count sites within the village habitat (high species density and richness). This is a theoretical concept that could be further investigated.

5.2.1.2 NUMBER OF BIRDS

As with species richness, all three villages showed a common trend with the number of birds observed in each habitat type. In Figure 4.5, the total number of birds is shown for each habitat type. In this graph, the lowest number of birds was in the edge habitats, with higher numbers in the natural habitats, and highest within the village habitats.

Once again, the interpolated maps for bird numbers produced in the geostatistical analysis provided a clearer indication of bird numbers in each habitat type. Figures 4.12 - 4.14 (pp. 81-82) clearly show that bird numbers were lowest in the natural habitat and increased towards the village edges. The highest bird numbers were observed in the village habitat. It can thus be concluded that bird numbers also increase with urbanisation.

This increase is also shown in the one-way ANOVA of bird numbers. Figures 4.66 - 4.68 (pp. 112-113) indicated that the number of birds was lowest in the natural habitats, higher in the edge habitats, and peaked in the village habitats. Natural vs. village habitat had p-values of <0.001 at all three villages, indicating that the most significant variance in bird numbers was between those two habitat types. The post tests for linear trends reported p-values of < 0.05 for all three villages, indicating a significant linear trend as the number of birds increased from natural to village habitat.

The two-way ANOVA for the mean number of birds indicated a small, but significant, variance in the number of birds found between the three villages (Figure 4.73). The source of variance between the villages accounted for 12.08% of the total variance. This may be due to village size as larger villages may accommodate more birds. The biggest variance, however, was still between the three habitat types, which accounted for 49.21% of the variance. As a variable, habitat type was highly significant with $p <$

0.0001. Figure 4.73 (p. 116) showed a clear increase in bird numbers from the natural habitat towards the edge habitat and a further increase into the village habitat.

Studies have found that urbanisation normally leads to increasing population densities and lower species diversity in urban areas than in adjacent wildlands (Marzluff, 2001). However, in the present case, population densities as well as species diversity increased, as was shown in the previous section. Land-use intensification can often elevate bird numbers (Clergeau *et al*., 1998; Soderstrom and Part, 2000; Crooks *et al.*, 2004), presumably due to higher primary productivity due to fertilization, irrigation, and food introduced purposely or incidentally by humans, through habitat enhancement in the form of plantings and buildings that increase opportunities for territory or nesting sites (Sodhi, 1992; Petit *et al*., 1999), or due to fewer natural predators (Gering and Blair, 1999; Anderies *et al*., 2007). Campbell (2009) found that urban areas usually contain a large number of only a few generalist species. However, this may be true for more densely urbanised areas, but in this study, many birds other than generalists were found within the village, as can be seen from Tables 4.4, 4.8 and 4.12 (pp. 58, 64, 69).

Generalist species found in villages	Specialist species observed in villages
Rock Dove, Speckled Pigeon, Laughing Dove, Cape Sparrow, House Sparrow, Southern Grey-headed Sparrow, Southern Masked-weaver, Red-headed Finch, and Black-throated Canary	Gabar Goshawk, Lanner Falcon, White-backed Mousebird, Red-faced Mousebird, Diderick Cuckoo, Common Scimitarbill, Spotted Flycatcher, Lesser Grey Shrike, Red-backed Shrike, and Marico Sunbird

Davies *et al*. (2009) found that in developed regions with intensive use of the wider landscape, particularly through agriculture, has resulted in population declines of bird species. Urban areas therefore seem to become increasingly important for sustaining regional abundances. In a desert margin area such as the Bophirima District, these villages may very well be unrecognised and important conservation sites for many bird species that are otherwise threatened by desertification and agricultural practices.

5.2.1.3 GUILD DISTRIBUTION

The distribution of the different feeding and nesting guilds brought some interesting patterns to light which might help explain the overall distribution of species in the villages. Figure 4.7 and Table 4.15 (p. 76) compares the bird feeding guild compositions for each village. Insectivorous species were the highest, followed by granivores. Carnivores, frugivores, and omnivores had lower numbers of species present at each village. In the nesting guild analysis, which is represented by Figure 4.8 and Table 4.16 (p. 77), tree-nesters showed the highest number of species at each village, followed by ground-, shrub-, and structure-nesters, respectively.

To get a clear indication of how the different guilds are distributed across the different habitat types, interpolated maps were produced and data analysed by two-way ANOVA. The results clearly showed that some guilds increased with urbanisation, while others decreased and showed higher numbers in the natural habitat. Insectivores and carnivores were the two feeding guilds that decreased in species numbers towards the village habitat. Figures 4.15, 4.17 and 4.19 (pp. 83-85) represent the interpolated maps for insectivore species richness at each village. In these figures, clear patterns can be observed – with insectivore species occurring in higher numbers in the natural habitat and decreasing toward the village habitat. This pattern can most clearly be seen in Figure 4.19 (p. 85), which represents the insectivore species richness at Southey. Figure 4.17 (p. 84), which represents Mmagabue’s insectivores, is somewhat ambiguous, with the lowest and highest insectivore species counts within the village. However, the spot within the village where a peak in insectivore species is indicated was located in a large patch of semi-natural vegetation and bare ground with no buildings.

Insectivores found within villages

Crowned Lapwing, Diderick Cuckoo, European Bee-eater, Little Bee-eater, African Hoopoe, Golden-tailed Woodpecker, Fork-tailed Drongo, Ashy Tit, Groundscraper Thrush, Familiar Chat, Kalahari Scrub-robin, Chestnut-vented Tit-babbler, Black-chested Prinia, Cape Wagtail, and African Pipit

Insectivores exclusive to natural habitat

Cattle Egret, Orange River Francolin, Northern Black Korhaan, Burchell’s Sandgrouse, African Cuckoo, Bearded Woodpecker, Cape Clapper Lark, Spike-heeled Lark, Mountain Wheatear, Capped Wheatear, Ant-eating Chat, Southern Pied Babbler, Cape Penduline-Tit, Yellow-bellied Eremomela, Long-billed Crombec, Desert Cisticola, and Crimson-breasted Shrike

Figures 4.27, 4.29 and 4.31 (pp. 89-91) indicate the interpolated carnivore species richness at each village. Again it can clearly be seen that the number of carnivore species was very low within the village boundaries. The highest carnivore species richness was found within the natural habitats at each village. The two-way ANOVA confirmed these findings. Figures 4.76 and 4.77 (p. 118) indicate that the number of insectivore and carnivore species were the highest in the natural habitat and gradually dropped towards the edge and village habitats.

Carnivores recorded within villages

Lanner Falcon, Gabar Goshawk, Common Fiscal, and Red-backed Shrike

Carnivores exclusive to the natural habitat

Grey Heron, Black-chested Snake-eagle, Black-shouldered Kite, Steppe Buzzard, Red-footed Falcon, and Lesser Kestrel

Figures 4.21, 4.23 and 4.25 (pp. 86-88) represent the interpolated granivore species richness, and show the opposite pattern. At each village, a clear increase in granivore species was seen from the natural habitat to the edge habitat, with a further increase and maximum in the village habitat. Figure 4.75 (p. 117) represents the number of granivore species in each habitat type as analysed by two-way ANOVA. The graph indicated a large and significant increase in the number of granivore species from the natural to the village habitat.

In terms of nesting guilds, ground- and shrub-nesting species preferred the natural habitat while tree- and structure-nesters preferred the village habitat. This can be seen in the interpolations of ground- and shrub-nesting species, represented by Figures 4.33, 4.35, 4.37, 4.45 and 4.47 (pp. 92-94; 98-99). Figure 4.49 (p. 100), which represents the interpolation of shrub-nesting species at Southey, is the only figure where this pattern is not clear-cut. The village habitat held more shrub-nesting species than some of the natural habitat. However, the number of shrub-nesting species still peaked at some points in the natural habitat. Figures 4.78 and 4.79 (pp. 119-120) represent the results of the two-way ANOVA for ground- and shrub-nesting species, respectively. Both graphs also showed a decrease in species from the natural habitat towards the edge habitat, and a further decrease into the village habitat.

Shrub-nesters found in villages

Namaqua Dove, Kalahari Scrub-robin, Black-chested Prinia, Chat Flycatcher, Common Fiscal, Cape Wagtail, Violet-eared Waxbill, and Yellow Canary

Shrub-nesters exclusive to natural habitat

Long-billed Crombec, Yellow-bellied Eremomela, and Golden-breasted Bunting

Ground-nesters found in villages

Crowned Lapwing, Blacksmith Lapwing, and African Pipit

Ground-nesters exclusive to natural habitat

Spur-winged Goose, Orange River Francolin, Helmeted Guineafowl, Northern Black Korhaan, Double-banded Courser, Namaqua Sandgrouse, Burchell's Sandgrouse, Rufous-naped Lark, Cape Clapper Lark, Spike-heeled Lark, Sabota Lark, Mountain Wheatear, Capped Wheatear, Ant-eating Chat, and Lark-like Bunting

The number of tree- and structure-nesting species, on the other hand, clearly reached maximum in the village habitat. The interpolations of tree-nesting species were represented by Figures 4.39, 4.41 and 4.43 (pp. 95-97) and also showed that tree-nesters peaked within the village habitat. The same can be seen for structure-nesting species in Figures 4.51, 4.53 and 4.55 (pp. 101-103). Figures 4.80 and 4.81 (pp. 120-121) show the ANOVA for those two nesting guilds, and both showed a clear increase in the number of species from the natural habitats to the village habitats.

Other feeding and nesting guilds were present, but in low numbers. Four frugivorous species were observed during the study and most of them showed a preference for the village habitat (Tables 4.4, 4.8 and 4.12). The Marico Sunbird was the only nectarivore recorded in the study, and was much more abundant within the village habitats (Tables 4.4, 4.8 and 4.12). Only three omnivore species were observed, with two showing a preference for the natural habitat and one preferring the village habitat.

Frugivores preferring village habitat

White-backed Mousebird, Red-faced Mousebird, African Red-eyed Bulbul

Omnivores preferring natural habitat

Acacia Pied Barbet,

Omnivores preferring village habitat

Cape Glossy Starling

Omnivores preferring natural habitat

Southern Yellow-billed Hornbill and Wattled Starling

In terms of nesting guilds, grass-nesters, reed-nesters, brood parasites and extralimital breeders made up the rest of the species. Only two grass-nesting species and were observed; the Red-billed Firefinch, which preferred the village habitat (Table 4.8), and Desert Cisticola, which preferred the natural habitat (Tables 4.7 and 4.11). The remainder of the species consisted of brood-parasites and extralimital breeders. Brood-parasites showed mixed reactions to the habitat types while extralimital breeder all preferred the natural habitat.

Brood parasites preferring village habitat

Diderick Cuckoo, Shaft-tailed Whydah, and Village Indigobird

Brood parasites preferring natural habitat

African Cuckoo and Long-tailed Paradise-whydah

Extralimital breeders preferring natural habitat

Steppe Buzzard, Little Stint, Blue-cheeked Bee-eater, Barn Swallow, Sand Martin, Spotted Flycatcher, Lesser Grey Shrike, and Red-backed Shrike

Several studies on bird distribution in urban habitats have found patterns similar to the current study. Blair and Johnson (2008) discovered consistent patterns in the functional characteristics of bird communities that shift with intensifying urbanisation, such as a decrease in insectivorous individuals and an increase in granivorous individuals. Other studies have shown that urban avifaunas are typically dominated by granivores, medium-sized omnivores, and sedentary or partially migratory species (Bezzel, 1985), while ground-nesters, migrants and forest species, especially foliage-gleaning insectivores, are less common (White *et al*., 2005). Several studies agreed that insectivores are negatively impacted by urbanisation or development (Clergeau *et al*., 1998; Allen and O'Connor, 2000; Lindsay *et al*., 2002; Lim and Sodhi, 2004) and the same has been found for carnivores (Lim and Sodhi, 2004).

Ground-nesting species and those with specialized habitat requirements, that require large habitat patches, or are associated with more complex vegetation structures, most noticeably forest interior specialists, most likely will be to be lost from urbanised areas (Marzluff 2001, McKinney 2006, Clark *et al*., 2007). The loss of habitat specialists in urban centres often results in bird communities that lack ground- and shrub-nesting species (Blair, 1996; Lim and Sodhi, 2004; Clergeau *et al*., 2006). As areas become urbanised, certain species colonise and increase in abundance by taking advantage of new anthropogenic habitats, supplemental food (Nuorteva, 1971; Lancaster and Rees, 1979), and nest sites (Donnelly *et al*., 2006). Cavity- or structure-nesting species, for example, tend to increase with urbanisation (Miller *et al*., 2003).

5.2.1.4 INDICATOR SPECIES

Bird numbers and species composition was mostly influenced by the habitat changes brought on by urbanisation and human development. However, in the case of this study, the influence of urbanisation was not all negative, with overall diversity being higher within the disturbed habitat. The indicator species analysis for each village presented some interesting results.

The most conspicuous pattern which was found in the analyses of all three villages, was that the indicator species for the natural habitats comprised mostly of insectivorous and ground-nesting birds while the indicators for the village habitat were predominantly granivorous and structure-nesting species.

Many studies have found that granivorous (Bezzel, 1985; Blair and Johnson, 2008) and structure-nesting (Miller *et al*., 2003) species increase with urbanisation while insectivorous (White *et al.,* 2005; Blair and Johnson, 2008) and ground-nesting (Blair, 1996; Clergeau *et al.,* 2006) species decrease and prefer to remain in natural environments.

In the natural habitat, there were no species which were classified as indicators at all three villages. However, the Black-chested Prinia, Red-backed Shrike, Cape Clapper Lark, Spike-heeled Lark, and Northern Black Korhaan were each classified as indicators at two of the villages (Tables 4.19 – 4.21). These species are all insectivores and half of them are also ground-nesters.

In the edge habitats, the Crowned Lapwing was classified as an indicator at Austray and Southey. Other species which were classified as indicators consisted of granivores and insectivores, but they were only classified as indicators for edge habitat at one out of the three villages.

In the village habitat, several species were classified as indicators for all three of the villages, and clearly had an affinity for the urbanised environment. These species were Rock Dove, Speckled Pigeon, Laughing Dove, Familiar Chat, Marico Sunbird, House Sparrow, Southern Grey-headed Sparrow, Southern Masked Weaver, Red-Headed Finch and Black-throated Canary. 80% of these species were granivores. The Familiar Chat is an insectivore, but nests in rooftops, which explains its strong presence in the village habitat. The Marico Sunbird is a nectarivore and might quite possibly be more prevalent in the village habitat due to the presence of flowering plants which grow in gardens within the village.

In addition to the species named in the indicator species analysis, there were other species which showed preferences for a particular habitat type, as can be seen in Tables 4.2 - 4.4 (pp. 56-58), 4.6 - 4.8 (pp. 62-64) and 4.10 - 4.12 (pp. 68-69). A select few species which were found only in the natural habitat and did not occur within the villages or village edges at all, and it is quite possible that these species could also be used as indicators.

Among the species which were not found within the villages and might be useful as indicators of urban land-use, were the Black-chested Snake Eagle, Steppe Buzzard, Orange River Francolin, Ant-eating Chat, Cape Penduline-tit, Southern Pied Babbler, Yellow-bellied Eremomela, Desert Cisticola and Crimson-breasted Shrike.

Other species were present in both habitats, but clearly declined in numbers as they neared the village habitat. Among these species were the Fork-tailed Drongo, Ashy Tit, Kalahari Scrub-robin, Chestnut-vented Tit-babbler, Lesser Grey Shrike and African Pipit. Then there were birds that occurred almost exclusively within the village or at least were more abundant within the village habitats. Among these were the Namaqua Dove, African Hoopoe, Groundscraper Thrush, Red-headed Finch and Yellow Canary.

Ecological indicators can be used to assess the condition of the environment, to provide an early warning signal of changes in the environment, or to diagnose the cause of an environmental problem (Dale and Beyeler, 2001). At a broad scale, focal species can indicate overall landscape quality, and species abundance data allows environment suitability to be determined. At a local scale, focal species abundances can be related to structural characteristics of landscape elements, thus providing valuable indications of the most effective locations for restoration projects (Padoa-Schioppa *et al.,* 2006). In desert margins, birds could possibly be used as indicators of land degradation. Due to time and logistical constraints, however, this study could not fully investigate the usefulness of bird species as surrogates for land degradation *per se*. Further research is needed to fully investigate and identify different species as indicators of land degradation.

5.2.2 REASONS FOR BIRD DISTRIBUTION PATTERNS

Now that the general trends or patterns of bird distribution have been established, it is important to determine the reasons behind these patterns. As was mentioned in the previous section, the most significant variance in bird distribution came from the different habitat types found at each village. These habitats were identified based on their vegetation structures, which would indicate that vegetation structure played a large role in bird distribution, but also on the increasing predominance of man-made structures and activities towards the village centres.

Vegetation structure was determined with the use of the broad-scale method described by Edwards (1983). It was clear in the classification of the vegetation structure at each village that the vegetation structure differed significantly between the interior parts of the village and the natural habitat outside the villages. Additionally, the vegetation structure at village edges differed from both the interior village habitat and the natural habitat, containing elements of both habitats. The NMS ordinations, which are represented by Figures 4.60 - 4.62 (pp. 107-109), clearly indicate a separation in the point count sites located in the different habitat types. Natural and village sites were mostly located on opposite sides of the spectrum, with edge sites placed relatively in the middle of the two.

Although this study refers to the areas surrounding each village as natural habitat, these habitats were not entirely pristine, mainly due to livestock grazing and human footpaths. At the village edges, development moves outwards and some natural vegetation is removed either to be replaced by man-made structures or to make the area more accessible for the inhabitants of the village. Towards the centre of the village more and more natural vegetation is lost due to development, and much less vegetation cover is present than at the village edges.

In addition to the altered vegetation structure in villages is the construction of buildings, rooftops, roads, fences, telephone poles, and a variety of other man-made structures which create unique additional opportunities for birds in terms of perches, shelter, foraging sites, and nesting sites. While shrubs and grasses are often removed for development to take place, trees are the one growth form type that often manages to remain in urban habitats, mainly for the shade they provide. Another important note is that with urbanisation comes gardening and the planting of additional trees. Trees that are planted in gardens are often exotic species which grow much higher than some of the indigenous species. This leads to a very diverse vegetation structure in the village habitat in terms of height diversity, as was shown in Figures 4.1 – 4.3 (pp. 54, 60, 66).

Research by others has shown that that vegetation structure, rather than vegetation species composition and the amount of indigenous vegetation, plays an important role in avian species diversity (MacArthur and MacArthur, 1961; Dean, 2000; DeWalt *et al.,* 2003). The findings of the current study would seem to agree with those statements. Miss Elandrie Davoren, a fellow student at the NWU, conducted a study in Ganyesa, another village in the Bophirima District similar to the three villages surveyed in this study (See Figure 3.3, p. 38). Her research focussed on the distribution and diversity of plant species in and around Ganyesa. With her permission, the interpolated maps for plant species richness have been included in this chapter. This allows comparisons of the patterns found in bird species richness to those found in plant species richness. It must be noted though, that Ganyesa is a larger town (± 1200 ha) than the three in my study.

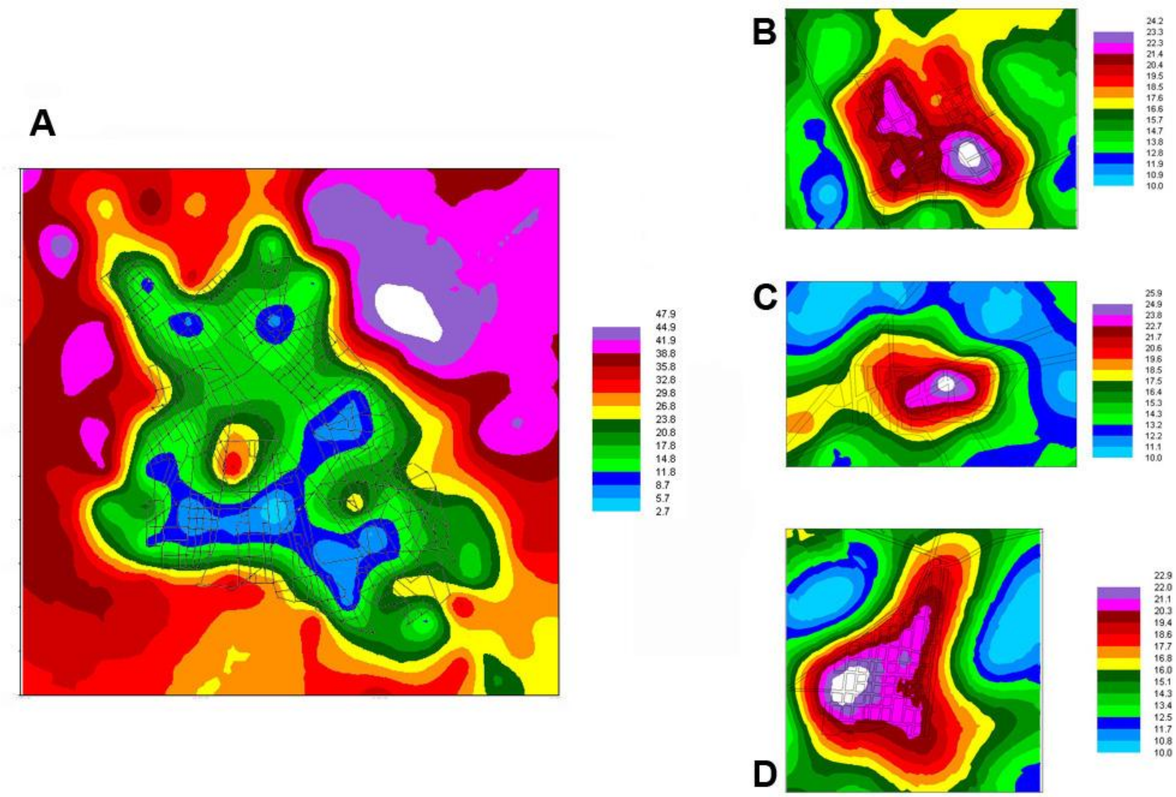

Figure 5.1: Interpolated distributions of (A) indigenous plant species richness in Ganyesa; (B) Bird species richness in Austray; (C) Bird species richness in Mmagabue; (D) Bird species richness in Southey. Figures are not to scale.

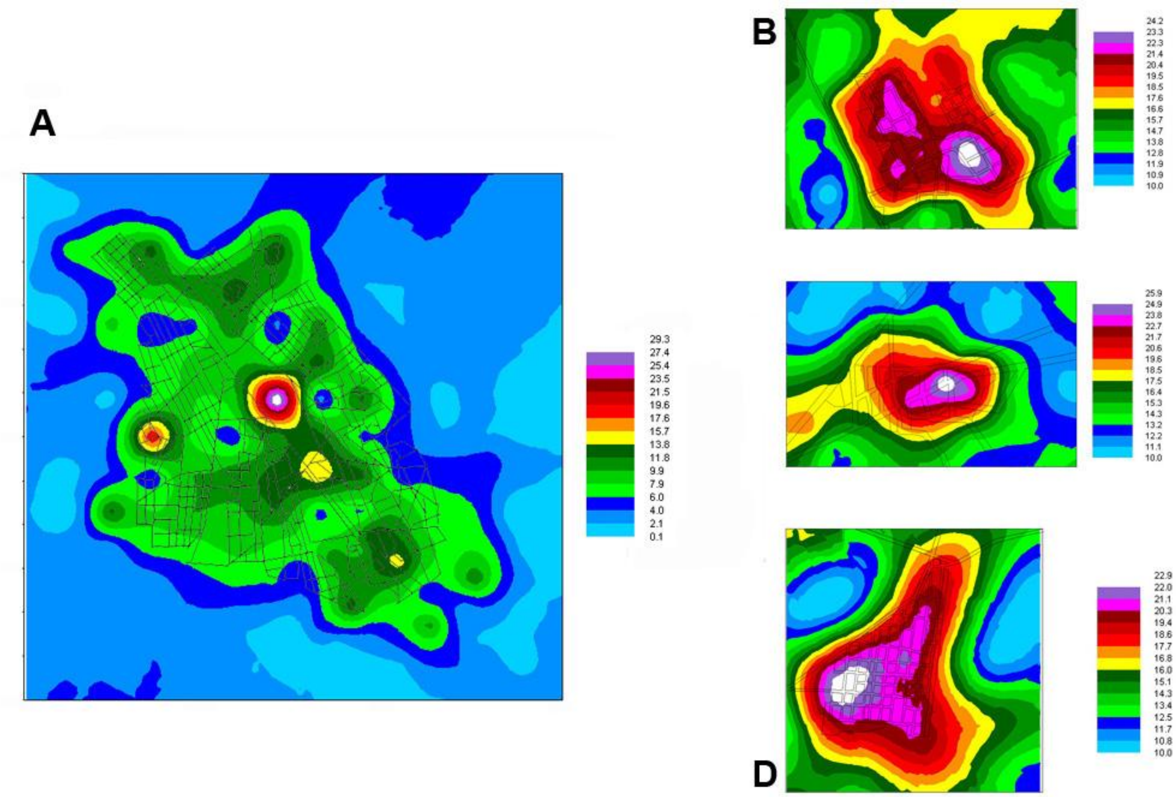

Figure 5.2: Interpolated distributions of (A) exotic plant species richness in Ganyesa; (B) Bird species richness in Austray; (C) Bird species richness in Mmagabue; (D) Bird species richness in Southey. Figures are not to scale.

From Figures 5.1 and 5.2 (pp. 139 -140) it is clear that indigenous vegetation decreased with urbanisation and exotic vegetation increased. Images B, C and D on the right indicate bird species richness distribution at the three villages, and are included for comparison. As has been mentioned, bird species richness increased within the villages, despite the loss of indigenous plants. This finding is in direct contrast with the findings of White *et al*. (2004). Their research found that a decrease in indigenous plants led to a decrease in bird species richness and total bird numbers. This may be true for towns in Australia, where their study took place; however in the current study, it is clear that a decrease in indigenous plant composition did not affect birds negatively.

Figure 5.3 (p. 141) compares the total plant species richness in Ganyesa to the bird species richness of Austray, Mmagabue and Southey. The natural habitat around the village contained a higher total number of plant species, which decreased toward the village edges and reached a minimum within the village habitat itself. The fact that total plant species richness decreased within the villages and bird species richness increased, strongly indicates that birds are not affected by plant species composition in these villages. A combined botanical, avian, and environmental factor study in the three villages should provide more concrete evidence, but visual comparisons of the various distributions shown here are striking and convincing.

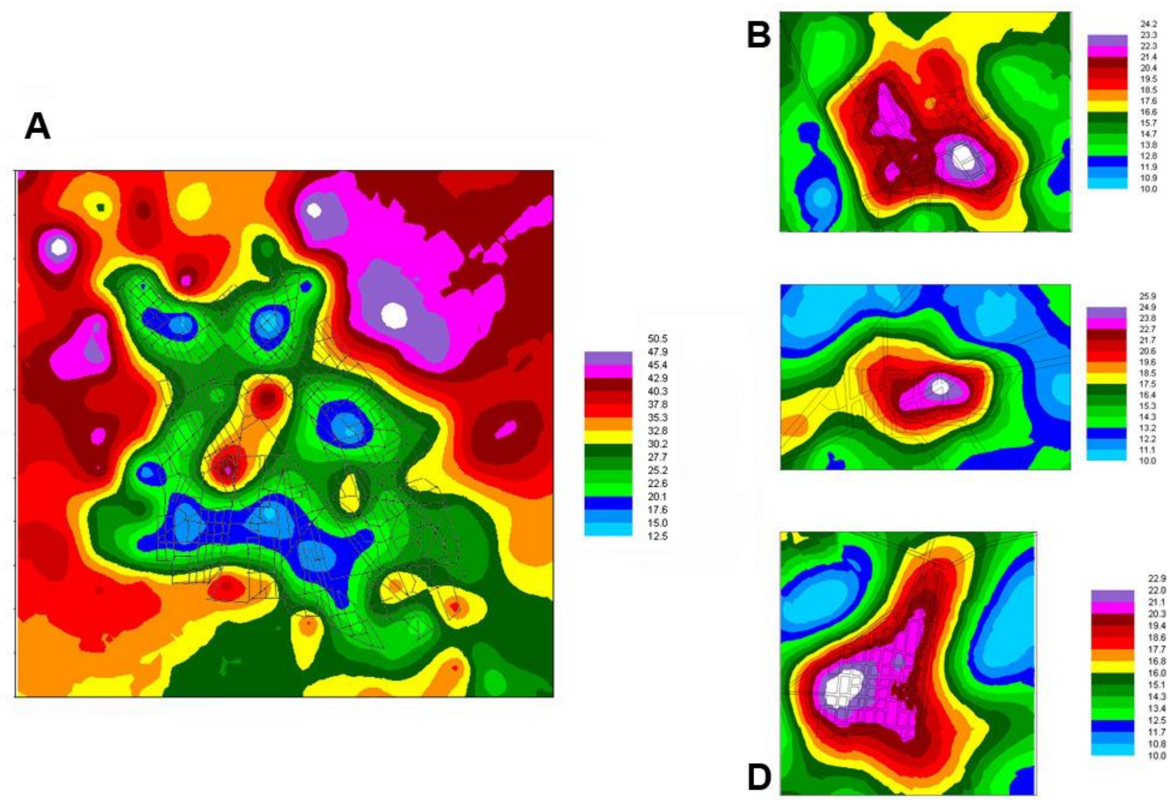

Figure 5.3: Interpolated distributions of (A) total plant species richness in Ganyesa; (B) Bird species richness in Austray; (C) Bird species richness in Mmagabue; (D) Bird species richness in Southey. Figures are not to scale.

Even though urbanisation generally reduces the quantity of native vegetation and alters its local structure and regional spatial pattern (Donnelly and Marzluff, 2006), alien plant richness increases with urbanisation and many of those plants have elaborate fruit displays, attracting generalist seed dispersers (Alston *et al.,* 2006) and frugivores.

The man-made structures brought on by urbanisation also contribute to the distribution of birds. Some species thrive under urbanised conditions by exploiting the unique nesting and foraging opportunities that such environments provide (Lancaster and Rees, 1979; Beissinger and Osborne, 1982; DeGraaf and Wentworth 1986). Birds respond positively to habitat heterogeneity (Olden *et al*., 2006) and studies have found that the introduction of roads, buildings, and other anthropogenic structures into wilderness may increase species richness and diversity by increasing the habitat heterogeneity in a landscape (Cam *et al*., 2000; Drapeau *et al*., 2000; Glennon and Porter, 2005). Factors possibly less apparent in studies in developed countries, but probably play an important role in villages such as in the Kalahari, include additional water sources (such as communal taps), food scraps from outdoor cooking, and the presence of livestock such as donkeys, goats and cattle, and their manure. The presence of new water sources is particularly important, since the study took place in a desert margin area where water is overall a scarce resource.

It is also important to note that the ability of certain species to survive in fragmented habitats sometimes depends on the quality of the surrounding matrix because of its potential role as a suboptimal habitat resource (Renjifo, 2001; Sekercioglu *et al*., 2002; Raman, 2006). For example, it was found that the Eurasian Hoopoe *Upupa epops* needs complementation between foraging and breeding habitats to establish successfully in developed habitats (Barbaro *et al*., 2006). Thus, conservation for this species requires the maintenance of breeding habitat (natural woods) and adjacent foraging habitat (short grass in developed areas), and consequently depends on the maintenance of habitat diversity at the landscape scale (Barbaro *et al*., 2006). In the current study, many species may also be dependent on both the natural and village habitats for different resources.

The results of this study showed that guilds responded differently to urbanisation. Many studies have found that food availability is a primary factor in the distribution of birds (Schluter and Repasky, 1991; Gonnet, 2001; Johnson and Sherry, 2001). Feeding guilds which were negatively impacted were insectivores and carnivores.

Lim and Sodhi (2004) stated that birds that feed on insects and other animals have declined in urbanised areas probably as a result of food limitations. Their research showed that the richness of insectivores and carnivores increased with increasing natural vegetation, but declined with increasing development and human population density. McIntyre *et al*. (2001) found that urbanisation leads to declines in the richness and abundance of insects and other arthropods, providing an answer to why insectivores are less abundant in urban areas. This is supported by the studies of Haila *et al*. (1989) and Bolger *et al*. (2000), who also found decreases in insects and other arthropods in urbanised habitats. Studies conducted in tropical forest locations also found that insectivores were more sensitive to human disturbances, habitat isolation and fragmentation than other guilds (Canaday, 1996; Bierregaard and Stouffer, 1997). However, in the present case, with a concentration of water, food, humans and animals, lights at night, etc in villages that conceivably attract and maintain more insects (flies, mosquitoes, moths, etc) than in the arid surrounding areas, an alternative hypothesis might be tested in the future: the reduction in insectivorous birds inside the villages may be due to the sensitivity of the birds to disturbance, rather than insect availability.

Carnivorous birds are to a great extent influenced by the availability of food sources since they tend to be much greater specialists than birds of other feeding guilds, with many species being dependent on specific kinds of prey (Casey and Hein, 1994) which might be more readily available in natural habitats.

Granivores showed a positive response to urbanisation, which agrees with the findings of other studies (Bezzel, 1985; Lim and Sodhi, 2004; Blair and Johnson, 2008). Many granivores are generalist feeders that often increase in developed habitats (Campbell, 2009) because they are able to exploit various food sources in urban areas (Alston *et al*., 2006). Lim and Sodhi (2004) stated that granivore abundance increases with urbanisation probably because of the availability of anthropogenic food due to littering, improper waste handling, or deliberate feeding. Another important factor regarding granivores is that they need a regular supply of water (Hockey, 2003; Dean 2004), especially in desert or desert margin landscapes (McKechnie, 2007). The overall landscape surrounding the villages was relatively arid, with a single watering hole for livestock just outside of each village (Figures 3.4, 3.6 and 3.8; pp. 40, 41, 43). The interpolated maps, however, did not indicate major increases at these spots, with the exception of Austray, where slight increases in species richness (Figure 4.9, p. 79), numbers of birds (Figure 4.12, p. 81), and all guilds (Figures 4.15, 4.21, 4.27, 4.33, 3.39, 4.45) except structure-nesters (Figure 4.51, p. 101) were indicated, compared to the rest of the natural habitat. Within the villages, communal water points for villagers were established on road corners every few blocks. Most of these taps were leaky, providing puddles of water where birds were often observed drinking from. Not only change in structure, but also change in resources, such as water and shade, seems to override any effects of changes in plant species composition due to urbanisation. These insights provide further opportunities for targeted investigations of factors affecting avian demography.

Keyser (2002) identified nesting sites as an important factor influencing bird distributions and in the current study, nesting guilds did indeed respond differently to urbanisation. Those that were negatively impacted by urbanisation were ground- and shrub-nesters. Other studies have also found declines in ground-nesting species in urban areas (Blair, 1996; Marzluff, 2001; Lim and Sodhi, 2004; White *et al*., 2005; Clergeau *et al*., 2006; McKinney, 2006; Clark *et al*., 2007). With urbanisation comes increased movement by humans and livestock, which puts the nests of ground-nesting species at risk of being trampled. Declines in shrub-nesting species richness in urban areas were found by Blair (1996), Lim and Sodhi (2004), and Clergeau *et al*. (2006). The lack of suitable nest sites was found by Lim and Sodhi (2004) to be a key factor in the poor responses of these guilds to urbanisation. They also mentioned that urban vegetation is subjected to regular maintenance such as mowing, spraying of chemicals, and removal of dead trees and other vegetation, and this may make it unattractive to species that require an intact shrub layer, dead trees, or generally undisturbed habitats. Mowing and spreading of chemicals is not practiced in the villages in the present study. Lawns are very uncommon (Figures 3.5, 3.7, 3.9; pp. 40, 42, 43) and poverty restricts the use of chemicals. Birds are thus unlikely to be influenced by these practices.

Tree- and structure-nesters, however, showed positive responses to urbanisation. Birds nesting in tree canopies are less sensitive to a decrease in fragment size and can better utilise disturbed habitats compared to ground- or shrub- nesters (Park and Lee, 2000; Fernández-Juricic, 2000). Lim and Sodhi (2004) also found that tree-nesters were the nesting guild with the highest species richness in urban areas. Their conclusion was that tree-nesting species are more adapted to urbanisation probably because their nesting sites are more readily available and their nests are better protected from disturbances and predation due to the taller trees. As has been mentioned, the villages in this study contained a large number of structurally diverse trees (Figures 4.1- 4.3, pp. 56, 60, 66).

Structure nesters traditionally breed on cliffs, rock faces, or other natural cavities. However, urbanisation presents species with an array of new nesting sites and Kang *et al*. (1990) found that structure-nesters respond favourably to urbanisation, probably because some species of the guild readily use anthropogenic structures as nesting sites (Kang *et al*., 1990). These structures include buildings, walls, rooftops, telephone poles, etc. Research by Miller *et al*. (2003) also reported increases in resident- and cavity-nesting species in urbanised habitats. From observations, this was also found in the present study, but more work in this regard is needed.

5.3 CONCLUSIONS

The conclusions of the study will be set out according to the hypotheses listed in Chapter 2.

HYPOTHESIS 1: At intermediate levels of disturbance, represented by small rural villages in the Kalahari, bird numbers and species richness will increase.

Assuming a gradient of increasing disturbance from the natural area to the village centres (as indicated by vegetation structure in Table 4.13 (p. 70) and graphically in Figures 4.1 – 4.3, pp. 56, 60, 66) hypothesis 1 was supported by the findings of this study. At each of the three villages surveyed, bird numbers and species richness was considerably higher within the villages than in the natural habitat surrounding each village. These findings agree with the intermediate disturbance hypothesis, which was set out by Connell (1979) and also supported by others (Marzluff, 2001; Tratalos *et al.,* 2007; Blair and Johnson, 2008).

The study confirmed that villages in the Bophirima District affected bird numbers and species richness. At each village, the sites with the highest species richness and bird numbers were located within the village habitat (Figures 4.9 – 4.14; pp. 79-82, and Figures 4.63 – 4.68; pp. 110-113). The geostatistical analysis and ANOVA also showed that different guilds had different reactions to the habitat changes found in the area, indicating that change in structure, food, nesting sites, and other factors were the biggest determinants of bird distribution.

HYPOTHESIS 2: Bird numbers and species richness will decrease towards the edges of the villages and outside the villages, where the opportunities brought on by intermediate disturbance become less or are located further away.

The second hypothesis was also supported by the findings of the study. To confirm this statement, the results of the geostatistical analysis and ANOVA can once again be used. As can be seen in Figures 4.9 - 4.14 (pp. 79-82) and Figures 4.63 – 4.68 (pp. 110-113), the highest species richness and number of birds was always found within the village habitat. Towards the edges of the villages, species richness continually decreased and in the natural habitats, decreased even more.

This indicates that the village habitat – and the intermediate disturbance brought on by it – definitely holds advantages and opportunities for birds, and these advantages and opportunities were absent from the natural habitat. Many studies have found vegetation structure to be very important in bird distribution and the reason for this is that vegetation structure plays a direct role in several other factors influencing birds. Food, nesting sites, perches, roosting sites, and shelter are all influenced by the structure of the vegetation in the area and in return influence the diversity and abundance of birds. In addition to the vegetation structure, habitat heterogeneity is increased by man-made structures within the villages (Cam *et al.,* 2000; Drapeau *et al.,* 2000; Glennon and Porter, 2005) and these structures provide unique opportunities for many bird species (Nuorteva, 1971; Lancaster and Rees, 1979; Clergeau *et al*., 1998; Petit *et al.,* 1999; Soderstrom and Part, 2000; Crooks *et al*., 2004; Donnelly and

Marzluff, 2006). With urbanisation, additional food and water sources also become available for birds.

HYPOTHESIS 3: Different guilds will respond differently to urbanisation; some increasing in richness while others decrease.

The findings of the study also supported hypothesis 3. There was a clear indication that birds were influenced by different habitat types based on their feeding and nesting guilds, since there was a divide in the richness and abundance different guilds between the urbanised and natural habitats. The results of the geostatistical interpolations and two-way ANOVA illustrated this most clearly. Guilds which were more prominent inside the village were granivores (Figures 4.21 – 4.26, pp. 86-88; and Figure 4.75, p. 117), as well as tree-nesters (Figures 4.39 - 4.44, pp. 95-97; and Figure 4.80, p. 120) and structure-nesters species (Figures 4.51 – 4.56, pp. 101-103) and Figure 4.81, p. 121). Guilds which seemed to benefit more from the natural habitat were insectivores (Figures 4.15 - 4.20, pp. 83-85; and Figure 4.76, p. 118) and carnivores (Figures 4.27 - 4.32, pp. 89-91; and Figure 4.77, p. 118), as well as ground-nesters (Figures 3.33 - 4.38, pp. 92-95; and Figure 4.78, p. 119) and shrub-nesters (Figures 4.45 - 4.50, pp. 98-100; and Figure 4.79, p. 120). The study indicated that bird species definitely occurred in higher numbers wherever their feeding and nesting requirements are best met.

5.4 IMPLICATIONS FOR CONSERVATION

The loss of biodiversity in the modern era is a matter of considerable concern (Scholes & Biggs, 2005). Environmental conservation in villages in arid areas such as investigated in this study seems to be more important than previously recognised. Species are threatened with local extinction if sufficient quantities of their habitats are not available. The richness of our aesthetic experience depends on the richness of habitats and communities as well as the richness of species. South Africa is a major tourist destination, mainly because of the richness of the country's biomes and the different attractions they offer.

Money is usually the deciding factor when it comes to questions regarding the protection of species or biological communities (Primack, 2002). Questions always arise about how much it will cost or how much it is worth? The economic value of something is generally determined by the amount of money people are willing to pay for it. Another way of assigning a value to something is by means of ethical, aesthetic, scientific, or educational methods. Government and corporate officials, however, base major decisions mainly on economic valuation (Primack, 2002).

It is thus easier to convince government to conserve biodiversity when there is an economic incentive involved. Different approaches for assigning values to biodiversity have been proposed. Useful frameworks have been used by McNeely *et al*. (1990) and Barbier *et al*. (1994), in which the values of biodiversity are divided in direct use values, which are assigned to products harvested by people, and indirect use values, which are benefits provided by biodiversity and don't involve harvesting or destroying it.

Products with indirect use values are crucial to the continued availability of natural products which are needed for economies and societies to function (Primack, 2002). This approach can be applied to villages in the Kalahari, since the area is burdened by severe poverty and constrained by drought. By conserving the area for birds and other species, sustainable development can be enhanced for poor communities that cannot afford to lose more natural resources. There is even the possibility of developing tourist attractions in these villages (such as bird guiding, and arts and crafts), which will hold conservational benefits for wildlife, as well as economic benefits for the human communities. Future research in this regard is needed.

5.5 IMPLICATIONS FOR MANAGEMENT

The most important information that came to light during this study was the fact that the diversity and abundance of birds definitely increased in urbanised habitats. The problem with this, however, is that it can easily be assumed that urbanisation in the area can only be good and that there are no negative impacts. It is commonly known that more intense levels of urbanisation – as found in most developed towns and cities across the globe – will lead to a lower diversity of wildlife. Blair (1996) demonstrated that species richness initially increases with suburbanisation and then decreases with urbanisation. Blair and Johnson (2008) found that species richness, species evenness and Shannon diversity increased initially and then decreased significantly as the levels of urbanisation increased. It is almost inevitable that a point will come when humans will want to further develop the infrastructure and composition of these small villages. When that point comes, steps should be taken to ensure that the loss of biodiversity will be at a minimum. It is thus important that strategies be designed to make sure that the diversity, as it is in these villages, be maintained.

In the UK, government has been actively promoting wildlife gardening to counteract the effects of urbanisation (Davies *et al.,* 2009) and some promising results have been seen. Similarly, in Texas, USA, backyard wildlife management programs in residential areas are used as a new conservation tool in areas undergoing development. Participation in these programs emphasizes the importance of water conservation, using native plants in landscaping, the use of natural alternatives to pesticides, and the control of predation by domestic pets to reduce impacts from residential land-use (Damude and Bender, 1999; Texas Parks and Wildlife, 2008). Residential areas which incorporate natural landscapes into their design attract a greater variety of birds than traditionally landscaped residential areas (Aurora *et al.,* 2009). There are thus ways to conserve bird diversity within urban areas. Whether this would be true and feasible in the context of very poor communities in an arid, desert margin area, remains to be seen.

Kendle and Forbs (1997) identified the following as the most important elements that should be included in a conservation orientated planning and management programme:

- The identification of the main reservoirs of wildlife by systematic surveys.
- The identification of the main corridors for wildlife in built-up areas.
- The identification of key linkages between different reservoirs and corridors.
- The protection and enhancement of the above mentioned factors.

- The identification of the main areas where semi-natural habitats are not accessible or available to humans.
- The implementation of policies aimed at these areas of need.
- The implementation of policies aimed at ensuring that the public can enjoy wildlife in responsible and informed manners.
- The design of standards for building development which make the most of opportunities to add to wildlife habitats and which cause the least possible damage to existing wildlife habitats throughout the whole built-up area.
- The design of policies that encourage local initiatives to achieve success.

5.6 RECOMMENDATIONS FOR FUTURE RESEARCH

There are several aspects regarding bird species diversity and distribution which are still unclear. Future studies could thus focus on:

- Determining the effect of vegetation structure on certain individual species to determine whether they can be used as indicators of land degradation.
- Determining on a finer scale how big an influence all the different factors have on bird species diversity and abundance. In addition, other factors can be identified which were not taken into account in this study.
- Determining on a larger scale how far the effect of a village extends.
- Further developing the concept of 'species density'.
- Conducting surveys in the same area during the four different seasons to determine what the impact of seasonal variation is on bird diversity and distribution.
- Conducting studies in larger, more developed villages in the area to see whether bird numbers and species richness will decline once the threshold of an "intermediate disturbance" is crossed.
- Determining the exact reasons for certain guild responses, such as insectivore declines in urban areas, since there is some debate about the issue.

- Determining the balance required in terms of conservation of birds in villages and birds in nature reserves, to conserve as many species as possible in a matrix of disturbed (villages, roads, cattle ranges) and conserved areas.
- Determining the attitudes and practices of villagers towards birds.
- Determining how bird diversity (and perhaps other biota) and their conservation can be developed as tourist attractions in the villages.

It is possible to conserve wildlife within urban areas while at the same time improving the area for humans; these methods simply have to be implemented into future development plans. Desert margins are already fragile ecosystems, which need proper conservation in order to prevent desertification, land degradation, and increased levels of poverty.

The task of interweaving the demands of climate change into South Africa's settlement development policies is yet to be attempted in a focussed manner (du Plessis *et al*., 2003). This is importance since birds (and other biota) in deserts and desert margins are facing the threat of possible extinction due to climate change and desertification. The villages in these areas may be important and currently unrecognised conservation sites for birds, which makes proper management and sustainable development key elements to the successful future of birds and humans in these desert margins.

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