EFFECTS OF LAND-USE ON AVIAN DEMOGRAPHY IN THE KALAHARI AREA OF THE NORTH-WEST PROVINCE, SOUTH AFRICA

ADRIAN HUDSON

Dissertation submitted in partial fulfillment of the requirements for the degree Magister Scientiae in Environmental Science at the North-West University (Potchefstroom Campus)

Supervisor: **Prof. H. Bouwman**

2004

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ACKNOWLEDGEMENTS

The author would like to express his sincere gratitude to the following people and organizations:

Prof. Henk Bouwman	For his professional guidance and support yet relaxed hands off, leadership approach, as well as all his additional support during the course of my postgraduate studies.
Prof. Klaus Kellner	For giving me the opportunity to work on the Desert Margins Programme.
The Desert Margins Programme	For financial and logistical support to make this research possible.
Global Environment Facility	For their financial assistance during the course of my study
North-West Parks and Tourism Board	For giving me the run of Molopo Nature Reserve in order for me to conduct my research.
North-West Department of Agriculture and Environment	For their assistance with regard to the studies done on the communal farms in the Molopo region.
Mr. Steven Gore (Molopo Nature Reserve Park Warden)	For all his assistance during the course of my research.
Mr & Mrs. Pierre Bruwer	For all their assistance and unprecedented hospitality during the course of my study.
Ms Leonè Wolmarans	For all the love, support and understanding she gave me throughout the three years of study for this degree, and also for all the sacrifices she made in order to make it possible
My Parents	For their ever-unconditional support and encouragement
Prof. P. D. Theron	For his help with the translation during the writing up of this thesis

THE EFFECTS OF LAND-USE TYPES ON AVIAN DEMOGRAPHY IN THE KALAHARI AREA OF THE NORTH-WEST PROVINCE OF SOUTH AFRICA

Abstract

Desertification, whether due to anthropogenic pressures, climate change or other factors, has become a global concern. The far-reaching effects of desertification have prompted the formation of the United Nations Convention for the Control of Desertification (UNCCD) and the initiation of the Desert Margins Programme (DMP) in order to attempt to control desertification.

This study forms part of the first phase of the DMP and will thus aim to keep to the objectives of the DMP.

The principal aims of this study was to determine what effects, if any, land-use types in the desert margins areas of the North-West Province, South Africa, will have on avian demography of the area, and to ascertain whether these changes in avian demography can be used in order to indicate land degradation in these areas.

Vegetation structure is widely known to influence avian demography, along with factors such as food availability, nesting sites, water availability and climate. Vegetation structure was also found to be dramatically altered by the effects of land-use in the study area.

The hypotheses formulated for this study were that: 1) Bird populations are noticeably influenced by the vegetation structure of the area they inhabit; 2) bird species diversity as well as bird numbers decline with an increase in land degradation in the study area; and 3) Bird species diversity will act as a good surrogate for land degradation in the study area.

In order to test these hypotheses, the study area was selected in the Molopo district of the North-West Province. This district falls within the desert margin area and is earmarked as one of the target areas for the Desert Margins Programme in South Africa. Within the study area four sites were chosen to represent different degrees of degradation. Vegetation structure analyses were carried out at each of the sites in order to determine the degree of change in vegetation structure brought about by land use in the area. The birds at each of these sites were surveyed using three transects. Surveys were repeated over four seasons to give some indication of the effects of seasonality on bird populations of the different sites.

The results showed a definite decline in bird species diversity with an increase in land degradation, especially due to the simplification of the vegetation structure because of anthropogenically induced alteration of the vegetation structure of the area. Both bird species diversity and the number of birds occurring at the sites declined with an increase in land degradation. The guild analysis done showed that, although the actual number of species occurring at the various sites changed, aggregations remained relatively similar with regard to feeding guilds. At all the sites, analysis of feeding guilds showed that insectivores were the guild most represented, with granivores second most and then a variation in other guilds at each site. Breeding guilds showed a much greater variation in percentage composition of the guilds. At sites with less shrub and tree strata, ground nesting species were most represented, whereas the sites with a more well developed tree and shrub strata had a greater occurrence of tree nesting birds than the other guilds. The deduction to be made from this is that bird species composition changes can be attributed to their nesting needs, to a much greater extent than their feeding needs.

Bird species varied in their response to changes in the vegetation structure at different sites with specialist species, such as raptors and specialist insectivores, being more vulnerable to changes in vegetation structure than generalist species, such as granivores and generalist insectivores.

From the results of this study it appears that vegetation structure played the most important role in determining species diversity, in the Molopo district of the North-West Province. Many of the other factors that have been shown to influence bird species diversity in other studies were shown to be negated due to the uniqueness of the study area.

The result of this study showed that bird species diversity is definitely influenced by the effects of land use on vegetation structure due to land

degradation in the desert margin areas of the North-West Province. This also appears to indicate that bird species diversity will be a good surrogate for the indication of land degradation in the study area. More studies are however needed in order to adequately understand how and why species diversity is affected by vegetation structure and how the changes in avian diversity will affect the ecosystem processes in the desert margins areas. Due to the decrease in species diversity on, what was supposed to be, a well managed commercial farm, this study has also shown that more studies need to be done on the long term effects of management in the desert margin areas.

Bird species diversity has also been shown by this study to have potential as a cost effective, easy way of determining the degree of degradation occurring in an area as well as a possible tool for monitoring the effectiveness of restoration of degraded areas.

Molopo Nature Reserve was found to be more important to the bird species of the area than first anticipated. The results seem to indicate that Molopo Nature Reserve acts as a refuge for resident bird species in the colder, drier winter months. This was most clearly shown by the increase in bird numbers at Molopo Nature Reserve during the winter survey, when bird numbers at all the other sites declined.

EFFEK VAN GRONDVERBRUIK OP DIE VOËLDEMOGRAFIE IN DIE KALAHARI OMGEWING VAN DIE NOORDWES-PROVINSIE VAN SUID AFRIKA

(The Effects of Land-use Types on Avian Demography in the Kalahari Area of the North-West Province of South Africa)

Opsomming

Verwoestyning, hetsy as gevolg van antropogeniese (menslike) druk, klimaatsverandering of ander faktore, gee aanleiding tot wêreldwye kommer. Die verreikende gevolge van verwoestyning het gelei tot die ontstaan van die "United Nations Convention to Combat Desertification" (UNCCD) en die instelling van die "Desert Margins Programme" (DMP) om verwoestying te probeer voorkom en beheer.

Hierdie studie vorm deel van die eerste fase van die DMP in Suid-Afrika en dit word beoog om die doelstellings van die DMP na te streef.

Die doelwit van hierdie studie was om te bepaal watter effekte, indien enige, grondverbruiktipes het op die voëldemografie van die woestynrandgebiede van Noordwes-Provinsie in Suid Afrika. Verder is ondersoek ingestel om te bepaal of die veranderinge in voëldemografie gebruik kan word as aanduiding van landelike degradasie in hierdie droë gebied.

Plantgroeistruktuur is algemeen bekend as 'n faktor wat voëldemografie beïnvloed. Ander bydraende faktore is die beskikbaarheid van voedsel, geskikte nesbou-strukture in die omgewing, voldoende toegang tot water asook klimaat. Plantgroeistruktuur is in 'n opvallende mate gewysig deur die effek van grondverbruik en grondbestuurmetodes in die studiegebied.

Die hipoteses geformuleer vir hierdie studie sluit die volgende in:

1) voëlbevolkings word merkbaar beïnvloed deur die plantgroeistruktuur van die omgewing wat hulle bewoon, 2) voëlspesiediversiteit asook voëlgetalle neem af met 'n toename in landelike degradasie in die studiegebied en 3) voëlspesiediversiteit sal as goeie plaasvervanger kan dien ten opsigte van die herstel van landelike degradasie in die studiegebied.

Ten einde die hipoteses te toets, is studiegebiede uitgekies in die Molopo-distrik van die Noordwes-Provinsie. Hierdie distrik val binne die area aangrensend aan die woestyngebiede en is uitgesonder as een van die teikengebiede vir die DMP in Suid-Afrika.

Binne hierdie studiegebied is vier sones gekies met onderling verskillende grade van degradasie. Plantgroeistruktuuranalises is gedoen by elkeen van die studiesones met die doel om 'n aanduiding te kry van die graad van verandering in plantgroeistruktuur soos veroorsaak deur grondverbruik in die omgewing. Opnames van voëlspesies en -getalle is by elke gebied uitgevoer deur middel van die plasing van transekte waarlangs opnames gedoen is. Hierdie opnames is herhaal tydens al vier seisoene om 'n aanduiding te gee van die seisoenale verspreiding van voëlbevolkings oor die studiegebied.

Resultate toon 'n definitiewe afname in voëlspesiediversiteit met 'n toename in landelike degradasie, veral as gevolg van die vereenvoudiging van die plantegroeistruktuur wat veroorsaak word deur menslike interaksie en veranderings aan die plantegroei van die omgewing. Beide voëlspesiediversiteit en voëlgetalle het afgeneem met 'n toename in landelike degradasie.

Die analise van voedingsgildes toon dat voëldiversiteit relatief dieselfde gebly het met betrekking tot voedingsgildes alhoewel die getal spesies wat voorgekom het by die studiegebiede onderling verskil het. By al die liggings was insektivore die mees algemeen, gevolg deur graanvreters. 'n Vergelyking van broeigildes toon egter 'n baie groter afwyking in samestelling van broeigildes tussen die verskillende liggings. In areas met min bome en struikgewasse het heelwat meer voëlsoorte wat op die grond nesmaak voorgekom, en waar struike en bome teenwoordig was, het meer voëlsoorte voorgekom wat in bosse en bome nesmaak. Die afleiding wat gemaak kan word is dat veranderings in voëlspesiesamestellings tot 'n groter mate toegeskryf kan word aan nesboubehoeftes as aan voedingsbehoeftes.

Voëlspesies wissel ten opsigte van hul reaksie tot veranderings in die plantegroeistruktuur in verskillende gebiede. Die gespesialiseerde spesies, soos roofvoëls en gespesialiseerde insektivore, is meer sensitief vir veranderings in plantegroeistruktuur as die meer veelsydige voeders soos saadvreters en algemene insektivore.

Uit die resultate van hierdie studie blyk dit dat plantegroeistruktuur, en die veranderings daaraan as gevolg van grondverbruik, die belangrikste rol speel in die bepaling van voëlspesiediversiteit in die Molopo-distrik van die Noordwes-Provinsie. Baie van die ander bepalende faktore soos aangedui in ander soortgelyke studies, word weerspreek deur hierdie studie as gevolg van die unieke, en ariede, aard van die studiegebied.

Resultate van die studie wys ook dat daar 'n verband bestaan tussen plantegroeistruktuur veranderings en landelike degradasie in die woestynrandgebiede. Dit blyk 'n aanduiding te wees dat voëlspesiediversiteit 'n goeie indikator is vir die aantoon van die mate van landelike degradasie en plantegroeistruktuur veranderings in die studiegebied.

Verdere studies is nodig ten einde te verstaan hoe en hoekom spesie diversiteit afhanklik is van plantegroeistruktuur en hoe die veranderings in voël-diversiteit sal inwerk op ekosisteemprosesse in soortgelyke gebiede.

Na aanleiding van die onverwagse verlaging in spesiediversiteit op die kommersiële plaas, wat (volgens algemene mening) na gelang van goeie landelike bestuurspraktyke bedryf word, behoort verdere navorsing gedoen te word om die langtermyneffek van landelike bestuurspraktyke in gebiede aangrensend aan woestyngebiede te ondersoek.

Die potensiaal van voëlspesiediversiteit as 'n koste effektiewe, relatief eenvoudige manier om die graad van landelike degradasie in 'n gebied te bepaal, is in die studie bewys. Verder kan dit ook moontlik gebruik word om die effektiwiteit van restourasie van gedegradeerde gebiede te moniteer.

Op grond van die resultate van hierdie die studie blyk dit dat die Molopo-natuurreservaat 'n belangrike toevlugsoord is vir standvoëls in die kouer, droër wintermaande. Gedurende die opnames in die wintermaande, was daar 'n duidelike toename in voëlgetalle in die Natuurreservaat, terwyl alle ander areas 'n afname in voëlgetalle getoon het. Molopo-natuurreservaat speel dus 'n belangriker rol in voëlspesiediversiteit as wat aanvanklik verwag was.

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LIST OF ABBREVIATIONS

ANOSIM – Analysis of Similarities

DACE – Department of Agriculture, Conservation and Environment

DMP – Desert Margins Programme.

GEF – Global Environmental Facility.

GPS – Global Positioning System.

IBA – Important bird area

MDI – Multivariate Dispersion Indices.

NM MDS – Non-Metric Multidimensional Scaling.

NWPTB – North-West Parks and Tourism Board

PCA – Principal Component Analysis.

RAC – Resource Assessment Commission.

UN – United Nations.

UNCCD – United Nations Conference to Control Desertification.

UNEP – United Nations Environmental Program.

USGS – United States Geological Service.

CHAPTER 1
GENERAL INTRODUCTION

1.1 INTRODUCTION

Desertification, whether due to anthropogenic pressures, climatic change or other factors has become a global concern (Kellner, 2000). Desertification not only accelerates species loss, but also impacts on human development in areas where it occurs.

Desertification threatens over one billion people worldwide, with an estimated 135 million people in danger of being driven off their land as it becomes progressively desertified. Desertification also costs the world an estimated $42 billion per year, with Africa alone losing some $9 billion per year. It is estimated that 73% of Africa's drylands are moderately or severely affected by desertification. With 40% of the global land area classified as dryland, it is important for conservation efforts to target these areas for intervention (Kellner, 2000).

1.1.1. DESERTIFICATION, DEGRADATION AND LAND-USE

Desertification is defined, by the United Nations Conference to control Desertification (UNCCD), as: "land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities."

1.1.1.1 CONVENTIONS ON DESERTIFICATION

The recognized importance of controlling desertification prompted the United Nations to adopt the Convention to Combat Desertification on the 17th of June 1994; the Convention to Control Desertification was ratified by 115 countries by

October 1995 (www.unccd.int/main.php). The fact that Africa is one of the areas worldwide where desertification is of greatest concern, prompted the UN General Assembly to adopt resolutions that recommended urgent action for Africa (Kellner, 2002).

Desert margins are defined in Reich *et al.* (2000) as the transition zone between the typical deserts and regions where there is adequate moisture supply for plant growth during the warm season which is characterized by low rainfall, high evapotranspiration and high variability of rainfall.

Desertification is a serious concern from a scientific, socio-economic and conservation point of view in the desert margin areas throughout the world. So much so that the Desert Margins Programme (DMP) was established to study and monitor the desert margin areas of Africa (Kellner, 2002).

In order to effectively conserve an area, sufficient knowledge has to be built up concerning the different species existing in that area as well as the biotic and abiotic interactions between occurring in that area. The Desert Margins Programme in arid and semi-arid areas has the following objectives as derived from Kellner (2002):

- Conservation and sustainable use of endemic biodiversity in dryland ecosystems where biodiversity is threatened by intensified land-use, drought and desertification.
- Prevention and control of land degradation through development of sustainable-use methods for biodiversity conservation.
- Integrated approaches to conservation, sustainable land-use systems and strategic interventions to rehabilitate degraded land.
- Public participation in project design and implementation.

Although this project is concerned mainly with biodiversity, elements of all four of these objectives have been addressed in the present project.

1.1.1.2 Factors Influencing Desertification

Desertification can be resultant from various factors including climatic variation and human activities (Kellner, 2002). The relative importance of climatic and anthropogenic factors in causing desertification, however, remains unresolved (Gonzalez, 2002)

Climatic Factors

Major climatic driving forces generally assumed to affect desertification include declines in precipitation, increase in temperature, and sea surface temperature anomalies (for instance El Niño and El Niña).

Climate change affects the range and rate of desertification through the alteration of spatial and temporal patterns in temperature, rainfall, solar insolation, and winds. Desertification could also aggravate climate change through the release of carbon dioxide from dead and cleared vegetation, as well as through the reduction of carbon sequestration potential of desertified land. These feedbacks between vegetation change and precipitation also exacerbate the problem of desertification in drylands globally (Gonzalez, 2002).

Desert margins are fragile ecosystems, in other words have low resilience with regard to change brought by disturbances, and thus highly susceptible to land degradation (Reich *et al*, 2000). Land degradation in these fragile desert margin areas can lead to the advancing of deserts, thus in order to minimize the advancement of desert areas, land degradation in the desert margin areas needs to be controlled (Gonzalez, 2002).

Anthropogenic Factors

Major anthropogenic factors driving desertification are unsustainable agricultural practices, overgrazing, heavy grazing, use of fire as a management tool, provision of non-moveable water points and deforestation. Human population growth can ultimately drive desertification if it increases the land area subjected to unsustainable agricultural practices, overgrazing, or deforestation (Gonzalez, 2002). Land degradation is usually the outcome of these anthropogenic factors driving desertification,

Land degradation is defined in Kellner (2002) as: "A process where a reduction in or loss of productivity can be observed, it is accompanied by denudification, soil erosion, bush encroachment and a change in rangeland status to a poorer condition."

Although loss of biodiversity is implied in this definition, it is however agricultural/pastoral in its outlook and does not express the loss of biodiversity that accompanies desertification. The UNCCD defines land degradation as: "reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land-uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical and biological or economic properties of soil; and (iii) long-term loss of natural vegetation." (www.unccd.int).

The definition given by the UNCCD includes biological productivity, but also tends to imply, rather than express loss of biodiversity.

Desert margins in South Africa are widely utilised by both commercial and communal stock farmers (Kellner, 2000). In many regions of the world, grazing has reduced the density and biomass of many plant and animal species, reduced biodiversity, aided in the spread of exotic species and disease, altered ecological succession and landscape heterogeneity, altered nutrient cycles and distribution, accelerated erosion, and diminished both the productivity and land-use options for future generations (Kauffman and Pyke 2001).

Due to the fact that unsustainable agricultural practices and overgrazing are two of the main anthropogenic factors driving desertification (Gonzalez, 2002), it is important to study, on different scales, what effects these practices have on biodiversity, as well how land-use practices can be changed in order for them to become more sustainable or less damaging.

Disturbance is the process by which the natural processes within an ecosystem are altered (Begon *et al*, 1996); severe disturbance of ecosystems can lead to land degradation which, in desert margin areas, can lead to desertification.

Doherty *et al*, (2000) named the five key agents of habitat disturbance as: fire, pollution, water supplementation, fragmentation, and land-use activities.

Not all land-use activities cause degradation, as conservation can also be classified as a type of land-use and keeping to the correct stocking rates on these reserves could actually benefit the state of that veld.

There is, however direct evidence to prove that the current rapid loss of species on earth, and management practices that decrease local biodiversity, threaten ecosystem productivity and sustainability of nutrient cycling (Doherty *et al*, 2000).

Of the five agents named by Doherty *et al* (2000), four could be of significant importance in the current study area (Molopo district of the North-West Province). Fire is used extensively here as well as throughout the savannah areas of Africa as a management tool, although its effectiveness has been questioned in more arid areas such as the Molopo area due to the slow recovery rate of the veld (Low & Rebelo, 1998)

In dry areas, water supplementation causes a concentration of stock and game in the areas where watering points are established. This has a degrading effect on the veld surrounding these watering points that tends to increases in size during the dry season and droughts (James *et al,* 1999; S. Gore pers. comm.)

Fragmentation of habitats is well documented as having a negative effect on species in the area where it occurs (Meffe & Carroll, 1997; Primack, 1998). Further fragmentation could occur in the Kalahari area due to bush clearing, bush encroachment and overgrazing.

Land-use activities in the current study area that have the greatest influence on degradation are cattle farming and communal farming (Kellner, 2000). Overstocking on cattle farms is the main cause of degradation (Kellner, 2000), and fire regimes that can cause disturbance (Low & Rebelo, 1998), are also used as management tools on commercial cattle farms. Overstocking, of cattle, sheep and/or goats on communal farms, is the main cause of degradation (Kellner, 2000; Van den Berg & Kellner 2001), and this degradation often manifests itself through bush encroachment in these areas.

In this study I have decided to use birds as an indicator of land degradation in the Molopo area of the North-West Province due to the fact that birds are widely used as indicators of changes in environmental conditions (Bibby,1993; Adamus, 2002; O' Halloran *et al*, 2002). In the following section the importance and usefulness of birds are outlined.

Some confusion may be forthcoming with regard to the terms overgrazing, degradation, disturbance and fragmentation. For the purpose of this thesis the terms can be interpreted as follows:

- Overgrazing is the anthropogenic process by which (due to human stocking pressure) too many animals are grazed on a certain area, thereby exceeding the carrying capacity of that area, and causing the decline in both quality and quantity of the habitat, which is difficult to reverse.
- Degradation is the decline in the quality of a habitat due to natural or anthropogenic disturbances, but also, in this case, refers to a loss of habitat quantity.
- Disturbance refers to the cause of habitat quantity or quality loss.
- Fragmentation is the reduction in the size of a suitable habitat due to the effects of degradation.

These terms can be used at both landscape and site level.

1.1.2 General, Ecological and Scientific Significance of Birds

Birds, in general, are significant in the sense that:

- Birds form part of charismatic fauna; therefore they are often the objects of conservation efforts worldwide due to human affinity for birds (Adamus, 2002).
- Birds are often used as flagship or "umbrella" species in conservation efforts and whole ecosystems are conserved under the umbrella of conserving the bird species in question (O' Halloran *et al*, 2002).
- Birds are very visible biota and their presence or absence is easily noticed by the general public thus raising environmental concern as to the reason for their disappearance or death (Adamus, 2002; O' Halloran *et al*, 2002).

- Birds are economically important due to the revenue generated by bird-watching worldwide, as well as game bird hunting (O' Halloran *et al*, 2002). In South Africa alone an approximate R100-220 million is generated by birding related activities (Turpie & Ryan, 1999).

Birds are ecologically significant for the following reasons:

- Factors that benefit birds may also have a positive influence on other biota, e.g. increased light can also benefit butterflies and ground flora or standing dead wood can also benefit fungi and insects (O' Halloran *et al*, 2002).
- Vegetation structure variation is likely to provide diverse conditions that will increase diversity of not only birds, but a range of other biota as well (O' Halloran *et al*, 2002).
- Frugivorous, granivorous and omnivorous birds play a major role in the dispersal of seeds (O' Halloran *et al*, 2002).
- Sources of food for raptorial birds or other predators (O' Halloran *et al*, 2002)
- Birds often hold relatively high positions within the food web and because of this position tend to be good indicators of a variety of environmental variables (Adamus, 2002; O' Halloran *et al*, 2002).
- Control of pest species; insectivorous species, especially birds, play an important role in the natural control of pest species (Anon, 2002).
- Birds also have intrinsic importance as an individual species regardless of other importance (Adamus, 2002).

Scientific importance of birds can be summarized under the following:

- Ease of survey – bird species are visible and abundant by day (Adamus, 2002).
- Useful focal species due to their positions near the top of the food web (Adamus, 2002)
- Mobility gives bird species the ability to move away from unsuitable habitats and towards suitable habitats (Adamus, 2002).

- Ease of identification and study without the need to collect and analyze samples and identify them with complex taxonomic keys (Adamus, 2002).
- Analysis of guilds can be useful in many different spheres of scientific research (Adamus, 2002; Bibby, 1993).

Importance of birds in arid zones

- Analysis of guilds can be useful in scientific research in arid zones.
- Control of pest species – insectivorous birds play an important role in the natural control of pest species (Anon, 2002).
- Birds also help to elevate nutrient levels of the soil in arid areas, especially under large trees (Dean, Milton & Jeltsch, 1999).
- Seed dispersal – frugivorous and granivorous birds play a major role in the dispersal of seeds in arid areas (Bibby, 1993; Dean, Milton & Jeltsch, 1999).

The above-mentioned factors, especially the ecological and scientific significance of birds, indicate the usefulness of birds as an animal group for this study. Due to their mobility, birds easily move away from areas unsuitable for their needs and towards suitable areas, thus the presence or absence of certain bird species could give a good indication of what effects a certain land-use type has on the environment.

1.2 MOTIVATION AND PROBLEM STATEMENT

The Desert Margins Programme was initiated by the United Nations Environment Program in order to attempt to stabilize and maintain the desert margins through the collaboration the scientific community, non-government organisations and members of the local communities (Kellner, 2002). The first stage of the programme was to determine a biodiversity baseline for the study area. Part of the baseline biodiversity study was an inventory of species occurring in the study area. Later efforts will attempt to enhance understanding of processes of biodiversity loss and land degradation in the study area (Kellner, 2002). This study forms part of these two objectives of the Desert Margins Programme; the biodiversity inventory for birds was done during the course of this study, but will not be handled in this thesis. This thesis will, however, help to gain some insight into the identification of birds as indicators of land degradation for further use in the course of the Desert Margins Programme.

Due to widespread utilization of desert margins in South Africa for agricultural/pastoral purposes, these fragile ecosystems are placed under increased pressure due to gazing, general utilization and management practices (Kellner, 2000). These may have a profound detrimental effect on the ecological integrity of the desert margins.

The key agents of habitat disturbance, mentioned by Doherty *et al.* (2000), are all interlinked in the various land-use areas of the desert margins of the North-West Province. Land-use activities not only impact the area due to the grazing of livestock that occurs, but fire is commonly used as a management tool in the area to combat bush encroachment and also to increase pastures on the farms. This leads to habitat fragmentation and widespread landscape change in the area. Already low water tables may be impacted by the continued pumping of water in these areas in order to water livestock or for human use (James *et al*, 1999).

The impacts of these practices on the area are as yet not adequately researched. Sustainable use of the area is impossible without a proper understanding of the ecology of these fragile ecosystems. Research concerning the effects of the land-use on the ecosystem needs to be carried out in order to reduce negative impacts such as loss of species and decreased land quality and so doing prevent the ever-increasing rate of desertification (Kellner, 2000).

Once a better understanding of the effects land-use practices have on the desert margins is gained, factors causing negative impacts can be determined and mitigation of those factors can be planned and implemented.

To try and examine every aspect of the ecology of areas of different land-use types would be an exhaustive exercise, for which few researchers have the time, funding or expertise. For this reason avian species diversity is examined as a surrogate for land degradation of the sites within the study area.

The motivation for the study can, therefore, be summarized as follows:

- Desert margins are fragile ecosystems that are also utilised for communal and commercial stock farming
- In accordance with the World Summit on Sustainable Development, 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
- To identify whether birds could be used as surrogates to assess land degradation
- To identify whether avian diversity could be indicative of the sustainability of land-use practices

Problem statement: Do land-use types affect avian demography in desert margin areas? If so, can these changes in avian demography be used to indicate land degradation in these areas?

In order to address this problem statement, a literature review will be done in Chapter 2. Based on the literature review a number of hypotheses, which will be tested by this study, will be formulated.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

In order to address the problem statement formulated at the end of Chapter 1, a literature review needs to be done, so that information can be accumulated in order to formulate hypotheses that can be tested by this study.

Limited research has been done on the effects of land-use on avian demography in arid areas, thus information needs to be accumulated by integrating parts of various literature sources that are (or could be) relevant in the study of the effects of land-use on avian diversity. The following literature study includes a general review of biodiversity, a review of literature concerning the factors influencing avian diversity as well as a review of the effects of land use on avian diversity.

2.2 BIODIVERSITY – A REVIEW

Biodiversity is a very important yet often ambiguous field of science due to the misinterpretation of terminology. This section is included in the literature review in order to clarify the use of many of the concepts related to biodiversity as well as to indicate how they can be related to avian biodiversity. Although some of the information contained within this section is relevant to the current study, the study has not been designed to test all of the concepts given within this section and they may, therefore, not be discussed in future with regard to this study.

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).

The problem with most definitions of biodiversity is that they have become synonymous with all living organisms, thus making it difficult for scientists to identify indicators of biodiversity as defined, and easier to just give indicators of certain components of biodiversity (Doherty *et al*, 2000).

Working definitions, which specify the units used in its measurement are therefore required (Doherty *et al*, 2000). Gaston (1996) noted that the concept, biodiversity, operated over a number of biological levels of organization, and also at different scales.

The debate as to the utility of the term "biodiversity" continues in the scientific community. Authors such as Ghilarov (1996) argued that biodiversity is just the re-emergence of an old theme (diversity) under the semblance of a new theme.

Generally biodiversity can be divided into four units, namely:

- Ecosystem diversity – these are the largest units of diversity, comprising of a number of habitats, the species within them and the genetic diversity within individuals of those species (Doherty *et al*, 2000).
- Habitat diversity – can be defined as the diversity within a habitat (Doherty *et al*, 2000). However the term habitat has also come under fire

from the scientific community, habitats are usually considered as a location in space, however Andrewartha and Birch (1984) proposed that "habitat" be extended to the influences on the survival and reproductive ability of the species.

- Species diversity – refers to the variations in organisms according to their differences and is the conventionally accepted measure of diversity (Doherty *et al*, 2000), although it was considered inappropriate by Beck (1998), because it does not take into account differences in functional importance of species. Species can be seen as the fundamental unit of organization in ecology and taxonomists have been able to distinguish between species consistently over time, despite problems with synonymy and fine description (Doherty *et al*, 2000).
- Genetic diversity – "fine scale" measure of diversity, expressed in genetic differences between individual organisms.

2.2.1 Habitat Complexity, Habitat Quality and Ecosystem Processes

Habitat complexity can be described on the basis of characteristics of species, with regard to richness, connectance, interaction strength and evenness, within that habitat (Pimm, 1984). Habitat complexity should not be considered a synonym for habitat heterogeneity; habitat heterogeneity refers to spatial and temporal change across a landscape, with regard to species composition, whereas habitat complexity refers more to the strength of interaction between species and between species and their environment (Doherty *et al*, 2000).

Habitat quality can be referred to as the extent to which a habitat has been affected by anthropogenic and natural disturbances, and the effect this has on the suitability of that habitat for a particular species or community of species (Doherty *et al*, 2000). Habitat quality should, however, be defined in a species-specific manner in order for it to have applicable meaning.

Habitat quality is related to any biotic or abiotic factors that affect individuals or populations. These may range from very small scale changes (e.g. the availability of a song perch for a breeding bird to large scale changes (e.g.

fragmentation of an area that affects suitability of an area for nesting) (Doherty *et al*, 2000).

Key agents of habitat disturbance include: fire, pollution, water supplementation, fragmentation and land use, such as farming. All these factors will affect habitat quality (Doherty *et al*, 2000). Overall composition of the habitat (including temperature, rainfall and vegetation) and biogeography factors (such as fragment size, shape and edge size), also affect habitat quality for different species (Doherty *et al*, 2000).

Ecosystem processes and ecological processes are often used interchangeably, however, ecological processes are thought by some to be processes that only encompass biological interactions (i.e. interactions between biota)(Gaston, 1996). Ecosystem processes on the other hand incorporate biotic and abiotic processes within an ecosystem (Doherty *et al*, 2000).

The effects of ecological and ecosystem processes are poorly understood, mainly due to the fact that these processes are difficult to manipulate and study over a large spatial scale (Doherty *et al*, 2000).

2.2.2 The Role of Diversity in Ecosystem Function

The role of diversity in the functioning of ecosystem has been the topic of a great deal of debate. The fact that diversity does play a role in ecosystem function is not in question; however, the effect of a decline in diversity on ecosystem function has come into question (Doherty *et al*, 2000).

Three theories as to how species richness may affect ecosystem function were postulated by Wardle, Bonner and Nicholson (1997). These theories are:

- The "species redundancy hypothesis", which states that beyond a critical (low) diversity, most species are functionally redundant.
- The "ecosystem rivet hypothesis" that all species are potentially important to ecosystem function and, although some redundancy is built in, the loss of these "rivets" will make the ecosystem increasingly vulnerable to failure.
- The "idiosyncratic hypothesis", which states that diversity does change ecosystem function, but not in a predictable direction.

A fourth hypothesis the "insurance policy hypothesis" also exists which states that redundancy is built in to aid stability by having a multitude of species performing the same role so that the chances of some of these species surviving an extreme event to carry on fulfilling their function is much greater (Doherty *et al*, 2000)

The classification of species into guilds, once again, caused the argument of species redundancy to arise and questions as to what extent diversity can be decreased before an impact on ecosystem function can be detected.

Walker (1992) proposed that some species are more important than others. More important species can be described as ecosystem "drivers", and the less important species as "passengers". Removal of these "passengers" will have little or no effect, whereas removal of "driver" species will have a significant effect on ecosystem function.

A further, much earlier, debate is as to whether species diversity begets ecosystem stability. It must be remembered that ecosystem stability is also a function of time and that an ecosystem may appear unstable but temporal variations in the ecosystem show that state changes over a time period are similar thus indicating a stable system (Begon *et al*, 1996) Arguments for both sides range from Charles Darwin (1859) who stated that an increase in species diversity of grasses also increase productivity, to May (1973) who wrote that empirical evidence did not exist to prove that diversity does indeed promote stability. What also needs to be taken into account in this case is that without disturbance, systems tend towards a more homogenous state (McNaughton, 1977). In order for heterogeneity to be increased, disturbance and patch dynamics come into play within a system. Negative feedbacks increase system stability by resisting changes in ecosystem function (Chapin *et al*, 1996) and thus play an important role in the regeneration of the system after natural or anthropogenic disturbances.

Chapin also stated that a diversity of species competing for the same limiting resources generates negative feedback loops at the ecosystem level, thus agreeing with the argument that diversity begets stability.

All the ecosystem hypotheses appear to have some merit in the debate on ecosystem stability. Over time, species in a system may change due to a number of factors, including anthropogenic factors. The ability of the system to remain stable after these changes occur, depends on the species still present within that system. The rivet hypothesis indicates that the removal of species in a system may reduce the ability of that system to stay stable. In a sense this is correct, however, different species may be more (or less) important than other species in that system. The loss of keystone species will have a much greater effect on the system due to the cascade effect it will have on other species. A loss of species, that are members of a larger group of species that have the same function in a system, will have a much lesser effect on the system stability. The rivet hypothesis however, also states that the loss of this species will increase the vulnerability of the system to failure. If there are, for instance two species of that functional group, and one is lost, the vulnerability of the entire functional group is doubled.

The idiosyncratic system states that species loss changes the system function but not in a predictable direction. This means that the result of species loss on a system is very difficult to predict.

Time has a major effect on ecosystem stability. The loss of a species in a system may, over time, leave a niche that can be filled by another species (or group of species) thus returning the stability of the system.

Fluctuations in system stability are common (Begon *et al*, 1996), however the loss of species may cause the system to be unable to return to the normal fluctuations over time.

2.2.3 Habitat Complexity and Environmental Variation

Habitat complexity, although often used as a synonym for habitat heterogeneity, actually refers to the level or strength of interactions between a species and its environment (Doherty *et al*, 2000)

Abbott (1976) found a positive correlation between arthropod diversity and bird species diversity, as well as a positive correlation between vertical foliage height diversity and bird species diversity.

Positive correlations between soil fertility and vegetation communities with high levels of nutrients in the foliage have also been found (Braithwaite, 1984).

Climatic factors were also found to influence bird species diversity (Braithwaite, 1984). The types of vegetation (vegetation structure) were found to be, not only influenced by abiotic factors, but also an influence on the diversity of small mammals, arthropods and birds (Braithwaite, 1984; Coops & Catling, 1997).

From this literature it can be seen that environmental variation does indeed affect habitat complexity and, in turn, species diversity.

2.2.4 Effects of Disturbance on Diversity

Connell (1978, 1979) formulated the intermediate disturbance hypothesis, which states that an intermediate level of disturbance will lead to the greatest species diversity. Too little or excessive disturbance will cause a decrease in species diversity.

Fire is a disturbance that is naturally occurring as well as a management tool in South Africa (Tainton, 1999). Studies regarding fire, however, show different findings with regard to the effectiveness of fire as a method of increasing diversity. Some studies (Fox & Fox, 1986) show that fire does increase species diversity, whereas others (Low & Rebelo, 1998) indicated possible negative effects of fire on diversity.

What must be taken into account when studying the effects of fire as a disturbance are: the type of fire regime, the area in which fire is being studied and the type of fire that has occurred. For instance a hot fire may be detrimental to larger trees whereas a colder fire will serve to remove moribund material. Climax sweetveld grassland burned regularly will result in denudification, as well as a loss in species diversity (Tainton, 1999). Too frequent fires will reduce species diversity due to loss of obligate seedling regenerators (Fox & Fox, 1986), whereas with the correct frequency the same type of fire will increase species diversity.

Grazing by livestock or wildlife is also a major cause of disturbance in ecosystems, and may have a profound effect on species diversity (Doherty *et* *al*, 2000). Wimbush and Costin (1979) found that grazing had a definite negative effect on species diversity of sub-alpine vegetation. Continuous grazing by cattle can cause the inability of palatable species to reach maturity (Williams & Ashton, 1987).

Gibson and Kirkpatrick (1989) found that the cessation of grazing correlated strongly with a vegetation response of an increase in vegetation productivity.

Fragmentation leads to increased vulnerability of habitats to invasion by non-native species; it also makes species occupying that fragment more susceptible to local extinction due to stochastic events (Doherty *et al*, 2000). In the case of animal species, predation is increased in diminished patch size due to the accessibility of areas within the patch by predators usually excluded from the patch.

Askins *et al* (1987) found that bird species diversity is directly related to fragment size. General species diversity was found to decrease with fragment size by Dunstan and Fox (1996), Hobbs (1993) and Bennett (1987).

2.2.5 Surrogate Indicators

Surrogate indicators are defined as "*a quantity, or combination of quantities, used to obtain information about the target in lieu of measuring the target more directly*" (Resource Assessment Commission [RAC], 1993). The target is the entity of which information is desired.

The fundamental assumption made, when identifying any surrogate indicator of biodiversity, is that a correlation exists between the surrogate and biological diversity (Ferrier & Watson, 1996). The RAC (1993) furthermore states that this assumption can take the form of a simple qualitative model based on common sense or mathematical or statistical model based on large amounts of data.

Indicators have been used as measures of anything from biodiversity to a variety of disturbances. The close relationship between species abundance and habitat complexity (Doherty *et al*, 2000) shows that species abundance may be useful as a surrogate for habitat complexity. Habitat complexity also appears to be related to ecosystem function, thus dysfunctional ecosystems should be indicated by species abundance (or lack of species abundance) of that ecosystem.

The limits of surrogates must also be taken into account during the study; some disturbance agents such as fire, disease or land degradation will be captured by the use of a surrogate indicator. It will, however, be pointless to try and measure the presence or absence of feral animals by using surrogates (Doherty *et al*, 2000).

The effects or degree of land degradation can therefore be measured by surrogates; however, the causes of land degradation could not be measured by surrogates and would have to be investigated by other means.

2.3 Factors Influencing Bird Diversity

Birds, like all other living organisms, need certain resources and conditions to survive and propagate. The needs of birds, as well as the availability of resources and conditions to fulfil these needs, determine the distribution of these birds. The fact that humans alter the environment for a variety of needs causes changes in the factors determining birds ability to utilize those areas, and can (and usually does) cause a change in bird species composition in those areas (Hockey, 2003).

Effects of human intervention can have a negative effect on species diversity and numbers, deforestation, land degradation, invasion of exotics and other habitat destruction, caused by human activities, may cause areas to become unsuitable for species. Destruction of forest habitats will cause a decline or total disappearance of forest specialists in the same way draining wetlands to build residential areas will make the area unsuitable for wetland birds (e.g. aquatic birds and waders) and make the area more suitable for generalist species (e.g. starlings) and human commensals such as sparrows (Hockey, 2003).

Human intervention in the environment does, however, not always have a negative impact on bird species. Human movement westwards in southern Africa has caused an increase in man-made structures that form suitable breeding places for birds such as the South African Cliff Swallow (*Hirundo spilodera*) and human commensals such as the Southern Grey-headed Sparrow (*Passer diffuses*). Furthermore, the Southern Grey-headed Sparrow's (*Passer diffuses*) movements appear to be closely tracked by its nest parasite, the Lesser Honeyguide (Hockey, 2003). The construction of dams and mini-wetlands by humans, for irrigation and stock watering, has also increased the ranges of water-dependent bird species such as the Burchell's Sandgrouse (*Pterocles burchelli*) and Sclater's Lark (*Spizocorys sclateri*) (Hockey, 2003).

Although factors influencing bird diversity are well documented, there is still an ongoing debate as to which of the factors influencing bird diversity are more important in determining the presence or absence of bird species in a specific area. In a USGS paper (DeGraaf *et al*, 1991) on forest and rangeland birds, food, water and shelter were named as most important factors with nest sites, song posts and perch sites as secondary considerations. The paper does go on to mention that proximate factors such as vegetation structure give indications of ultimate factors such as food availability. Lack (1933) suggested that birds are "programmed" to select habitats by identifying features and patterns that are not immediately required for survival. Lack (1933) also proposed that different species are limited in their ranges by one of three factors more than the other two. The factors taken into consideration during the study were: suitable climatic conditions, sufficient food supply and a safe nesting place. Beecher (1942) suggested that birds do not adapt to a specific area, but choose the area because of their ability to recognise potentially satisfactory ultimate factors by means of the visible proximate factors.

2.3.1 Food and Feeding

Studies have been done to examine the possibility that food availability influences the distribution of birds. A study by Johnson & Sherry (2001) indicates that food availability does influence the distribution of birds; this study did, however, not take vegetation structure into account during the site selection process. If food availability is not a limiting factor, or if birds are unable to track variations in food availability between habitats, then food availability will not be a determining factor in the distribution of avian species.

Dewalt *et al* (2003) did show a correlation between frugivorous birds and the availability of food in tropical forest areas. Insectivore distributions may also be affected by food availability, although the effect may not be as profound, due to the wide distributions of insects. In the same way food availability may not be definitive indicator of distribution of granivorous birds in savanna or grasslands, due to the abundance of seed-bearing grasses in these areas (Dewalt *et al*, 2003).

Large and small raptor species are, to a much greater extent, restricted in their distribution by food availability (Casey & Hein, 1994) and tend to be greater specialists than birds of other guilds. Raptors also need perches from which to hunt as well as open areas in which to hunt (Casey & Hein, 1994) although some owl species, as well as eagle species such as the Crowned Eagle (*Stephanoaetus coronatus*) do hunt in forest areas.

2.3.2 WATER AVAILABILITY

Birds vary in their needs for water. Granivorous birds and birds such as Sclater's Lark (*Spizocorys sclateri*) and the sandgrouse species are also restricted in their distribution by their dependency on a daily supply of water (Hockey, 2003). Many of the birds occurring in the drier area of southern Africa are, however, not dependent on a regular supply of water (Maclean, 1993).

2.3.3 NESTING SITES

Bird species, particularly specialist species, require specific nesting sites. Some birds, for example Pinkbilled Lark (*Spizocorys conirostris*), Larklike Bunting (*Emberiza impetuani*) and Kori Bustard (*Ardeotis kori*) are ground nesting (Maclean, 1993). Others, for instance Jackal Buzzards (*Buteo rufofuscus*), Peregrine Falcons (*Falco peregrinus*) and Cliff Swallows (*Hirundo spilodera*), require cliffs, rocky ledges or sometimes man-made structures in areas where cliffs do not occur. Species that only nest in trees also exist, for instance Fork-tailed Drongo (*Dicrurus adsimilis*), Pied Babblers (*Turdoides bicolor*) and Bateleurs (*Terathopius ecaudatus*) (Maclean, 1993). Many species like the Pririt Batis (*Batis pririt*), Longbilled Crombec (*Sylvietta rufescens*) and Yellow-bellied Eremomelas (*Eremomela icteropygialis*) nest only in the habitat shrub layer (Maclean, 1993). The last section of birds that can be grouped according to breeding habits are birds such as the Desert Cisticola (*Cisticola aridulus*), White-winged Widowbird (*Euplectes albonotatus*) and Kalahari Robin (*Cercotrichas paena*) that nest in grass just above the ground (Maclean, 1993). The importance of nesting sites can not be marginalised; Ricklefs (1969) found that nest predation is the major cause of reproductive failure in birds.

2.3.4 COMPETITION

Competition is the process by which species or individuals within species compete for resources. Subsequently, certain species or individuals become deprived of those resources due to the inability to compete with more efficient or aggressive competitors (Begon *et al*, 1996).

Competition can be direct, whereby individuals actually interact in order to gain access to a resource (birds jostling for song perches), or indirect, whereby an individual's use of a resource leads to the inability of other individuals to utilize that resource (effective predatory birds hunting out prey so that there is less prey for less effective predatory birds) (Begon *et al*, 1996).

Interspecific competition can be defined as competition between different species (Begon *et al*, 1996). In the case of birds this can be competition for food, nesting sites, song perches and hunting perches. The result of interspecific competition is the reduction in fecundity, survivorship and growth as a result of the interference by individuals of another species (Begon *et al*, 1996). Interspecific competition is most pronounced in bird species that belong to the same guild or that in some way or another utilizes the same resources, be it for feeding breeding or nesting. This competition leads to the regulation of the numbers of individuals of species occurring in a system. In areas where resources competed over are in limited supply, competition is more pronounced and can ultimately lead to the complete exclusion of one or more of the weaker competing species.

Intraspecific competition is defined in Begon *et al* (1996) as competition between individuals of the same species. Competition between birds of the same species does not lead to the exclusion of the species from an area, but does have a profound effect on the numbers of individuals of the species in a system (Begon *et al*, 1996).

In the case of birds, competition has a much more profound effect on specialist species when compared with generalist species. Generalists are more resilient to environmental pressures due to the fact that they are more adaptable than specialists who, as their name would indicate, are much specialised in their choice of food type, methods of feeding, nesting areas or breeding (Maestas et al, 2003).

2.3.5 PREDATION

Predation is defined as the killing and consumption of one organism (prey) by another organism (predator) (Begon *et al.* 1996). Besides the obvious effects of predation namely: reduction of prey population size, "weeding out" of older and weaker individuals and reducing intraspecific competition within the prey population, predation can have other effects on a prey populations, depending on the conditions under which the predation takes place. In theory, prey populations will not be totally depleted by predators due to reduction in predator numbers when prey populations are decreased in number (Begon *et al*, 1996). However, due to human interference in system processes, prey populations can decrease below the critical level required by that population to regenerate itself, this can lead to local extinctions of those species. Human factors that can increase the intensity or effect of predation are: fragmentation of habitat (Bider, 1968; Keyser, 2002), introduction of predators, domestic or wild, (Maestas *et al*, 2003) and (in birds) destruction of suitable nesting habitat (Collias & Collias, 1984).

2.3.6 VEGETATION STRUCTURE

Dewalt *et.al.* (2003) states that, although the roles of vegetation structure in shaping faunal communities is not clear, vegetation can provide important resources for nesting, foraging and protection for a variety of taxa.

MacArthur & MacArthur (1961) showed a definite positive correlation between vertical height diversity of vegetation and number of bird species in North American forest areas.

Furthermore, studies in forest areas (Willson, 1974) and desert scrub (Tomoff, 1974) showed no positive correlation between foliage height diversity and bird species diversity. Dean (2000) also indicated that an increase in taller, woody vegetation shows an increase in avian species richness, when compared to the surrounding shrubland in the Karoo semi-desert areas of South Africa. Willson (1974) also found no positive correlation between spatial heterogeneity and bird species diversity. These findings appear to indicate that bird species diversity is either more dependent on other factors than spatial heterogeneity or that the findings of these studies were affected by variables that were not taken into account by the researchers.

Flather *et al* (1992) found that vertical habitat structure alone could not account for species diversity, and concluded that in order to predict avian species diversity effectively, spatial heterogeneity needed to be taken into account.

Whitford (1997) indicates that bird species diversity actually increased with an increasing degree of desertification (desertification usually indicates less floral species diversity).

A study of avian demography in afforested grasslands in Illinois, USA showed that the planting of trees in grasslands caused a rapid decline in not only grassland species, but in the total number of species in the afforested area (Naddra & Nyberg, 2001). This appears to oppose the school of thought that avian diversity is enhanced by vertical structural diversity.

2. 4 Effects of Land-use on Bird Diversity

Human intervention in the environment, invariably, has some kind of impact on the environment, even with the most careful of management programs in place, ecological processes are disturbed and habitats altered by human intervention. For this reason studies have been done to investigate the effects of different anthropogenic activities on the natural environment. These studies include: studies in vegetation structure and its effects on birds (Anderson & Ohmart, 1983), studies on the effects of exclusion of livestock on biodiversity (Blydenstein *et al*, 1958; Bock *et al*, 1984), habitat use of birds (Gregory & Baillie, 1998) and the effects of land use on bird species (Flather, 1996).

These studies have produced many conflicting papers on the effects of human intervention in the environment, ranging from no effects at all (Willson, 1974; Tomoff, 1974), to significant negative effects (Naddra & Nyberg, 2001).

Furthermore, literature concerning human impacts on birds, more specifically habitat altering land-uses impacting birds, appears to be confined to alteration of forest habitats or farmlands in Europe and North America (Lack, 1933; Brotons & Herrando, 2001; Winter & Faaborg, 1999; DeWalt, Maliakal & Denslow, 2002; O' Halloran, Walsh, Giller & Kelly, 2002), I found only one article on studies concerning land-use effects on birds in arid areas of Africa (Joubert & Ryan, 1999). Joubert and Ryan (1999) found that bird species richness and abundance was greatly reduced on the overgrazed communal farms, when compared to more conservatively stocked commercial farms. The great difference in habitat structure in forests of Europe and North America, as well as the difference in species types occurring in these areas and those of the African savanna, make it very difficult to correlate findings of these studies with studies done on the African savanna. For this reason the literature study is restricted to factors influencing bird diversity and the possible or known impacts of land use on those factors. Furthermore, most studies attempt to isolate one particular factor influencing bird diversity (or effects on a factor influencing bird diversity) and tend to ignore other factors that usually go hand in hand with that one. A case to illustrate this is the study done on the effects of afforestation on breckland avifauna (Lack, 1933). In this study Lack disregarded predation at the outset of the study due to the fact that humans had been destroyed almost all egg- and bird-eating predators. However, domestic animals such as dogs and cats are well known to eat both birds and eggs (Maestas et al, 2003).

By investigating and highlighting factors affecting avian population dynamics, and land-use effect on them, I hope to explain some of the reasons for the variations in avian demography of different land-use types in the arid African savanna areas.

2.4.1 Effects of Land- use on Food and Feeding

Unsustainable land-use is one of the main causes of land degradation worldwide (Doherty *et al*, 2000). According to Kellner (2002), land degradation is the process whereby a reduction or loss of productivity can be observed. The loss of productivity of vegetation in an area will hold serious implications for species higher up on the food chain. In the study concerned, a reduction in seed production should cause a reduction in the number of granivorous birds occurring in the area. Similarly, a reduction in fruit production by trees and shrubs will, in turn, cause a reduction in the frugivorous bird populations in the area affected by degradation, as was observed by Dewalt *et al* (2003).

Due to their inability to travel vast distances daily, herbivorous small mammals, such as rodents, are affected to a greater extent by degradation than granivorous or frugivorous birds (Bock *et al*, 1984). In an exclosure experiment Bock *et al* (1984) found that rodents consistently favoured ungrazed areas where food availability was less patchily distributed. The presence or absence of significant rodent populations will influence raptor populations in the area. Similarly, insectivorous birds are affected by the number of insects occurring in an area, which is in turn affected by the resources available to them (Rodenhouse *et al*, 1993). Different land-use management practices may influence the number of insects that occur in those areas, application of herbicides can not only reduce the food availability for granivorous and frugivorous birds, but also the food availability for insectivores by reducing the abundance of arthropods. Cultivation also results in the reduction of the number arthropods occurring in those areas (Hendrix *et al*, 1986). Reduction of dead plant and woody material can have a serious impact on insect populations due to the fact that many insects utilise this material (Rodenhouse *et al*, 1993).

2.4.2 EFFECTS OF LAND- USE ON WATER AVAILABILITY

Land use, generally, has a positive impact on water availability. Due to needs for water for human consumption, irrigation and watering of livestock, available water in an area is increased by the construction of dams, water troughs for livestock and sinking of boreholes and pumping subterranean water (Hockey, 2003). Possible negative impacts of pumping from boreholes, especially in drier areas, are the dropping of the water table. This could influence water availability to deep rooted vegetation, which relies on subterranean water, especially in times of drought. Drinking troughs in arid areas do also have secondary negative impacts, especially due to the denudification of the areas around these water holes by larger herbivores (James *et al*, 1999).

2.4.3 EFFECTS OF LAND- USE ON NESTING SITES

Land-use, especially agricultural land-use, does tend to impact on the nesting sites of birds (Gonnet, 2001). Overgrazing reduces grassland areas that provide nesting sites for grass-nesting birds, on the other hand, the denudification of grassland areas does increase the areas available for birds that nest on open ground.

Bush encroachment also often occurs as a result of overgrazing, and may cause the reduction of suitable nesting areas for grassland nesting birds, but increase the space available for shrub-layer nesting birds. Due to the fact that more bird species nest in shrub or tree layers (Maclean, 1993) the overall effect of bush encroachment may be an overall increase in nesting bird species in the area encroachment occurs.

Livestock farming can further influence ground and low level grass nesting birds by trampling and destroying nests, and by trampling, make previously suitable areas unsuitable for ground and low-level grass nesting birds (Gonnet, 2001).

Management practices used during livestock farming may also influence nesting bird populations. Many commercial farmers use fire as a management tool to combat bush encroachment (Tainton, 1999) This may have the opposite effect of overgrazing and bush encroachment, thus increasing breeding by grassland nesting birds and decreasing the prevalence of shrub-layer nesting birds. Depending on the type of fire and conditions under which it occurs, fire can also kill larger trees and eventually reduce the numbers of large trees in an area, thus decreasing the prevalence of tree nesting birds in that area. Alternative management methods (namely: mechanical methods or herbicides) have much the same effect as fire in reducing the number of trees and shrubs, but unskilled use of herbicides can cause damage to non-target species as well.

2.4.4 Effects of Land-use on Competition

The nature of competition, namely the fact that organisms need to compete with other organisms utilizing the same resources in order for the organism (and species as a whole) to survive (Begon *et al*, 1996) on its own, seems to imply that all the previously mentioned factors that decrease the amount of food availability for bird species, will tend to increase interspecific and intraspecific competition for food.

Competition is increased due to land use, especially due to livestock grazing, but management methods may also play a role. Interspecific and intraspecific competition between birds for grass and grass seeds (although cattle do not specifically target grass seeds, the seeds are invariably eaten during grazing) cause a decline in bird population size in areas where cattle occur (Grant, 1986). Competition for song perches and nesting sites can also be increased, as a result of livestock grazing and browsing, because of the effects these animals have on, not only the vegetation occurring in the areas they utilise, but also the structure of the individual trees and shrubs in the area (Gonnet, 2001).

2.4.5 Effects of Land- use on Predation

One of the main effects land-use, and management practices in land use, has on vegetation is fragmentation of habitats (Meffe & Carroll, 1997; Primack, 1998). Fragmentation of habitats can have far-reaching effects on biodiversity (Primack, 1998). One of the most important factors associated with fragmentation is the increased edge effect, a number of identical habitats with a total area of, for example, $10km^2$ will have a greater total edge which is exposed to external influence that a single $10km^2$ habitat. One of the outside influences to which the animals occupying the edges of these habitats will be exposed (to a greater degree than animals within the centre area of the habitat) is predation by animals that occur outside of that habitat fragment (Primack, 1998).

Predation in birds can be divided into two types, namely: adult predation (where adult birds are predated) and nest predation (whereby eggs or nestlings are predated). Both of these types of predation are increased in habitat fragments (Primack, 1998; Winter & Faaborg, 1999; Terborg, 1989), thereby causing a decline in the bird populations and decrease in the suitability of that habitat for those bird populations (Winter & Faaborg, 1999). Human habitation also influences the degree of predation that occurs in areas inhabited by humans. Human commensals such as dogs and cats will prey on birds and eggs if the opportunity arises (Maestas, Knight & Gilgert, 2003). Humans also have a secondary impact on the predation of birds by the destruction of bird predators, thus decreasing the risk of predation (Lack, 1933). Humans may also reduce the number of natural enemies of bird predators, which will in turn increase the risk birds have of being preyed upon.

2.4.6 Effects of Land- use on Vegetation Structure

Land-use affects both spatial heterogeneity as well as vertical height diversity of vegetation (Hansen & Urban, 1992; Thiaw, 1999; Brotons &Herrando). Effects of land use on vegetation structure are numerous, ranging from total and immediate destruction of existing vegetation structure and replacing it with crop fields (Anon, 2002), timber plantations (O'Halloran, Walsh, Giller & Kelly, 2002) or urban development (Maestas, Knight & Gilgert, 2003) to more subtle changes, over a longer period of time, due to the utilization of natural vegetation for livestock farming and land management practices used by livestock farmers (Anon, 2002; Gregory & Baillie, 1998; Lack, 1933).

Overgrazing is the main cause of structural changes in vegetation (Powell, Cameron & Newman, 2000); initially, an increase in increaser species (e.g. less palatable, pioneer grasses) and decrease in decreaser species (e.g. more palatable, climax grasses) occurs. These changes can also take the form of reduction in herbaceous material (grasses, forbes and herbaceous shrubs), increase in woody material (low trees and woody shrubs) or total denudification of vegetation (Thiaw, 1999).

Plant species in drylands are part of a very delicate system and are especially prone to the effects of degradation by unsustainable livestock farming and management practices. (Eswaran, Reich & Beinroth, 2000).

Another major cause of structural change in vegetation is the use of fire as a management tool (Anon, 2000), Fire is employed extensively in South Africa to reduce bush encroachment, increase grasslands and decrease fuel loads in order to prevent wildfires (Tainton, 1999).

In climax grassland systems regular use of fire will cause a reduction in grass cover density (Tainton, 1999) and reduction in their ability to function efficiently. Fire may be used in these areas to reduce bush encroachment or moribund grass after a number of exceptionally wet seasons, but should then be rested for a significant period of time (Tainton, 1999).

Vegetation structure influences feeding, nesting and breeding requirements of birds and changes in the structure of vegetation will therefore influence bird populations (Adamus, 2002). A further use birds have for vegetation is protection from predators and shelter from the elements. Changes in vegetation structure will influence the chances of a bird species survival in an area by reducing its ability to protect itself from the elements or predation.

Another structural aspect of importance to birds, in vegetation, is the availability of snags (dead, standing trees). Snags are important as nesting sites for cavity nesting birds as well as important sources of food for bark probing insectivores that predate insects in the bark of snags (Waterhouse, Mather &

Seip, 2002). Song perches play an important role in the mating behaviour of many bird species. Taller vegetation types such as trees, snags and larger shrubs are thus important to these bird species' existence in an area (Koford & Best, 1996).

2.5 Conclusion and Hypothesis

2.5.1 Conclusion

From the literature reviewed in this study it can be seen that the most important factors contributing to the diversity and distribution of birds are:

- Food availability
- Water availability (with the exceptions of birds that do not require free water)
- Nesting requirements
- Competition
- Predation
- Vegetation structure

An issue that arose in the literature was: which of these factors was the most important factor in determining the diversity and distribution of birds. Some studies indicated food availability as the most important factor (Gonnet, 2001; Schluter & Repasky, 1991; Johnson & Sherry, 2001). Others identified nesting sites as more important (Keyser, 2002). Importance of nest predation (Liebezeit & George, 2002) and plant species composition (Dean, Anderson, Milton & Anderson, 2002) were also highlighted. What is noticeable is that vegetation structure plays an important role in all of the other factors with the possible exception of water availability, although vegetation cover does affect the hydrological cycle (Valentin & d'Herbes, 1999).

Vegetation affects food availability, nesting sites (Chase, 2002) and areas in which birds can forage (Hino, Unno & Nakano, 2002), vegetation structure also dictates whether or not areas exist by means of which birds can escape aerial or terrestrial predators (DeWalt, Maliakal & Denslow, 2002) as well as the availability of song perches (Koford & Best, 1996) or perches from which to hunt, in the case of raptors (Maclean, 1993).

From this it can be seen that vegetation structure is very important in determining species diversity, as indicated by the positive correlation between foliage height diversity and bird species diversity found by MacArthur & MacArthur (1961). Although it has become generally accepted that foliage height diversity has a definite effect on bird species diversity, Roth (1976) found that patchiness and spatial heterogeneity also had a major role to play in the distribution of bird species. Patch size and the proximity of patches to each other were also shown by Kobal, Payne & Ludwig (1999) to have an effect on the distribution of bird species. The importance of these vertical height diversity and spatial heterogeneity, in comparison to each other, regarding the distribution of bird species is unclear as distinguishing the role each has to play is difficult, even more so when factors overlap such as vertical height diversity being a subset of spatial heterogeneity.

Nevertheless, the importance of vegetation structure in either of these planes is inviolable, as illustrated in literature by Roth (1976), MacArthur & MacArthur (1961), Kobal, Payne & Ludwig (1999) and others.

There is also a wealth of literature on the changes in vegetation caused by land use (Flather, Brady & Inkley, 1992; Knick, 2000; Gonnet, 2001; Maestas, *et al*, 2003), and this subject appears to be undisputed in the current literature.

The effects of land-use on the fragile ecosystems of desert margins are firstly more visible, and secondly, considerably more difficult to reverse due to the dryland vegetation type and slow recovery rate of disturbed areas of vegetation, occurring in the desert margins, because of low annual rainfall (Low & Rebelo, 1998).

Although the mechanisms of biological processes are poorly understood (Doherty *et al*, 2000), birds (especially specialist species) can be used as surrogates in measurements of habitat complexity (Doherty *et al*, 2000). Decreases in habitat complexity can in turn be indicative of the integrity of biological processes working within a system (Doherty *et al*, 2000).

The dependence of birds on vegetation structure should therefore make birds good indicators of degradation, as well as the integrity of biological processes, in these desert margins areas.

2.5.2 AIM OF THE STUDY

The aim of this study is to investigate the effects of different land-use types on avifaunal species diversity.

2.5.3 HYPOTHESES

HYPOTHESIS 1: Bird populations are noticeably influenced by the land degradation brought about by land-use of the areas they inhabit in the Molopo area of the North-West Province.

Activity 1	Determine whether land-use types in desert margins areas have a significant influence on avian diversity in the Molopo area of the North-West Province.
Activity 2	Determine which factors are most likely to influence bird diversity in the Molopo area of the North-West Province.

HYPOTHESIS 2: Bird species diversity, as well as bird numbers, will decline with an increase in land degradation, brought about by land-use in the Molopo area of the North-West Province, South Africa.

Activity 3	Determine whether land degradation caused by land-use types in desert margins areas cause a significant decline in avian diversity.

HYPOTHESIS 3: Bird species diversity will act as a good indicator for assessing the degree of land degradation brought about by land-use in the Molopo area of the North-West Province, South Africa.

Activity 4	Determine whether avian species diversity can be used as a surrogate for land degradation of the land-use types studied.

In order to test these hypotheses I carried out a study of bird populations on a number of land use types in the Kalahari Area of the North-West Province of

South Africa. The research framework and methodology used in the study are outlined in Chapter 3.

CHAPTER 3
METHODOLOGY

3.1 INTRODUCTION

The arid Kalahari area of the North-West Province was used as the locality for this study. This area was earmarked for study by the Desert Margins Programme (DMP). The locality was suitable for this study due to the fact that a single vegetation type persists throughout the entire region. This will aid in identifying changes in vegetation structure in order to investigate Hypothesis 1 and 2. Geomorphology is consistent throughout the region (Low & Rebelo, 1998) and, due to the fact that geomorphology influences vegetation type and structure (Low & Rebelo, 1998), it is advantageous to have an area with consistent geomorphology throughout.

Commercial and communal cattle farming is practiced in the area; the influences of differences in management practices between these two land-use types can be investigated in order to investigate Hypothesis 1 and 2.

There is no great variation in topography which is important because topography often affects vegetation characteristics and therefore also bird species (Waterhouse *et al*, 2002).

Changes in vegetation are easily visible in the persisting vegetation type occurring in the area; visible changes in vegetation are important in identifying degradation in order to investigate Hypotheses 1 and 2.

Bird species are abundant in the area, with about 160 species occurring within the study area (Maclean, 1993). Variations in abundance of birds and the local distribution of bird species will be investigated, and statistically tested, in order to test Hypothesis 3.

3.2 RESEARCH FRAMEWORK

Figure 3-1. A diagrammatic representation of the research framework.

3.3 STUDY AREA

The North-West Province occupies a total area of 116 320 km^2 (9.5% of the total area of South Africa) and is the sixth largest province in South Africa. It is geographically situated between 25 and 28 degrees south of the equator and 22 and 28 degrees longitude east of the Greenwich meridian. The North-West Province borders the provinces of the Northern Cape in the west, the Free State in the south, Gauteng in the east and Limpopo (formerly Northern Province) in the north-east. It shares an international border with the Republic of Botswana in the north (Mangold *et al*, 2002).

This study was conducted in the Kalahari area of the North West Province. The area is currently under investigation by the South African section of the Desert Margins Project, which is funded by the United Nations Environmental Program (UNEP) and the Global Environmental Facility (GEF). The study area forms part of an area known as the desert margins. Desert margins contain fragile dryland ecosystems, and occur between true desert areas and more temperate drylands. The area is utilised mainly as communal and commercial rangelands for cattle farming, although some game farming is practiced in the area and a conservation area also occurs within the study area. The study area consists of five sites at which the study was conducted. The sites were chosen according to land-use types and degree of degradation occurring at the sites.

3.3.1 POSITION

The study area (as shown in Figure 3-2) falls between the 25° South and 26°South lines of latitude and between the 22° East and 24° East lines of longitude. It falls within the boundaries of the Kalahari Desert and is situated on the South African border with Botswana. The sites were chosen at Driefontein Communal Farm (S26°27'; E23°29'), Heuningvlei Town (S26°27'; E23°29'), Heuningvlei Wetland Area (S26°27'; E23°29'), Molopo Nature Reserve (S25°48'; E23°49') and Lafras Commercial Farm (S25°48'; E23°49').

Figure 3-2: Position of the study area. The red square indicates the position of the study area on a global scale and the red circle indicates the position of the study area within South Africa.

3.3.2 Rainfall

The rainfall pattern is highly variable across the province as well as across the seasons and is largely indicative of the prevailing climatic conditions of the entire province (Mangold *et al*, 2002).

On average, eastern and south-eastern region receives over 600mm per annum, the central region around 550mm p.a., while the western region (where the study took place) receives less than 300mm per annum (Mangold *et al*, 2002).

Western parts of the province usually receive rain in the late summer, peaking in February, while the eastern parts usually peak in early summer around December. The central region rainfall predominantly occurs in mid-summer, peaking in January. Significant variability in the annual rainfall is observed in the province. This variability increases from high variability in the west to medium variability in the east (Mangold *et al*, 2002).

Evaporation exceeds precipitation in all areas of the province except in the south-eastern areas; this is especially true in the hotter, more arid north-western areas, where this study took place (Mangold *et al*, 2002).

Hailstorms do occur in summer, the southeast receives an average of 3 - 5 hailstorms per year, while the rest of the province receives about 1-3 hailstorms per year (Mangold *et al*, 2002).

A major source of veld fires are lightning strikes and in the far east of the province, the typical ground flash density is 8 - 9 flashes/km^2/yr, reducing to around 5 - 6 flashes/km^2/yr in the central parts and 2-3 flashes/km^2/yr in the west (Mangold *et al*, 2002).

3.3.3 VEGETATION TYPE

The vegetation type is consistent throughout the entire study area. The vegetation type of the study area is Kalahari Plains Thorn Bushveld, and is a subset of the Savanna Biome (Low & Rebelo, 1998).

This vegetation type is found mainly on deep loose sand, underlain by calcrete, in the north-western areas of the North-West Province, which is characterized by undulating to flat sandy plains (Low & Rebelo, 1998).

The vegetation of this area is characterized by a well developed tree stratum, dominated by *Acacia erioloba* and *Boscia albitrunca* trees. Other trees that are found as scattered individuals in the tree layer are *Acacia luederitzii* and *Terminalia sericea* (Low & Rebelo, 1998). The shrub layer is moderately to well developed and is comprised of *Acacia mellifera, Acacia hebeclada, Lycium hirsutum, Grewia flava* and *Acacia haematoxylon* (Low & Rebelo, 1998).

The herbaceous layer of the vegetation in the area is dominated by grasses with little to no forbs. Grass cover is dependent on the amount of rainfall that falls during the growing season and the dominant grass species are *Eragrostis lehmannia, Schmidtia kalihariensis* and *Stipagrostis uniplumis* (Low & Rebelo, 1998).

Low and Rebelo (1998) noted that the low rainfall of the area, in conjunction with the sandy soil and grazing by livestock influence the structure of this vegetation type, as well as the fact that this vegetation type is poorly conserved.

3.3.4 VARIABLES OF SITES

The positions of each of the individual sites are indicated in Figure 3-3, the sites all fall within a radius of 60 km or less, as the crow flies.

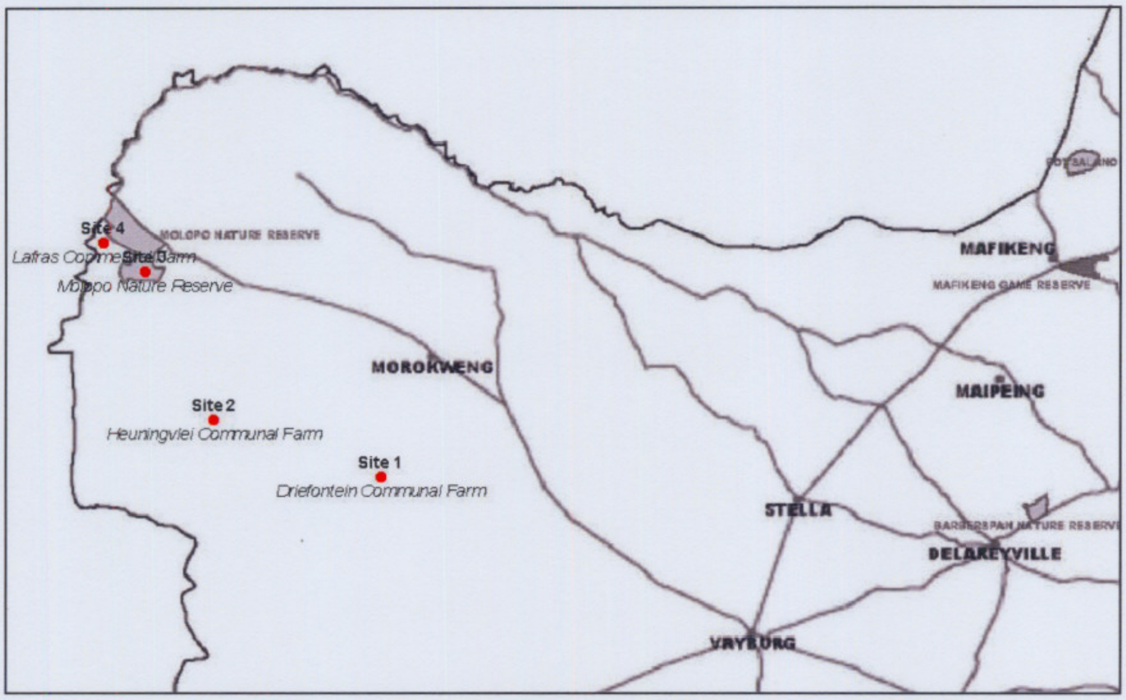

Figure 3-3: Position of the sites within the study area. The red circles indicate the position of the sites with in the study area.

Topography does vary slightly (<20m) with the undulating sandy plains but the variation in topography was considered negligible for the purposes of this study. Topography at all the sites was similarly flat, except for some low cliffs and rocky outcrops at the Heuningvlei site.

Land-use varies between the four sites. A more detailed description of each site will be provided in the following sections of this chapter.

Heuningvlei Communal Farm

Heuningvlei communal farm is situated close to Heuningvlei Pan and is the most degraded site of all. Overstocking of the area has led to large-scale denudification and trees in the area have been chopped down and used as fuel by inhabitants of the local village. The shrub layer has been reduced to low flat *Acacia mellifera* and *A. hebeclada* bushes. Grass cover is very sparse (Figure 3-4) and, in the dry winter months, becomes cropped so short that it gives the appearance of no cover at all.

Figure 3-4: Vegetation structure Heuningvlei communal farm (Note the sparse grass cover as well as the short flat growth forms of *Acacia mellifera*).

Lafras Commercial Farm

Lafras commercial farm is considered a well managed commercial farm. Management tools have been used to keep bush encroachment to a minimum. Livestock numbers have been kept to below the farm's carrying capacity so as to prevent overgrazing. Fire and chemical methods has been used extensively as a management tool to reduce the shrub layer thus increasing grazing capacity on the farm (See Figure 3-5). This method has been used very effectively over large tracts of the farm where the shrub layer is virtually, or totally, non-existent. Large denuded patches that form around watering points have been minimized by increasing the numbers of watering points on the farm and veld has been given the ability to rest at regular intervals by the implementation of a livestock rotation system (P. Bruwer, pers. comm.).

Figure 3-5: Vegetation structure on Lafras commercial farm (Note the lack of shrub layer and large open tracts of grassland due to effective management by means of fire).

Driefontein Communal Farm

Driefontein communal farm is moderately to heavily overgrazed, due to overstocking of cattle and smaller livestock. Figure 3-6 shows that there is visible bush encroachment by *Acacia mellifera* and *A. hebeclada* and areas of bare ground exist due to denudification of grass due to overgrazing. One of the main problems facing the communal farmers in this area is the availability of water for livestock. There are few boreholes to pump groundwater to the surface, thus stock movements are restricted by water availability. Drilling for water in this area is difficult, due to the sandy soil, and expensive due to the great depths at which the water table is found (150m to 300m+). Communal farmers in the area cannot afford to drill more boreholes and thus need to make do with the existing boreholes in the area. Bush encroachment is not managed in the area and fire is seldom used as a management tool.

Figure 3-6: Vegetation structure on Driefontein communal farm (Note the denuded ground as well as the large scale encroachment by *Acacia mellifera* and *A. hebeclada*).

Molopo Nature Reserve

The Molopo Nature Reserve site was used as a benchmark site for this study due to the fact that it closely resembles natural vegetation of the area. The reserve is not used at all for cattle grazing, although parts of it were in the distant past. Management is kept to a minimum and fire is used only to reduce fuel loads when necessary. Game numbers are kept just below the reserve carrying capacity and numbers are kept constant by hunting and game capture for resale (S. Gore pers. comm.). Watering points are also numerous and regularly spaced on Molopo Nature Reserve.

Figure 3-7: Degradation of the area around a watering point within the study area after an extended dry period (Note the trampling of the ground and hollow formed due to wind erosion).

It must, however, be noted that during extended dry seasons even numerous, well spaced watering points show signs of degradation, as shown in Figure 3-7, due to high concentrations of cattle or game in those areas.

Degradation shows definite visible variability across the spectrum of sites and land-use types. Molopo Nature Reserve shows the least amount of degradation as well as the least amount of anthropogenic interference with regard to management practices. The vegetation strata are well defined and well developed at all three levels, as seen in Figure 3-8. Bush encroachment is at a minimum and denudification, although present in certain areas (mainly around watering points), appears to be at a minimum. The vegetation is utilised by wildlife only and the game species that occur on Molopo Nature Reserve fall into the categories of both grazers and browsers.

Figure 3-8: Vegetation structure on Molopo Nature Reserve (Note the well developed vegetation strata).

3.4 Materials and Methods

3.4.1 Site selection

Sites were selected according to land-use type and degree of degradation at the sites, parties involved with the study (private land owners and land users, conservation officials and other interested parties such as the Department of Agriculture, Conservation and Environment (DACE) as well as the North-West Parks and Tourism Board (NWPTB)) were consulted with regard to the design of the project and indigenous knowledge available through these sources was used to assist in the experimental design of the project.

Rainfall, topography and vegetation type were similar at all sites in order to reduce the number of variables at the sites. Three 1000m transects were set out at each site, and the start and end position of each transect was noted using a Garmin 12 global positioning system. Transects at each site were selected so as to represent the predominant vegetation structure and degree of degradation of the site. Care was taken during the positioning of the transects to eliminate edge effects of habitat fragments, as well as to prevent the effects of watering points (where many bird species tend to congregate) causing anomalies in the data.

3.4.2 Temporal scale of study

The study took place from April 2003 until February 2004; sampling was done in April, July, October and December 2003. The sampling times were calculated in such a way that the results of the sampling gave an indication of the seasonal effect on species diversity at the sites. Each of the transects were repeated once per season. The trip in February 2004 did not include actual sampling, but it did serve to validate how thorough the surveys until then had been by investigating whether or not any new bird species could be identified at any of the study sites.

3.4.3 Vegetation Analysis

Vegetation analysis was done according the broad-scale classification of vegetation as set out by Edwards (1983). The reason this classification method was used was for ease of use as well as the fact that studies (Hockey, 2003) have shown that bird species diversity is more dependent on vegetation structure than the actual species composition of the vegetation (Refer to Section 2.3.6). Estimates for the vegetation analysis were done at the transect sites, as well as in other areas on the different land use types. The vegetation structure estimates were first done over larger areas of the farms or nature reserve, in order to determine that the vegetation structure of the transects were indicative of the predominant vegetation structure of the farm or reserve on which the transects were done.

The estimates at the sites of the transects were used in figures given in this thesis. The classification system uses a primary set of four growth form types (trees, shrubs, grasses and herbs), a primary set of for cover classes (closed, open sparse and scattered) and a set of four height classes (high, tall, short and low for each growth form type. A matrix is established to determine structural classes by means of the following process:

Growth form × cover = structural group

Structural group × height = formation class

In this way the vegetation structure at each of the transects was determined and these vegetation structures were in turn indicative of the vegetation structure over the entire area of that specific land use.

3.4.4 Surveys

Surveys which were carried out at each site were done around dawn each morning when bird activity is at its most (Bibby *et al*, 1993). As described by Bibby *et al* (1993), transects were carried out on foot at a steady walking speed of *circa* 3km/h. All species, as well as the numbers of individuals of each species, were noted on data sheets (Figure 3-9), GPS readings were taken at sightings as well as the quarter degree grid block in which the bird was sighted noted, the quarter degree grid blocks were not taken for the purposes of this study but rather for the benefit of the Avian Demographic Unit (ADU) who are collaborators with the Desert Margins Programme. Red data species were noted according to the South African Red Data book (Barnes, 2000). Only birds within a distance of 50m from the centre line of the transect, and birds flying over the transect from left to right, were counted. This survey method was derived from methods described by Bibby *et al* (1993), other methods also described in Bibby *et al* (1993), such as timed point counts, were considered. However I found that, due to the low bird densities at the sites in winter, this method produced insufficient data for this study.

10 X 25 Binoculars were used only to identify birds and not to note birds occurring outside the 50m limit from the transect. Bird field guides were used for the identification of unknown birds as birds were identified on visual confirmation, unless the bird was not identifiable visually only. In such cases calls were used in order to gain confirmation of the bird identity, it must be noted that bird behaviour is also included in this visual identification. In this thesis old bird names are used throughout. A list of old, new and biological names are given in Appendix A.

Three transect surveys were done at each site, during each of the four seasons, thus giving a total of 48 transect surveys done for the study.

BIRD DATA SHEET

Land use.............................
Habitat.............................
Date.............................
Time.............................
Survey.............................

Roberts No.	Bird Name	No. of Individuals	GPS Reading	Grid block	Disk and/or photo number	RDS (y/n)

GPS Reading Start:
End:

Figure 3-9: Data sheets used to note bird species and numbers while transect sampling was being performed.

3.5 DATA ANALYSIS

All transects were deliberately chosen so that they were carried out in an area where the vegetation represents the dominant vegetation structure of that land use type. Vegetation analyses were done of the vegetation structure of the area, and vegetation structure was classified according to vegetation structural classifications as set out by Edwards (1983). Data from the three transects at each site were combined in order to reduce the bulk of the data. I felt that this was acceptable because transects were deliberately selected and not taken at random and due to the similarity of the vegetation structure the three, one kilometer long, transects could be interpreted as one, three kilometer long, transect.

Transects were done for each season and data was arranged in order to show seasonal variations in bird species diversity and bird numbers between sites.

Furthermore, species were divided into guilds and data was arranged to show the distribution of guilds across the different sites. Data was investigated to show presence and absence of red data species at each site.

PRIMER 5™ was used to calculate diversity indices of all sites, as well as to conduct a principle component analysis (PCA) of the data obtained.

Microsoft Excel™ was used to create graphs and tables to illustrate the differences in bird diversity and abundance for different land-uses.

The results of the study and the data analysis of the collected data appear in Chapter 4.

CHAPTER 4
RESULTS

4.1 DATA COLLECTED

4.1.1 HEUNINGVLEI COMMUNAL FARM

Heuningvlei farm was identified as the most degraded area (Refer to section 3.3.4) during the reconnaissance section of the study. Heuningvlei farm is on tribal land, and livestock of many of the people from the local village are grazed on the land. Cattle, goats and, to a lesser extent, sheep are the main livestock kept by the people utilizing the land of Heuningvlei.

4.1.1.1 VEGETATION ANALYSIS

Heuningvlei vegetation is sparse due to extensive overgrazing, tree cover is <<0.1%, with an average tree height of 2-5m. Both shrub and grass cover of the area is <0.1% with an average height of <0.5m for both grasses and shrubs. The vegetation structure of Heuningvlei farm can therefore be classified, according to Edwards (1983), as predominantly mixed desert shrubland and desert grassland. Transects on Heuningvlei farm were selected so that they occurred in areas with this vegetation type. Transects were also positioned within these areas so as to minimize edge effects from dissimilar adjacent areas.

4.1.1.2 SPECIES PRESENT

Data collected at Heuningvlei during the data collecting trips are tabulated in Table 4-1. A total of 42 species and 362 individual birds were found to be present at Heuningvlei through the course of the year. The number of birds, as well as the number of species, observed at the transects varied with seasonality with the greatest number of birds and species occurring in summer and autumn with a definite decline over the drier and colder seasons.

Table 4-1: Data on bird species* and numbers collected at Heuningvlei communal farm

Robert's No.	Common Name	Heuningvlei Communal Farm				
		Autumn	Winter	Spring	Summer	Total
71	Cattle Egret		3		3	6
255	Crowned Plover				11	11
299	Burchell's Courser		2	2		4
301	Double banded Courser		2		2	4
345	Burchell's Sandgrouse		2			2
356	Namaqua Dove	9				9
417	Little Swift	2			2	4
425	Whitebacked Mousebird	14				14
437	Striped Kingfisher	2				2
493	Monotonous Lark	1			2	3
495	Eastern Clapper Lark				2	2
505	Dusky Lark	2			2	4
506	Spikeheeled Lark		3			3
507	Redcapped Lark	2	3	3	6	14
508	Pinkbilled Lark				1	1
516	Greybacked Finchlark	4	2		4	10
518	Eurasian Swallow				5	5
526	Greater Striped Swallow				7	7
533	Brownthroated Martin	4				4
548	Pied Crow	5	4	7	5	21
580	Groundscraper Thrush	1		2	4	7
583	Short-toed Rockthrush	2			2	4
587	Capped Wheatear		2	3	1	6
595	Anteating Chat	2	1	5	2	10
601	Cape Robin-chat	2				2
615	Kalahari Robin	3	8	5	5	21
664	Zitting Cisticola	1			1	2
665	Desert Cisticola	3	1		4	8
698	Fiscal Flycatcher	2	1		2	5
718	Plainbacked Pipit	2				2
719	Buffy Pipit	2	1	4	3	10
732	Fiscal Shrike	3			2	5
733	Redbacked Shrike	3			1	4
764	Cape Glossy Starling	1			9	10
799	Whitebrowed Sparrowweaver	3				3
803	Cape Sparrow	18	13	8	17	56
804	Southern Greyheaded Sparrow	15	12	3	14	44
805	Yellowthroated Sparrow				8	8
861	Shafttailed Whydah				2	2
870	Blackthroated Canary	6	1	3	8	18
878	Yellow Canary	2			2	4
887	Larklike Bunting		1			1
	Total Number of Birds	116	59	45	125	362
	Mean Number of Birds/Transect	38.7	19.7	15.0	41.7	30.2

* Species are numbered according to Maclean (1993) and arranged according to their evolutionary affiliations

4.1.1.3 COMMON SPECIES

Common species (Table 4-2) in the Heuningvlei area are the Southern Greyheaded Sparrow (*Passer diffusus*), Cape Sparrow (*Passer melanurus*), Pied Crow (*Corvus albus*), Kalahari Robin (*Cercotrichas paena*) and Blackthroated Canary (*Serinus atrogularis*). These species occurred in the area during all four seasons and were most abundant with regard to numbers of individuals.

Table 4-2: Common species occurring at Heuningvlei communal farm

Common Name	Biological Name	Mean No. of individuals/transect	Total No. of Individuals
Cape Sparrow	*Passer melanurus*	4.67	56
Southern Greyheaded Sparrow	*Passer diffusus*	3.67	44
Pied Crow	*Corvus albus*	1.75	21
Kalahari Robin	*Cercotrichas paena*	1.75	21
Blackthroated Canary	*Serinus atrogularis*	1.50	18

4.1.1.4 Uncommon Species

Species found to be uncommon (Table 4-3) in relation to other species at Heuningvlei Commercial Farm are the Larklike Bunting (*Emberiza impetuani*), Pinkbilled Lark (*Spizocorys conirostris*), Striped Kingfisher (*Halcyon chelicuti*), Cape Robin (*Cossypha caffra*), Plainbacked Pipit (*Anthus leucophrys*) and the Shafttailed Wydah (*Vidua regia*). Although these species are not commonly known as rare species they were found to be the rarest species at Heuningvlei Communal Farm in relation to the abundance of other species.

Table 4-3: Uncommon species occurring at Heuningvlei communal farm

Common Name	Biological Name	Mean No. of indviduals/transect	Total No. of Individuals
Larklike Bunting	*Emberiza impetuani*	0.08	1
Pinkbilled Lark	*Spizocorys conirostris*	0.08	1
Striped Kingfisher	*Halcyon chelicuti*	0.17	2
Cape Robin	*Cossypha caffra*	0.17	2
Plainbacked Pipit	*Anthus leucophrys*	0.17	2
Shafttailed Wydah	*Vidua regia*	0.17	2

4.1.1.5 Red Data Species

No red-data species were observed during data collection at Heuningvlei Communal Farm.

4.1.1.6 Extralimital Breeding Species

Extralimital breeding species were included in the data collected and the statistical analyses, but due to the relatively small number of these species the difference they made in the statistical analysis was negligible. Extralimital breeding species data was omitted from the breeding guild analyses.

4.1.2 LAFRAS COMMERCIAL FARM

Lafras commercial farm was chosen as a good example of a well managed commercial farm (Refer to section 3.3.4). Overgrazing on the farm is kept to a minimum by a good management plan, which includes: a lower than carrying capacity stocking rate, a rotation system of grazed and resting camps and management of bush encroachment. Only cattle are farmed at Lafras thus grasslands are the vegetation type preferred by the owner.

4.1.2.1VEGETATION ANALYSIS

Due to extensive control of bush encroachment by chemical methods and fire; the shrub layer on Lafras is virtually non-existent for the greater area of the farm. Although trees on the farm are large (5-10m) the tree cover is sparse <0.1%, percentage cover of shrubs on the farm is also very low (<<0.1%) with an average height class of 1-2m. Grass is by far the dominant growth form with 100-10% cover and a height class of 0.5-1m. The extensive bush control on the farm has led to the vegetation structure to be altered to what can be classified as short, closed grassland according to Edwards (1983). Once again transects were positioned to reflect the dominant vegetation structure on the farm and minimize edge effects.

4.1.2.2 SPECIES PRESENT

Data collected at Lafras commercial farm during the data collecting trips are tabulated in Table 4-4. A total of 52 species and 451 individual birds were found to be present at Lafras through the course of the year. As was the case in Heuningvlei, the number of birds, as well as the number of species, observed at the transects varied with seasonality with the greatest number of birds and species occurring in summer and autumn with a definite decline over the drier and colder seasons.

Table 4-4: Data on bird species* and numbers collected at Lafras commercial farm

Robert's No.	Bird Name	Lafras commercial farm				
		Autumn	Winter	Spring	Summer	Total
71	Cattle Egret	4		5		9
146	Bateleur	1				1
149	Steppe Buzzard	1				1
162	Pale Chanting Goshawk	1			1	2
194	Redbilled Francolin	4	2			6
200	Common Quail	1	3		1	5
203	Helmeted Guineafowl				9	9
230	Kori Bustard				1	1
237	Red-crested Korhaan	1				1
239b	Northern Black Korhaan	1	2	1		4
255	Crowned Plover		1		3	4
299	Burchell's Courser				4	4
411	Eurasian Swift				6	6
415	Whiterumped Swift				4	4
445	Swallowtailed Bee-eater				1	1
447	Lilacbreasted Roller	4	1	1	4	10
449	Purple Roller	1				1
451	African Hoopoe				1	1
459	Southern Yellowbilled Hornbill	2	2		2	6
493	Monotonous Lark	1		1	2	4
494	Rufousnaped Lark	2				2
495	Eastern Clapper Lark	5	2	2	4	13
497	Fawncoloured Lark	4				4
498	Sabota Lark	2			1	3
506	Spikeheeled Lark	1	5	2	4	12
507	Redcapped Lark		1		3	4
508	Pinkbilled Lark	3	2		5	10
515	Chestnutbacked Finchlark	1			5	6
518	Eurasian Swallow				4	4
526	Greater Striped Swallow				8	8
541	Forktailed Drongo	8	3	2	4	17
563	Pied Babbler		3			3
580	Groundscraper Thrush	3				3
589	Familiar Chat	1	1			2
595	Anteating Chat		4	5	3	12
615	Kalahari Robin	1	6	1	1	9
664	Zitting Cisticola	1		1	1	3
665	Desert Cisticola	3	3	2	5	13
695	Marico Flycatcher	2			1	3
697	Chat Flycatcher	2			1	3
716	Grassveld Pipit	1	1	2	4	8
719	Buffy Pipit				2	2
764	Cape Glossy Starling	14	9	12	19	54
799	Whitebrowed Sparrowweaver	2		3	9	14
803	Cape Sparrow	12	6	12	11	41
804	Southern Greyheaded Sparrow	20	1	6	16	43
806	Scalyfeathered Finch		5		5	10
845	Violeteared Waxbill	10	7	4	7	28
861	Shafttailed Whydah	1	3		2	6
870	Blackthroated Canary	6	3	2	4	15
884	Goldenbreasted Bunting	2			5	7
887	Larklike Bunting		2		7	9
	Total Number of Birds	95	68	46	180	451
	Mean Number of Birds/Transect	31.7	22.7	15.3	60.0	37.6

* Species are numbered according to Maclean (1993) and arranged according to their evolutionary affiliations

4.1.2.3 Common Species

Species common to Lafras commercial farm (Table 4-5) were the Cape Glossy Starling (*Lamprotornis nitens*), Cape Sparrow (*Passer melanurus*), Southern Greyheaded Sparrow (*Passer diffusus*), Violet-eared Waxbill (*Uraeginthus granatinus*) and Forktailed Drongo (*Dicrurus adsimilis*). Human commensals and generalists such as Cape Glossy Starlings (*Lamprotornis* *nitens*), Cape Sparrows (*Passer melanurus*) and Greyheaded Sparrows (*Passer diffusus*) were especially numerous.

Table 4-5: Common species occurring at Lafras commercial farm

Common Name	Biological Name	Mean No. of individuals/transect	Total No. of Individuals
Cape Glossy Starling	*Lamprotornis nitens*	4.50	54
Southern Greyheaded Sparrow	*Passer diffusus*	3.58	43
Cape Sparrow	*Passer melanurus*	3.41	41
Violeteared Waxbill	*Uraeginthus granatinus*	2.33	28
Forktailed Drongo	*Dicrurus adsimilis*	1.42	17

4.1.2.4 Uncommon Species

A number of species occurred only once in the year at Lafras. These species were mostly either the Red Data species (Bateleur (*Terathopius ecaudatus*), Kori Bustard (*Ardeotis kori*)), occurring in the area or raptor species (Steppe Buzzard (*Buteo buteo*)). Other uncommon species were the Swallowtailed Bee-eater (*Merops hirundineus*), Purple Roller (*Coracias naevia*) and Red-crested Korhaan (*Eudopotis ruficrista*).

Table 4-6: Uncommon species occurring at Lafras commercial farm

Common Name	Biological Name	Mean No. of indviduals/transect	Total No. of Individuals
Bateleur	*Terathopius ecaudatus*	0.08	1
Steppe Buzzard	*Buteo buteo*	0.08	1
Kori Bustard	*Ardeotis kori*	0.08	1
Red-crested Korhaan	*Eudopotis ruficrista*	0.08	1
Swallowtailed Bee-eater	*Merops hirundineus*	0.08	1
Purple Roller	*Coracias naevia*	0.08	1

4.1.2.5 Red Data Species

Two birds classified as Red Data Species were found on Lafras commercial farm. These are the Bateleur (*Terathopius ecaudatus*), which is classified as vulnerable (Barnes, 2000) and the Kori Bustard (*Ardeotis kori*), which is classified as vulnerable (Barnes, 2000).

4.1.2.6 Extralimital Breeding Species

Extralimital breeding species were included in the data collected and the statistical analyses, but due to the relatively small number of these species the difference they made in the statistical analysis was negligible. Extralimital breeding species data was omitted from the breeding guild analyses.

4.1.3 DRIEFONTEIN COMMUNAL FARM

Driefontein communal farm was identified as a degraded area for the purpose of this study. The Driefontein site was, however, less degraded than Heuningvlei, but still more degraded than Lafras commercial farm. The site was overgrazed, even though some forms of management are implemented. The implementation of the management of Driefontein was limited by a lack of funding, and bush encroachment was the main visible manifestation of land degradation at Driefontein communal farm.

4.1.3.1 VEGETATION ANALYSIS

As mentioned before, management at Driefontein was hampered by a lack of funding (large scale bush encroachment could not be combated effectively), limited water supply and distribution (hampers the rotation of stock to let areas recuperate) and ever increasing stocking pressure. The lack of effective management has resulted in large scale bush encroachment and denudification of large areas.

A number of the trees on Driefontein communal farm are large (5-10m), but the majority of trees fall within the 2-5m height class and the tree cover is relatively sparse 10-1%, percentage cover of shrubs on Driefontein is high for the area (100-10%) due to bush encroachment, with an average height class of 1-5m. Grass cover is limited for the area with 100-10% cover and a height class of <0.5m. The lack of bush control on Driefontein has led to the vegetation being dominated by shrubs and low trees, and can be classified as "low thicket" according to Edwards (1983). Transects were positioned to reflect the dominant vegetation structure on the farm and minimize edge effects.

4.1.3.2 SPECIES PRESENT

Table 4-7: Data on bird species* and numbers collected at Driefontein communal farm

Robert's No.	Bird Name	Driefontein communal farm				
		Autumn	Winter	Spring	Summer	Total
71	Cattle Egret	8		2	5	15
127	Blackshouldered Kite	1				1
162	Pale Chanting Goshawk	2	1	1	2	6
181	Rock Kestrel	1				1
203	Helmeted Guineafowl	23				23
230	Kori Bustard	1				1
237	Red-crested Korhaan	1			1	2
345	Burchell's Sandgrouse	17			13	30
349	Rock Pigeon	18	7	7	8	40
354	Cape Turtle Dove	15	9	4	7	35
355	Laughing Dove	12	4	1	6	23
356	Namaqua Dove	2			1	3
375	African Cuckoo				1	1
425	Whitebacked Mousebird	5	4		2	11
426	Redfaced Mousebird	5	10			15
447	Lilacbreasted Roller	2	1			3
449	Purple Roller	1				1
452	Redbilled Woodhoopoe			4		4
454	Scimitarbilled Woodhoopoe	5			4	9
457	Grey Hornbill	3				3
459	Southern Yellowbilled Hornbill	4	4	3	3	14
465	Acacia Pied Barbet	1				1
473	Crested Barbet	1	1			2
476	Lesser Honeyguide	1				1
481	Bennett's Woodpecker	1			1	2
483	Goldentailed Woodpecker		1			1
493	Monotonous Lark	1				1
494	Rufousnaped Lark	1	1		1	3
495	Eastern Clapper Lark	1	1		2	4
497	Fawncoloured Lark	6	2	2	4	14
498	Sabota Lark	1	2		2	5
506	Spikeheeled Lark	1				1
507	Redcapped Lark	2	2		1	5
516	Greybacked Finchlark	1				1
520	Whitethroated Swallow	6			6	12
523	Pearlbreasted Swallow	2			2	4
529	Rock Martin	1			1	2
541	Forktailed Drongo	9	4	3	3	19
547	Black Crow			1	1	2
548	Pied Crow	2	2	1	2	7
560	Arrowmarked Babbler	5				5
563	Pied Babbler	4	2		3	9
567	Redeyed Bulbul	5	10	5	3	23
580	Groundscraper Thrush	1	1			2
595	Anteating Chat	1	1		2	4
615	Kalahari Robin	6	7	6	11	30
621	Chestnut-vented Titbabbler	1	2		1	4
651	Longbilled Crombec	2				2
657b	Greybacked Camaroptera	2				2
665	Desert Cisticola	5	3		5	13
671	Tinkling Cisticola	4			3	7
685	Blackchested Prinia	1	2		1	4
689	Spotted Flycatcher	2				2
698	Fiscal Flycatcher	1	1		1	3
703	Pririt Batis	1				1
732	Fiscal Shrike	2	2	2	1	7
739	Crimsonbreasted Shrike	1	1	1	1	4
743	Threestreaked Tchagra			2		2
762	Burchells Starling	2			2	4
764	Cape Glossy Starling	13	9	14	19	55
779	Marico Sunbird				2	2
788	Dusky Sunbird	2				2
799	Whitebrowed Sparrowweaver	3	9	10	9	31
802	Great Sparrow	2				2
803	Cape Sparrow	3	5	3	4	15
804	Southern Greyheaded Sparrow	2	2	6	5	15
805	Yellowthroated Sparrow				1	1
814	Masked Weaver	9	6		11	26
829	White-winged Widowbird	3				3
845	Violeteared Waxbill	2	3	2	2	9
847	Blackcheeked Waxbill	5		5	5	15
856	Redheaded Finch	1			1	2
870	Blackthroated Canary	7	8	13	9	37
884	Goldenbreasted Bunting	11	7	4	12	34
	Total Number of Birds	273	137	102	193	705
	Mean Number of Birds/Transect	91.0	45.7	34.0	64.3	58.8

* Species are numbered according to Maclean (1993) and arranged according to their evolutionary affiliations

Data collected at Driefontein during the data collecting trips are tabulated in Table 4-7. A total of 74 species and 705 individual birds were found to be present at Driefontein through the course of the year. The number of birds, as well as the number of species, observed at the transects also varied with seasonality with the greatest number of birds and species occurring in summer and autumn with a definite decline over the drier and colder seasons.

4.1.3.3 Common Species

Table 4-8: Common species occurring at Driefontein communal farm

Common Name	Biological Name	Mean No. of individuals/transect	Total No. of Individuals
Cape Glossy Starling	*Lamprotornis nitens*	4.58	55
Rock Pigeon	*Columba guinea*	3.33	40
Blackthroated Canary	*Serinus atrogularis*	3.08	37
Cape Turtle Dove	*Streptopelia capicola*	2.91	35
Goldenbreasted Bunting	*Serinus atrogularis*	2.83	34

Common species (Table 4-8) in the Driefontein area were are the Cape Glossy Starling (*Lamprotornis nitens*), Rock Pigeon (*Columba guinea*), Cape Turtle Dove (*Streptopelia capicola*), Goldenbreasted Bunting (*Emberiza flaviventris*) and Blackthroated Canary (*Serinus atrogularis*). These species occurred in the area during all four seasons and were most abundant with regard to numbers of individuals.

4.1.3.4 Uncommon Species

Table 4-9: Uncommon species occurring at Driefontein communal farm

Common Name	Biological Name	Mean No. of indviduals/transect	Total No. of Individuals
Acacia Pied Barbet	*Tricholaema leucomelas*	0.08	1
Lesser Honeyguide	*Indicator minor*	0.08	1
Goldentailed Woodpecker	*Campethera abingoni*	0.08	1
Monotonous Lark	*Mirafra passerina*	0.08	1
Spikeheeled Lark	*Chersomanes albofasciata*	0.08	1
Greybacked Finchlark	*Eremopterix leucotis*	0.08	1

A number of uncommon species (Table 4-9) occurred only once in the year at Lafras; these species were mostly either the Red Data species (Kori Bustard (*Ardeotis kori*)) occurring in the area or specialist species (Lesser Honeyguide (*Indicator minor*)). Other uncommon species were two of the lark species

(Monotonous Lark (*Mirafra passerina*) and Spikeheeled Lark (*Chersomanes albofasciata*)).

4.1.3.5 Red Data Species

The only Red Data Species found on Driefontein communal Farm was the Kori Bustard (*Ardeotis kori*).

4.1.3.6 Extralimital Breeding Species

Extralimital breeding species were included in the data collected and the statistical analyses, but due to the relatively small number of these species the difference they made in the statistical analysis was negligible. Extralimital breeding species data was omitted from the breeding guild analyses.

4.1.4 Molopo Nature Reserve

Molopo Nature Reserve was identified as a benchmark site (Refer to section 3.3.4) because of the fact that it is as close to natural vegetation as can be found in the area. Molopo Nature Reserve has only wildlife which is kept at below carrying capacity. The reserve is not used for livestock grazing at all, although some parts of the reserve were former farms that were bought up by the Parks Board more than 30 years ago.

The vegetation structure of Molopo Nature Reserve is typical of the vegetation type of the area described by Low and Rebelo (1998).

4.1.4.1 Vegetation Analysis

The vegetation structure on Molopo Nature Reserve consists of three well developed strata (grass, shrubs and trees) and bush encroachment is at a minimum. The reserve policy to keep the stocking rate just below the reserve carrying capacity as well as the incorporation of both grazers and browsers in the herbivore population helps reduce the stress on the grass layer and also helps keep the shrub layer on the reserve from encroaching onto denuded areas.

Although grass is the dominant layer on the reserve, the well developed shrub layer and tree layer cannot be excluded from the vegetation analysis. Trees on Molopo Nature Reserve are in the 5-10m height class and in the 10-1% cover class; the shrub layer is well developed with 10-1% cover and a height of 1-5m. The grass averages 0.5 - 1m high in the 100-10% cover class. According to Edwards (1983) the vegetation can be classified as Mixed Short Closed Grassland and Short Bushland.

4.1.4.2 SPECIES PRESENT

Table 4-10: Data on bird species* and numbers collected at Molopo Nature Reserve

Robert's No.	Bird Name	Molopo Nature Reserve				
		Autumn	Winter	Spring	Summer	Total
1	Ostrich		2		2	4
118	Secretarybird	2			2	4
123	Whitebacked Vulture	48	35	42	17	142
124	Lappetfaced Vulture	1	4	9	5	19
136	Booted Eagle	2				2
140	Martial Eagle		1		1	2
146	Bateleur	1	1	2	2	6
149	Steppe Buzzard				1	1
161	Gabar Goshawk	1				1
162	Pale Chanting Goshawk	2	3	3	2	10
169	Gymnogene			1		1
171	Peregrine Falcon				1	1
200	Common Quail	2	3			5
230	Kori Bustard	1	1			2
255	Crowned Plover	4	5			9
297	Spotted Dikkop	2				2
345	Burchell's Sandgrouse	30	12			42
354	Cape Turtle Dove	9	14	11	14	48
356	Namaqua Dove	4	5	1	5	15
378	Black Cuckoo	1			1	2
382	Jacobin Cuckoo	1				1
386	Diederik Cuckoo	1				1
397	Whitefaced Owl			1		1
398	Pearlspotted Owl	1	1	1	1	4
401	Spotted Eagle Owl		1		1	2
406	Rufouscheeked Nightjar				1	1
411	Eurasian Swift				12	12
415	Whiterumped Swift				4	4
438	Eurasian Bee-eater				5	5
444	Little Bee-eater				2	2
445	Swallowtailed Bee-eater	1			3	4
451	African Hoopoe				1	1
452	Redbilled Woodhoopoe		6			6
474	Greater Honeyguide	2				2
483	Goldentailed Woodpecker		1		1	2
486	Cardinal Woodpecker			1		1
487	Bearded Woodpecker		1			1
497	Fawncoloured Lark	6	6	2	11	25
498	Sabota Lark	9	8	6	13	36
506	Spikeheeled Lark	1	1		2	4
507	Redcapped Lark	2	5		7	14
508	Pinkbilled Lark	1			2	3
526	Greater Striped Swallow				7	7
541	Forktailed Drongo	6	6	3	5	20
543	Eurasian Golden Oriole				1	1
552	Ashy Tit		1			1
560	Arrowmarked Babbler	5				5

Table 4-10: (Continued.) Data on bird species and numbers collected at Molopo Nature Reserve

Robert's No.	Bird Name	Molopo Nature Reserve				
		Autumn	Winter	Spring	Summer	Total
563	Pied Babbler	10	15	10	16	51
589	Familiar Chat	1			1	2
595	Anteating Chat	1	6	2	5	14
613	Whitebrowed Scrub-robin	2	1			3
615	Kalahari Robin		6	4		10
664	Zitting Cisticola	2				2
665	Desert Cisticola	2	6	2	6	16
671	Tinkling Cisticola	4	4	2		10
693	Grey Tit-flycatcher	2				2
695	Marico Flycatcher	2	2	4	2	10
697	Chat Flycatcher	2	1		1	4
698	Fiscal Flycatcher	3	2	1	2	8
713	Cape Wagtail	1				1
739	Crimsonbreasted Shrike	4	5	2	6	17
743	Threestreaked Tchagra		1			1
762	Burchells Starling	3				3
764	Cape Glossy Starling	24	28	18	24	94
779	Marico Sunbird				2	2
799	Whitebrowed Sparrowweaver	6	5	3	6	20
803	Cape Sparrow	14	20	16	22	72
804	Southern Greyheaded Sparrow	29	33	27	26	115
806	Scalyfeathered Finch		18	12		30
814	Masked Weaver	8	14		11	33
821	Redbilled Quelea	8		6	5	19
834	Melba Finch				2	2
845	Violeteared Waxbill	12	21	18	21	72
847	Blackcheeked Waxbill	7		7	5	19
861	Shafttailed Whydah	6	7	3	7	23
870	Blackthroated Canary	13	18		11	42
878	Yellow Canary	8	26	6	16	56
884	Goldenbreasted Bunting	6	24	9	9	48
887	Larklike Bunting		21	21		42
	Total Number of Birds	249	339	187	295	1327
	Mean number of Birds/Transect	83	113	62.3	98.3	442.3

* Species are numbered according to Maclean (1993) and arranged according to their evolutionary affiliations

Data collected at Heuningvlei during the data collecting trips are tabulated in Table 4-10. A total of 79 species and 1327 individual birds were found to be present at Molopo Nature Reserve through the course of the year.

4.1.4.3 Common Species

The five most common species found on Molopo Nature Reserve (Table 4-11) are Whitebacked Vulture (*Gyps africanus*), Southern Greyheaded Sparrow

(*Passer diffusus*), Cape Glossy Starling (*Lamprotornis nitens*), Cape Sparrow (*Passer melanurus*) and Violeteared Waxbill (*Uraeginthus granatinus*).

Table 4-11: Common species occurring at Molopo Nature Reserve

Common Name	Biological Name	Mean No. of indviduals/transect	Total No. of Individuals
Southern Greyheaded Sparrow	*Passer diffusus*	9.58	115
Cape Glossy Starling	*Lamprotornis nitens*	7.83	94
Cape Sparrow	*Passer melanurus*	6.00	72
Violeteared Waxbill	*Uraeginthus granatinus*	6.00	72

4.1.4.4 Uncommon Species

The uncommon species on Molopo Nature Reserve are listed in Table 4-12. The uncommon bird species include a number of raptors, specialist species and migrants.

Table 4-12: Uncommon species occurring at Molopo Nature Reserve

Common Name	Biological Name	Mean No. of indviduals/transect	Total No. of Individuals
Steppe Buzzard	*Buteo buteo*	0.08	1
Gabar Goshawk	*Micronisus gabar*	0.08	1
Gymnogene	*Polyboroides typus*	0.08	1
Peregrine Falcon	*Falco peregrinus*	0.08	1
Jacobin Cuckoo	*Oxylophus jacobinus*	0.08	1
Diederik Cuckoo	*Chrysococcyx caprius*	0.08	1
Whitefaced Owl	*Otus leucotis*	0.08	1
Rufouscheeked Nightjar	*Caprimulgus rufigena*	0.08	1
African Hoopoe	*Upupa africana*	0.08	1
Cardinal Woodpecker	*Dendropicos fuscescens*	0.08	1
Bearded Woodpecker	*Thripias namaquus*	0.08	1
Eurasian Golden Oriole	*Oriolus oriolus*	0.08	1
Ashy Tit	*Parus cinerascens*	0.08	1
Cape Wagtail	*Motacilla capensis*	0.08	1
Three-streaked Tchagra	*Tchagra australis*	0.08	1

4.1.4.5 Red Data Species

Red data species occurring on Molopo Nature Reserve were the Bateleur (*Terathopius ecaudatus*), Secretary Bird (*Sagittarius serpentarius*), Whitebacked Vulture (*Gyps africanus*), Lappet-faced Vulture (*Torgos tracheliotus*), Kori Bustard (*Ardeotis kori*) and Peregrine Falcon (*Falco peregrinus*).

4.1.1.6 EXTRALIMITAL BREEDING SPECIES

Extralimital breeding species were included in the data collected and the statistical analyses, but due to the relatively small number of these species the difference they made in the statistical analysis was negligible. Extralimital breeding species data was omitted from the breeding guild analyses.

4.1.5 COMBINED DATA

4.1.5.1 VEGETATION ANALYSIS

The vegetation analysis of the sites showed a significant difference in the vegetation at the four sites. Table 4-13 and Figures . 4-1 through 4-4 show how a combination of stocking- and management practices have altered the vegetation structure of the area from the original structure, which is assumed to be similar to that of Molopo Nature Reserve.

Table 4-13: Vegetation classification of sites according to Edwards (1983)

Land Use	Transect	Primary Growth Form	Trees: %cover	Shrubs: %cover	Grass: %cover	Trees: Height Class	Shrubs: Height Class	Grass: Height Class	Vegetation Classification
Heuningvlei communal farm	1	Mixed grass and Shrub	<<0.1%	< 0.1%	< 0.1%	2-5m	< 0.5m	< 0.5m	Mixed Desert Shrubland and Desert Grassland
	2	Mixed grass and Shrub	<<0.1%	< 0.1%	< 0.1%	2-5m	< 0.5m	< 0.5m	Mixed Desert Shrubland and Desert Grassland
	3	Mixed grass and Shrub	<<0.1%	< 0.1%	< 0.1%	2-5m	< 0.5m	< 0.5m	Mixed Desert Shrubland and Desert Grassland
Lafras commercial farm	1	Grass	<0.1%	<<0.1%	100-10%	5-10m	1-2m	0.5 - 1m	Short Closed Grassland
	2	Grass	<0.1%	<<0.1%	100-10%	5-10m	1-2m	0.5 - 1m	Short Closed Grassland
	3	Grass	<0.1%	<<0.1%	100-10%	5-10m	1-2m	0.5 - 1m	Short Closed Grassland
Driefontein communal farm	1	Mixed Trees and Shrub	10-1%	100-10%	10-1%	2-5m	1-5m	<0.5m	Low thicket
	2	Mixed Trees and Shrub	10-1%	100-10%	10-1%	2-5m	1-5m	<0.5m	Low thicket
	3	Mixed Trees and Shrub	10-1%	100-10%	10-1%	2-5m	1-5m	<0.5m	Low thicket
Molopo Nature Reserve	1	Mixed Grass and Bushland	10-1%	10-1%	100-10%	5-10m	1-5m	0.5 - 1m	Mixed Short Closed Grassland and Short Bushland
	2	Mixed Grass and Bushland	10-1%	10-1%	100-10%	5-10m	1-5m	0.5 - 1m	Mixed Short Closed Grassland and Short Bushland
	3	Mixed Grass and Bushland	10-1%	10-1%	100-10%	5-10m	1-5m	0.5 - 1m	Mixed Short Closed Grassland and Short Bushland

The graphical representations (Figures 4-1 through 4-4) of the data in Table 4-13 were included in this thesis in order to give a better indication of the actual visible difference in vegetation structure.

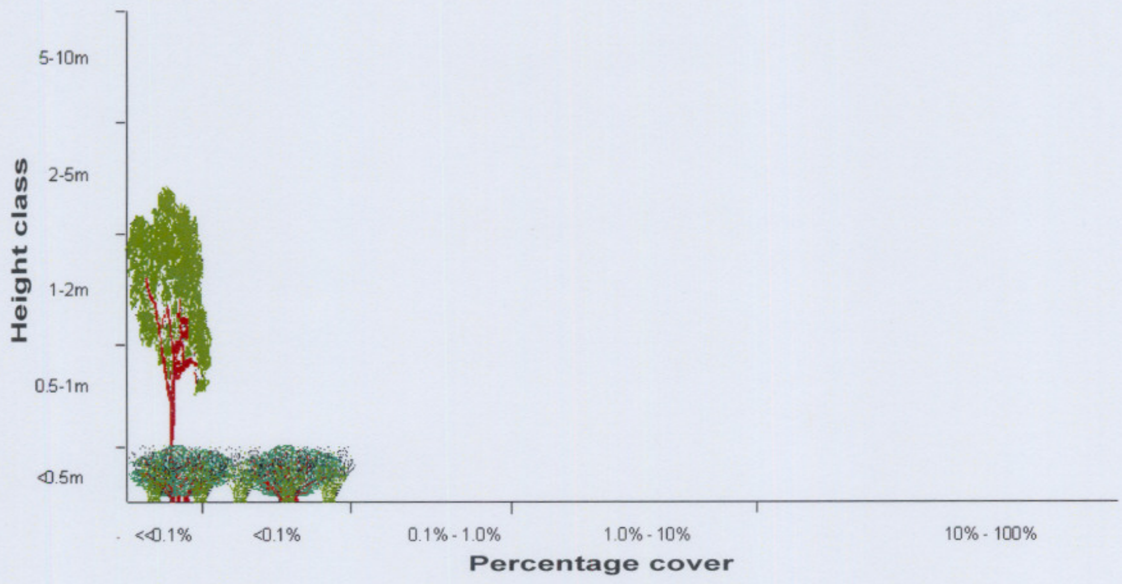

Figure 4-1: Graphical representation of vegetation structure at Heuningvlei communal farm

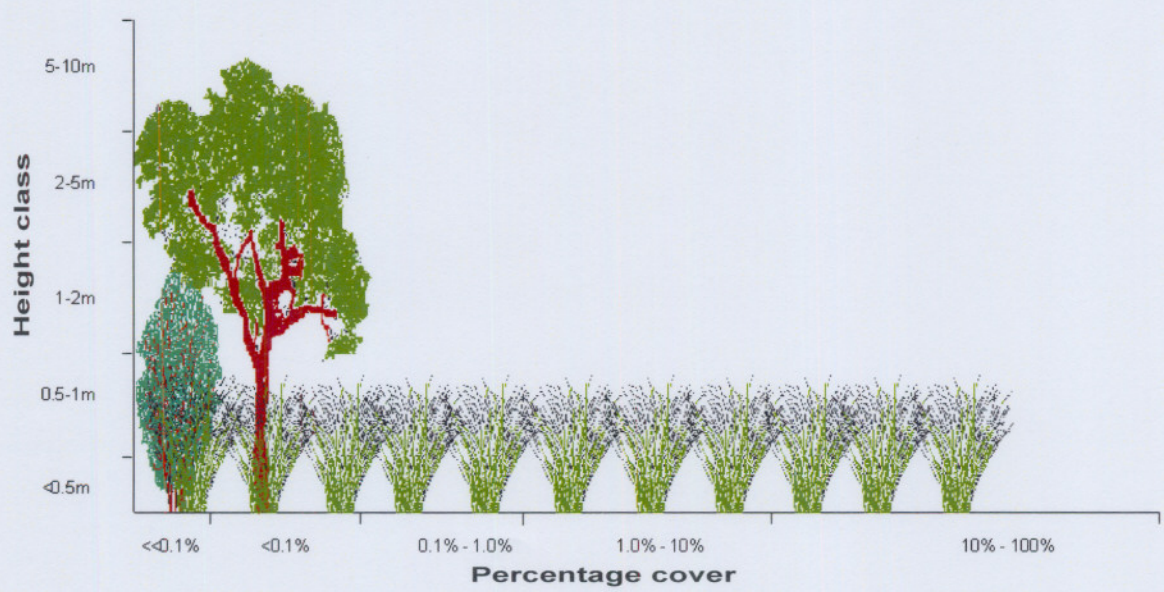

Figure 4-2: Graphical representation of vegetation structure at Lafras commercial farm

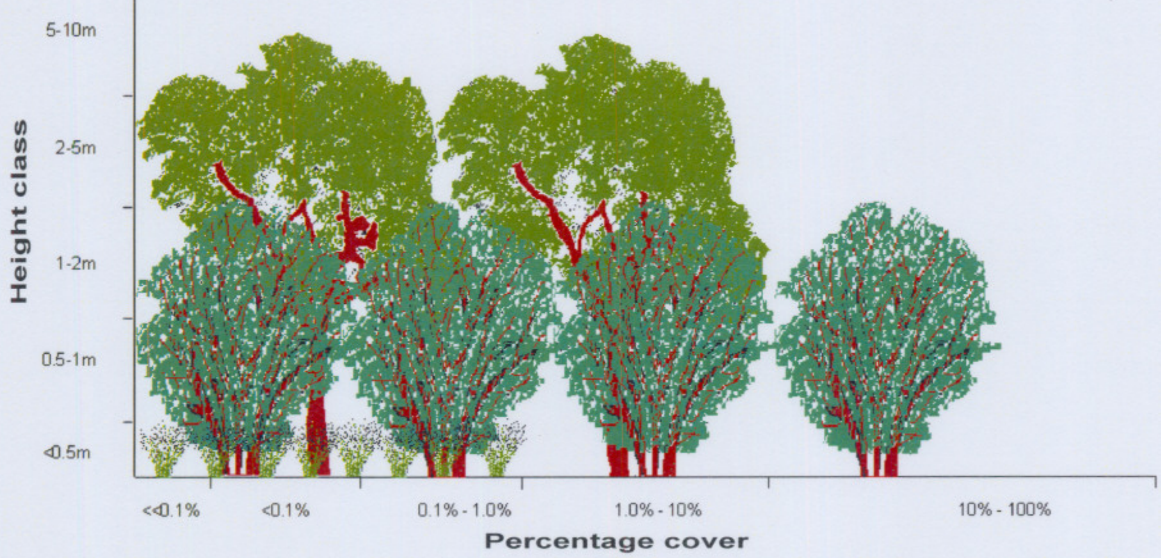

Figure 4-3: Graphical representation of vegetation structure at Driefontein communal farm

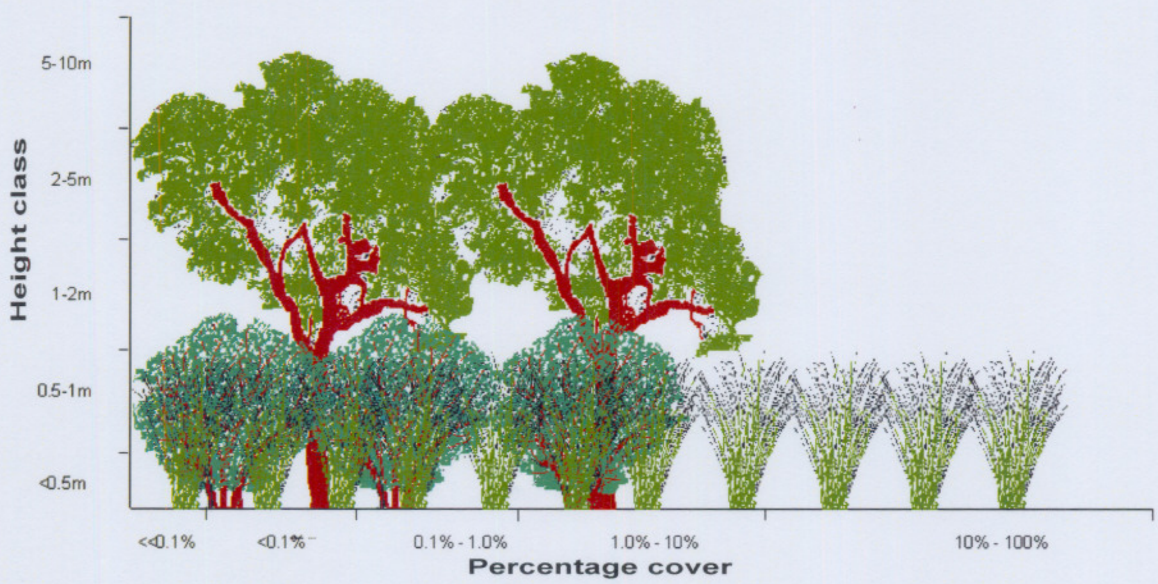

Figure 4-4: Graphical representation of vegetation structure at Molopo Nature Reserve

4.1.5.2 Bird Numbers

The total bird count at each of the sites is graphically represented in Figure 4-5. Bird numbers varied greatly between sites investigated for this study. Heuningvlei communal farm had the least total combined number of birds for the year of study and Molopo Nature Reserve had the highest total combined number of birds for the study. Molopo Nature Reserve had a total of 1309 birds observed for the year, Driefontein communal farm had a total count of 705 birds for the entire year, Lafras commercial farm had a total count of 451 birds and Heuningvlei communal farm had a total of 362 birds counted for the year.

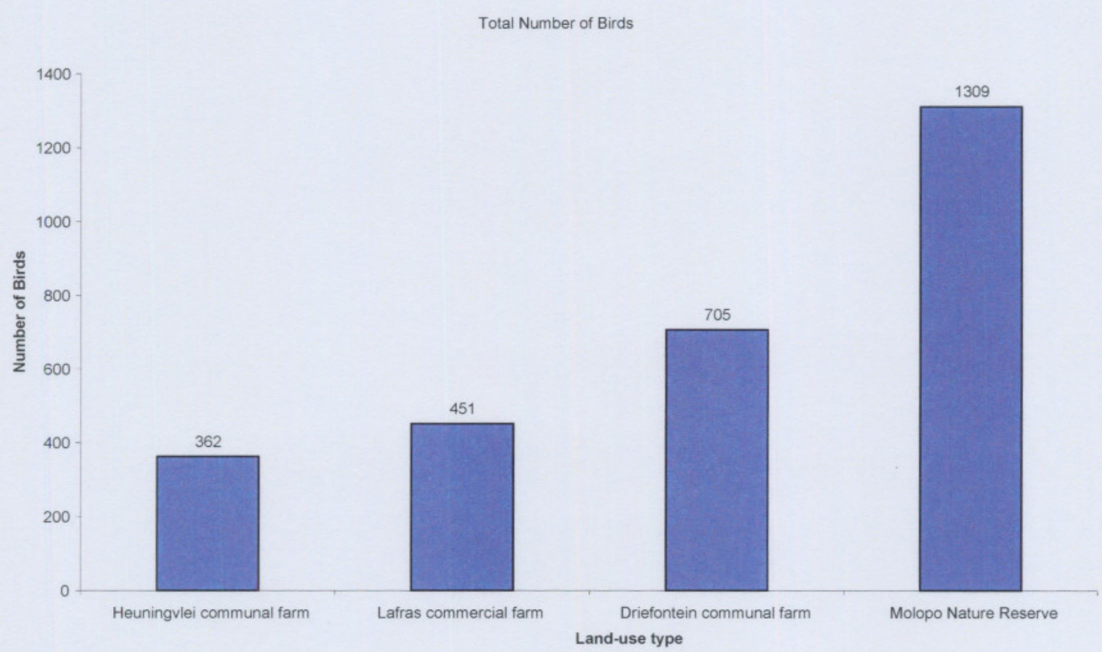

Figure 4-5: Total bird count per site for the year 2003

Figure 4-6 shows the number of birds recorded per site for each of the seasons the trends tend to stay the same at all sites with a decline in bird numbers during the colder, drier months and an increase in bird numbers in summer. One observation that was noted during the study was the increase in bird numbers on Molopo Nature Reserve in winter when all of the other sites showed a decline in bird numbers. Another fact that is highlighted by the use of this graph is the consistent higher bird count at Molopo Nature Reserve in comparison with the other three sites. Another observation made was the percentage decrease in bird numbers from the highest to lowest numbers at the sites the decrease at Heuningvlei communal farm was 61.2%, the decrease at Lafras commercial farm was 50.4%, the decrease at Driefontein communal farm was 62.6% and the decrease at Molopo Nature Reserve was only 19.6%.

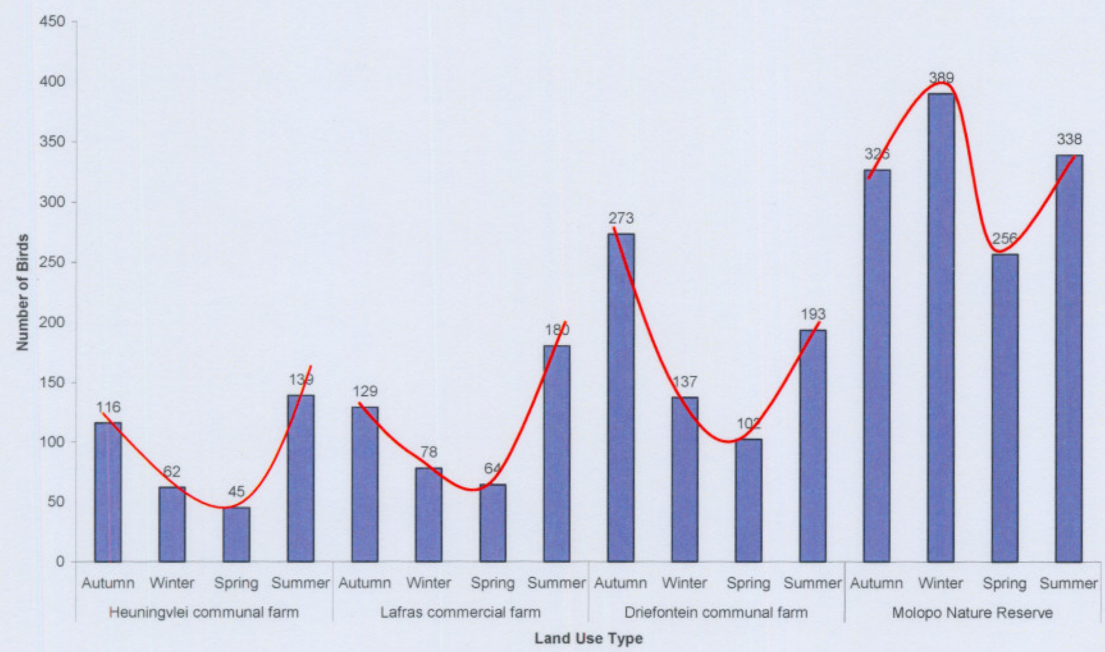

Figure 4-6: Spatio-temporal distribution of birds recorded for 2003

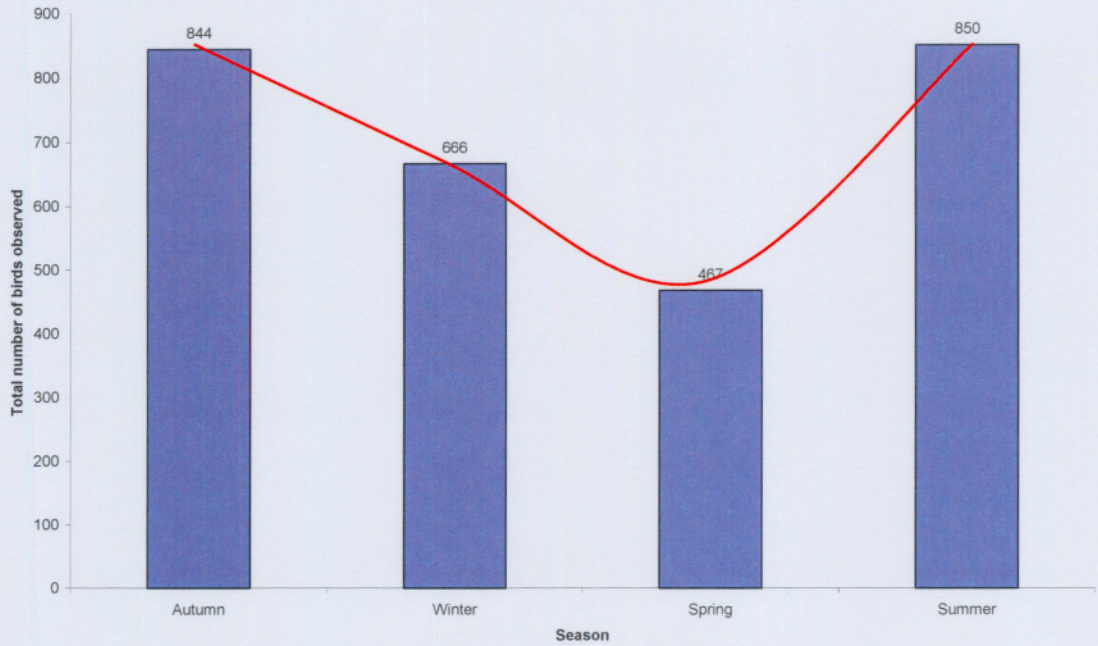

Figure 4-7: Effects of seasonality on total bird numbers per survey for all four sites.

Temporal change (seasonality) also had an influence on bird numbers in the study area. Total bird numbers showed a marked decline in the colder drier winter months and then an increase again in the summer survey. Figure 4-7 indicates the effects of seasonality on the total number of birds recorded for each survey.

4.1.5.3 BIRD SPECIES RICHNESS

Bird species richness also showed marked changes both spatially and temporally in the study area. Bird species richness was highest on Molopo Nature Reserve (Figure 4-8) and lowest at Heuningvlei communal farm. Driefontein communal farm also had higher species richness than Lafras commercial farm.

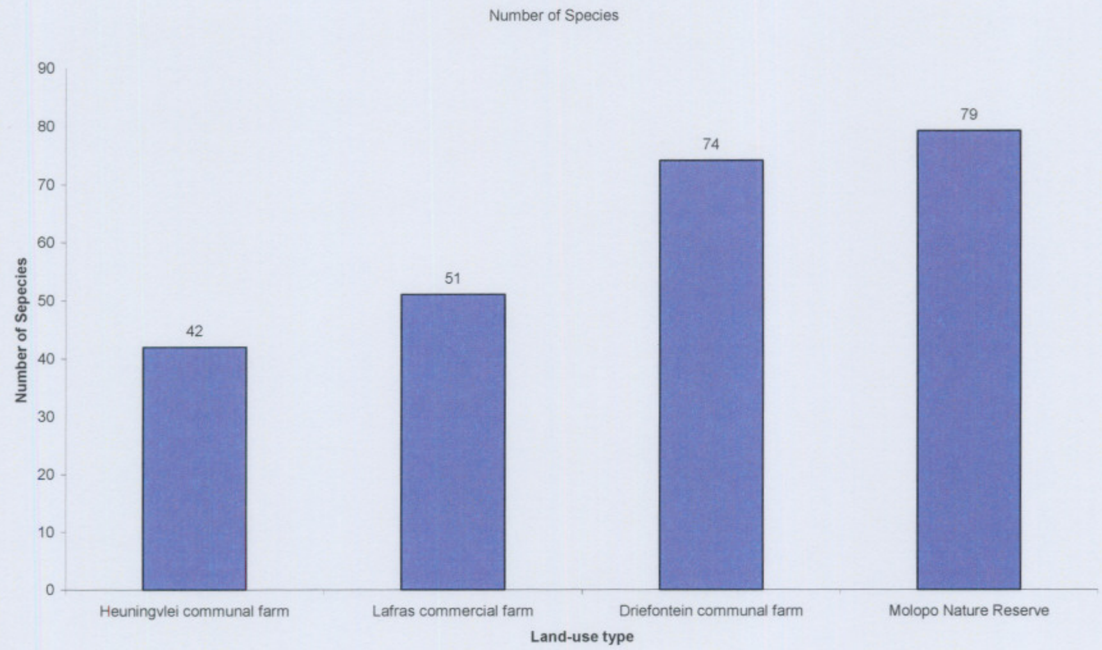

Figure 4-8: Variations in bird species richness with regard to land use

Bird species richness also showed a marked variation over a spatio-temporal scale. Not only did bird species numbers vary with land use, but they also showed marked variation with seasonality. Figure 4-5 shows the spatio-temporal variations in bird species richness found in the study.

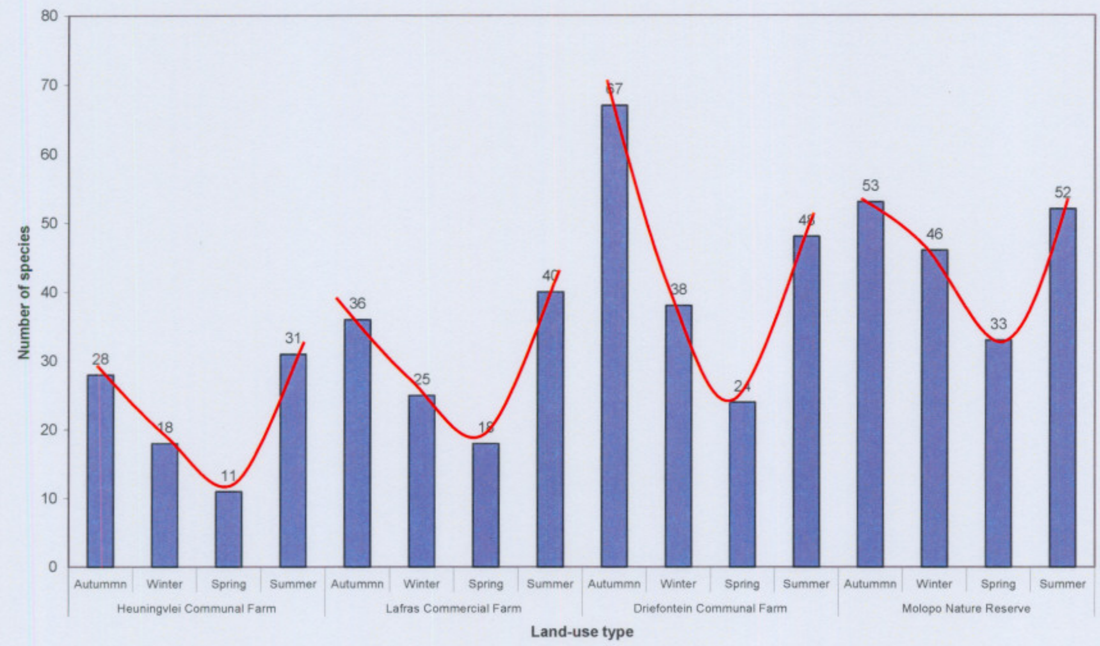

Figure 4-9: Spatio-temporal variations in bird species richness

Figure 4-6 shows trends of bird species richness at the various sites over different seasons. The trends of species richness appear to be consistent for

Figure 4-10: Seasonal trends of bird species richness at different sites

all the sites, with a decline in species richness during the colder, drier seasons and an increase in species richness during the warmer, wetter months. The only variation on the trend is the fact that the rate of decline (determined by the slope of the lines in Figure 4-6) in species richness varies for different sites and between different seasons.

4.1.5.4 Bird Species Occurrence

Species varied in their occurrence at different sites (see Figure 4-7). These ranged from very common species such as Cape Sparrow (*Passer melanurus*) and Southern Greyheaded Sparrow (*Passer diffusus*) that occurred at all the sites during all the seasons to very uncommon species such as the African Cuckoo (*Cuculus gularis*) and Eurasian Golden Oriole (*Oriolus oriolus*) that occurred only once (i.e. at only one site during only one season)

Bird species occurrence is also important with regard to the identification of indicator species. In this, however, the increase or decrease in numbers and presence or absence of species is important. Birds were also arranged according to whether their numbers increased or decreased with respect to an increase in degradation. The increaser and decreaser species as well as the presence and absence of species is shown in Tables 4-14 and 4-15 respectively.

Table 4-14: Species that increase in number with a decrease in land degradation

Common Name	Biological name
Pale Chanting Goshawk	*Melierax canorus*
Forktailed Drongo	*Dicrurus adsimilis*
Pied Babbler	*Turdoides bicolor*
Desert Cisticola	*Serinus atrogularis*
Blackthroated Canary	*Cisticola aridulus*
Crimsonbreasted Shrike	*Laniarius atrococcineus*

Table 4-15: Species that occur only in very degraded or undegraded areas

Common Name	Biological name	Very degraded	Undegraded
Doublebanded Courser	*Rhinoptilus africanus*	✓	
Burchell's Courser	*Cursorius rufus*	✓	
Pinkbilled Lark	*Spizocorys conirostris*	✓	
Redcapped Lark	*Calandrella cinerea*	✓	
Martial Eagle	*Polemaetus bellicosus*		✓
Secretarybird	*Sagittarius serpentarius*		✓
Bateleur	*Terathopius ecaudatus*		✓

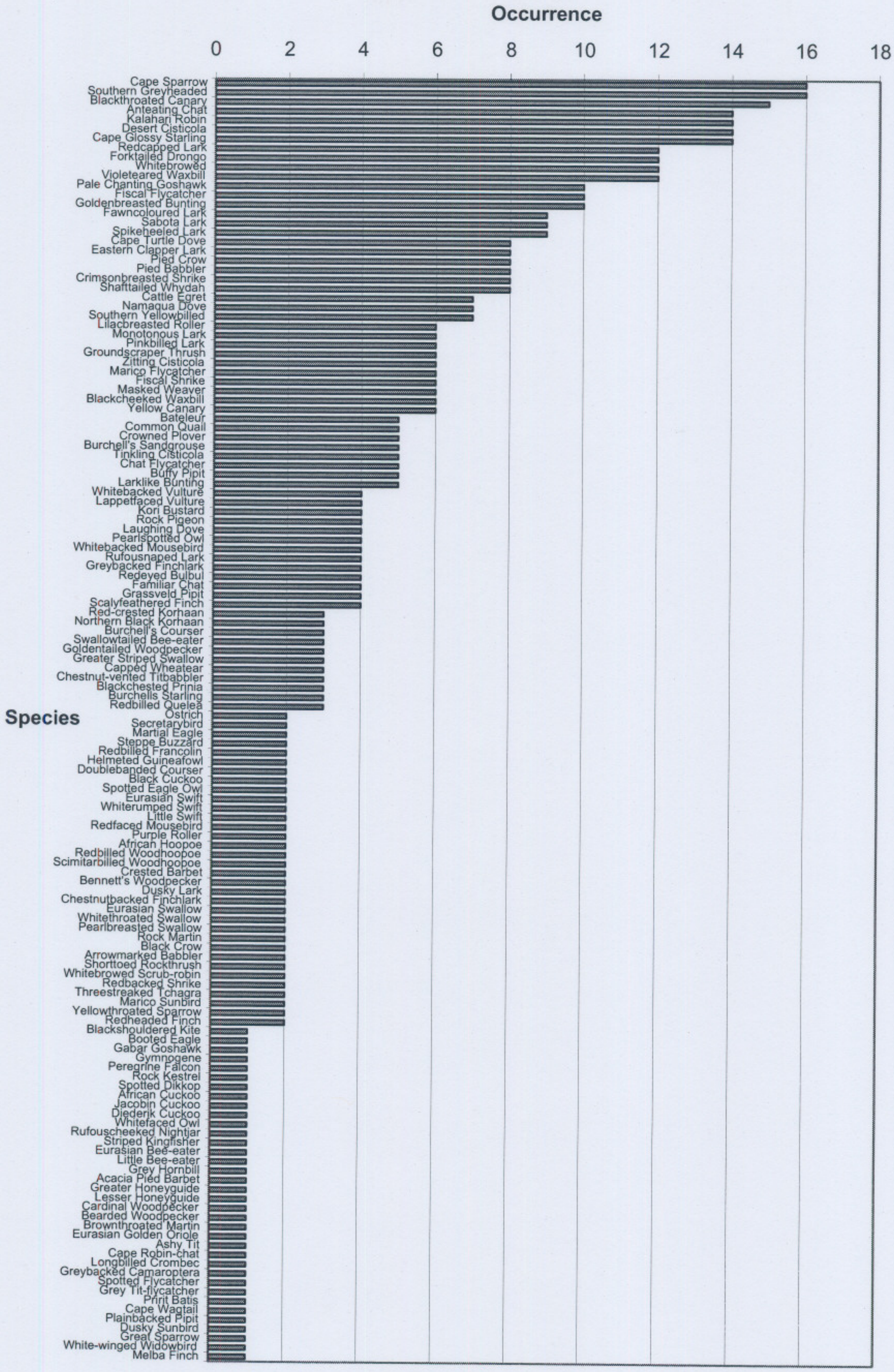

Figure 4-11: Numbers of times species occurred during the 16 surveys done through the course of the study

4.1.5.5 GUILD ANALYSIS

Guild analyses were done on all the bird species at each of the sites. Bird species were divided into guilds according to feeding and breeding.

Birds of the study area were divided into guilds according to what they ate (Table 4-16). Carnivores were added as a guild to include carnivorous birds that could not be classified as raptors (Refer to Appendix 1).

Table 4-16: Classification of feeding guilds for the purposes of this study

Guild	Description of guild members
Insectivores	Bird species that eat only or mainly insects as adults
Granivores	Bird species that eat only or mainly seeds as adults
Raptors	Bird species that can be classified as raptors
Frugivores	Bird species that eat only or mainly fruit as adults
Omnivores	Bird species that will eat a variety of foods as adults
Nectivores	Birds species that eat only or mainly nectar as adults
Carnivores	Bird species that eat only or mainly meat as adults, excluding raptors
Scavengers	Bird species that eat mainly carrion as adults

Guilds that made up less than 3% of the total species of an area were disregarded in the analysis of the feeding guilds. What was obvious from the graphical representation of the percentage composition of feeding guilds on the various sites (Figure 4-12 to 4-15) was that the basic assemblage of guilds stayed reasonably constant throughout the sites. With insectivores the dominant guild making up over 50% of the guilds at all sites, with granivores second to insectivores at all sites making up over 20% of the bird species occurring at the sites.

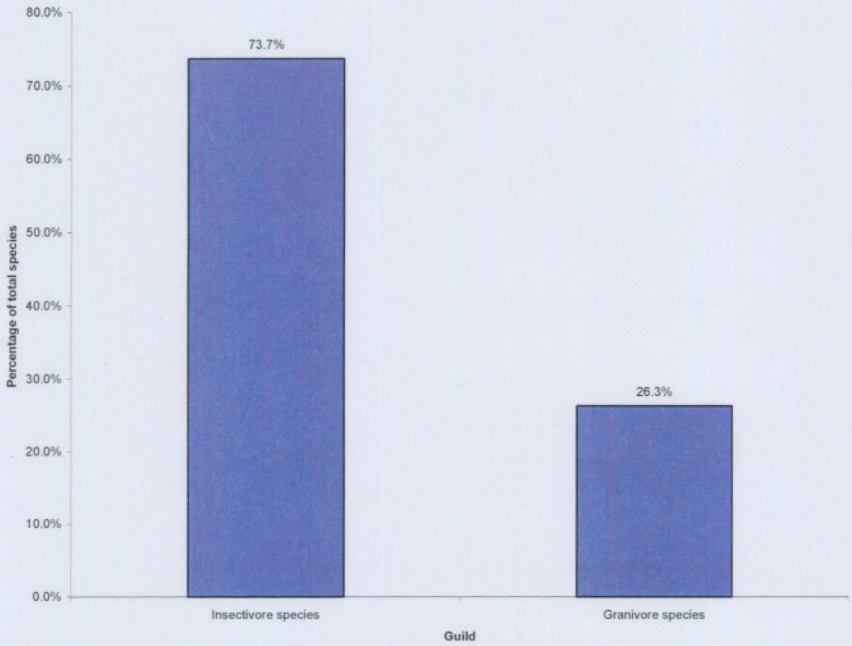

Figure 4-12: Percentage composition of birds by feeding guild for Heuningvlei communal farm

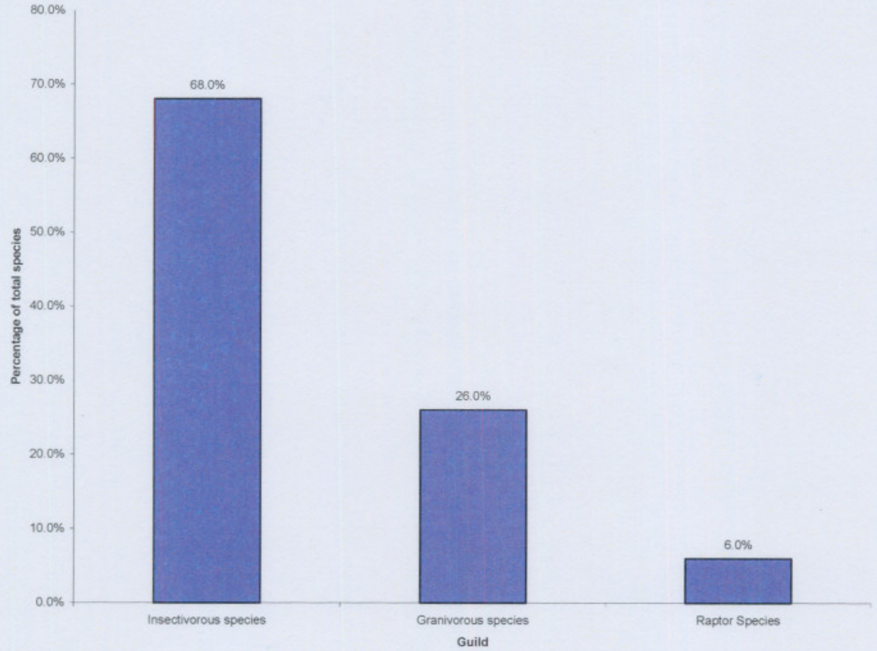

Figure 4-13: Percentage composition of birds by feeding guild for Lafras commercial farm

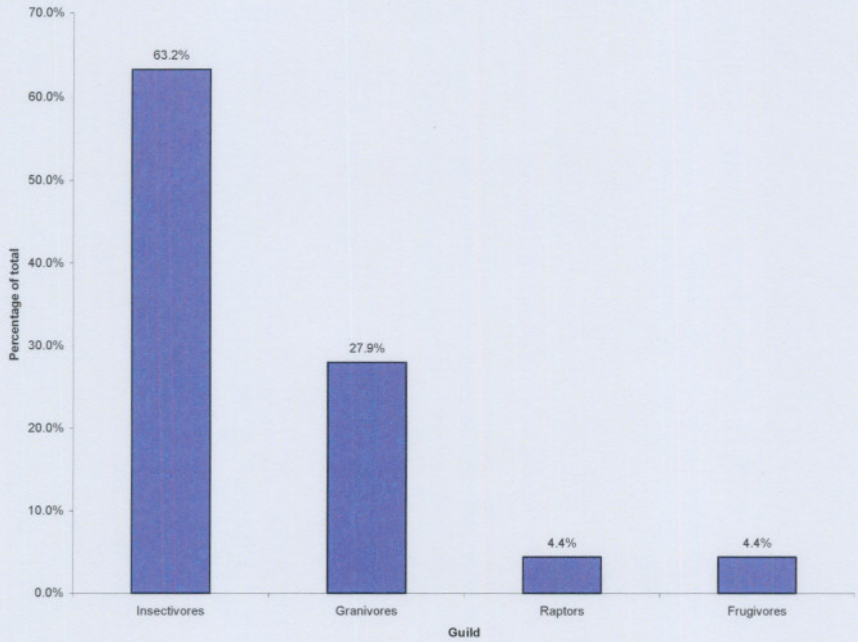

Figure 4-14: Percentage composition of birds by feeding guild for Driefontein communal farm

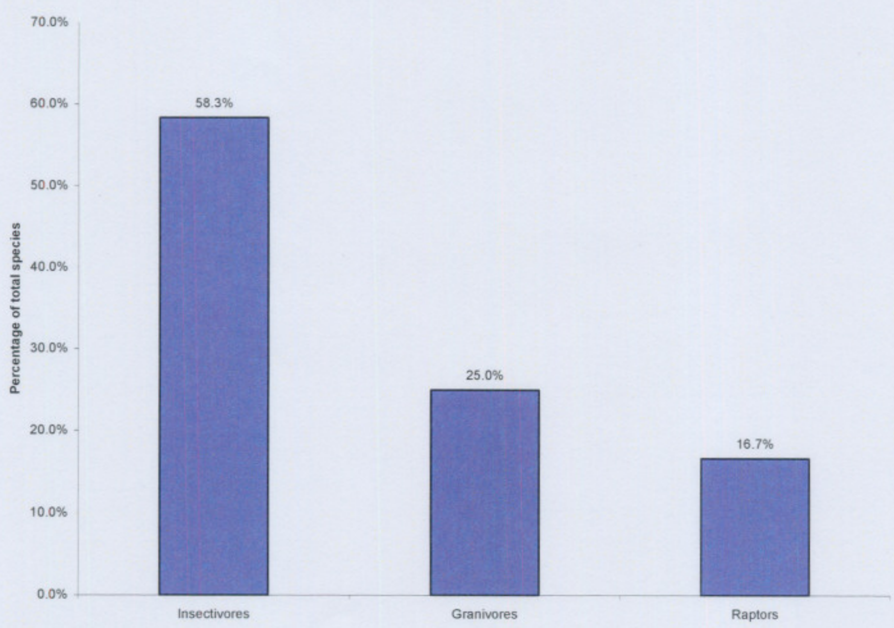

Figure 4-15: Percentage composition of birds by feeding guild for Molopo Nature Reserve

Birds were also divided into nesting guilds, these guilds grouped bird species according to the location they prefer in which to nest where they nest. Grouping guilds by nesting preference yielded a total of five guilds as outlined in Table 4-17. These figures exclude all extralimital-breeding migrants.

Table 4-17: Classification of nesting guilds for the purposes of this study

Nesting guild	Description of nesting preference of guild member
Ground-nesting	Nest in a scrape, hole or burrow on or in the ground
Tree-nesting	Nest in trees usually higher that 3m off the ground
Shrub-nesting	Nest within the shrub layer usually lower than 3m off the ground
Structure- or Cliff-nesting	Nest on cliff faces or man-made structures
Grass-nesting	Nest in the grass above ground level

Graphical analysis of the nesting guilds occurring at each site showed a variation in the nesting guilds occurring at each site. This variation is illustrated in Figures 4-16 to 4-19.

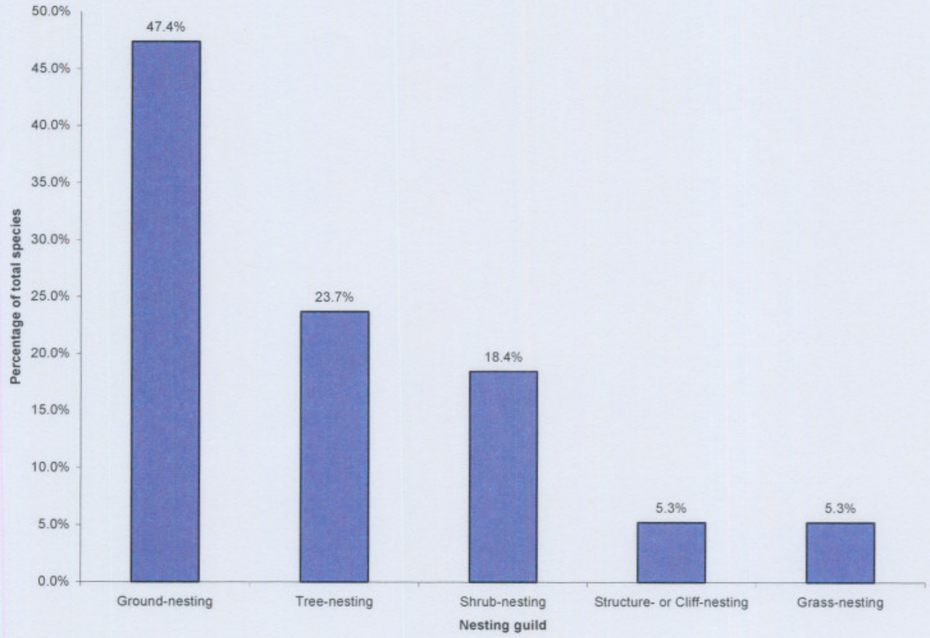

Figure 4-16: Percentage composition of birds by nesting guild for Heuningvlei communal farm

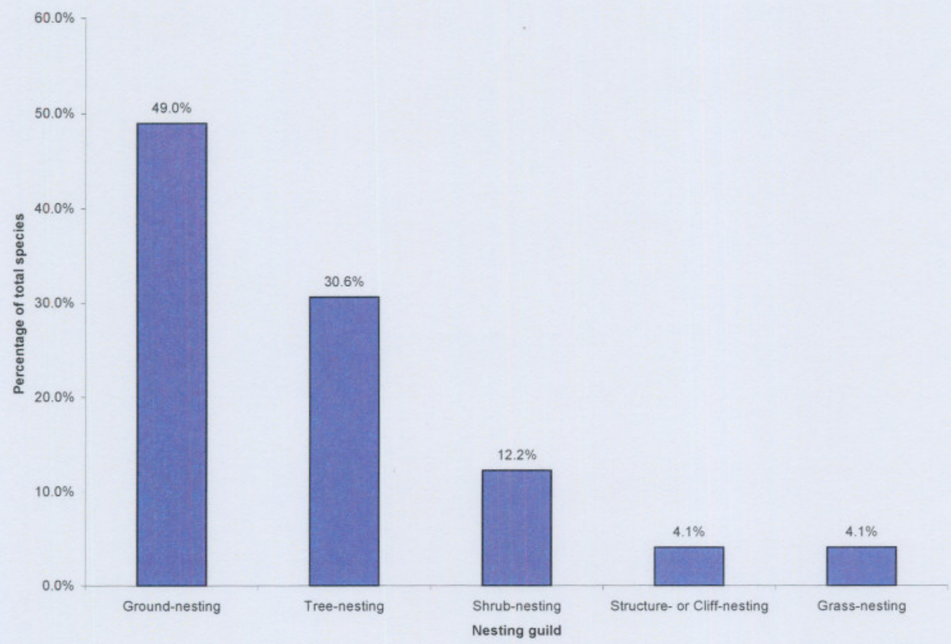

Figure 4-17: Percentage composition of birds by nesting guild for Lafras commercial farm

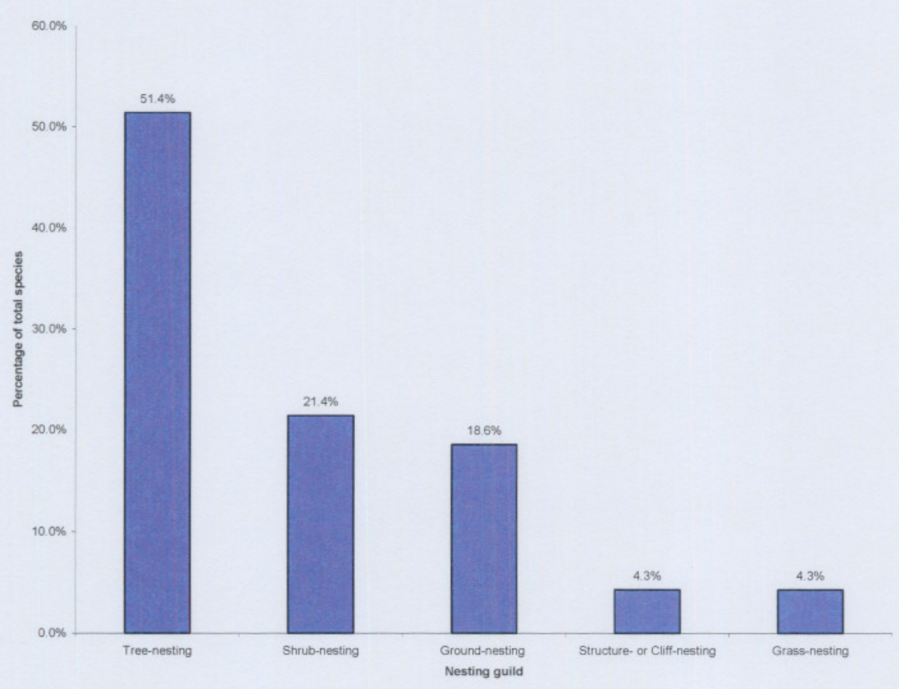

Figure 4-18: Percentage composition of birds by nesting guild for Driefontein communal farm

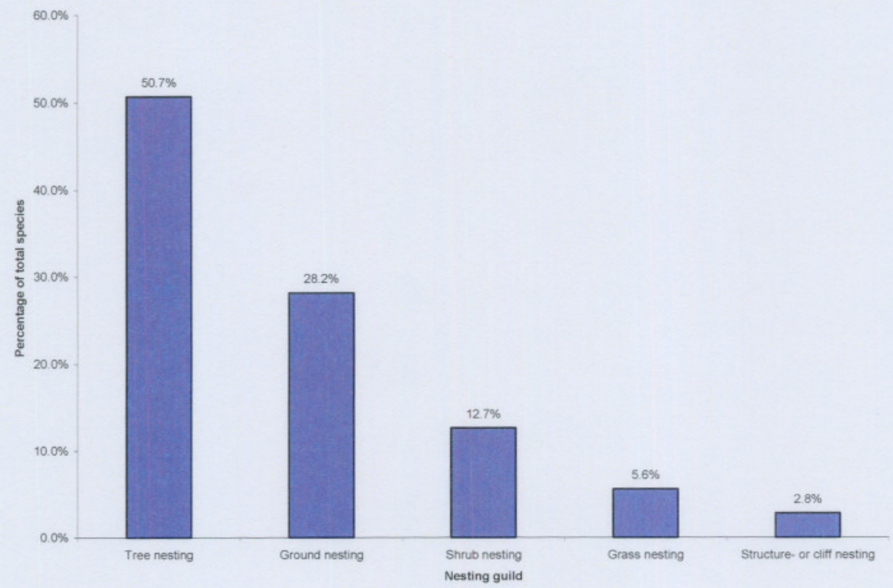

Figure 4-19: Percentage composition of birds by nesting guild for Molopo Nature Reserve

The analysis of nesting guilds at the different sites showed a similarity between percentages of species accounted for by nesting guilds at Heuningvlei communal farm and Lafras commercial farm, with the guilds occurring in the following order of significance: Ground nesting > tree nesting > shrub nesting > structure- or cliff nesting > grass nesting. The analysis of guilds also showed a similarity between guilds occurring at Driefontein communal farm and Molopo Nature Reserve. At Molopo Nature Reserve and Driefontein communal farm tree nesting species were the most numerous, at Driefontein shrub nesting species were second most numerous, then ground nesting species followed by structure- or cliff nesting species and, lastly, grass nesting species. On Molopo Nature Reserve ground nesting species were second most numerous followed by shrub nesting, grass nesting and structure- or cliff nesting species, in that order of significance.

4.2 STATISTICAL ANALYSIS

4.2.1 DIVERSITY INDICES

Diversity indices were calculated using the Primer 5™. Diversity indices were calculated for all transects done at each site and the mean calculated using Graphpad Prism™ 3.03 computer program. The mean diversity indices of all the sites are given in Table 4-18 as well as the evenness (equitability) of each site.

Table 4-18: Mean diversity indices of all study sites

	Heuningvlei	Standard Deviation	Lafras	Standard Deviation	Driefontein	Standard Deviation	Molopo	Standard Deviation
Margelef	3.79	±0.65	4.48	±0.23	5.02	±0.22	5.40	±0.57
Evenness	0.92	±0.02	0.93	±0.02	0.92	±0.01	0.84	±0.03
Shannon	2.34	±0.20	2.60	±0.04	2.80	±0.03	2.85	±0.19
Simpson	0.12	±0.03	0.09	±0.01	0.08	±0.01	0.09	±0.03

As can be seen from Table 4-16, there is a definite difference between the diversity indices of each site. The diversity indices can however be misleading due to the fact that the evenness (equitability) of all the sites was very low. This indicates that there are few similar common species at all of the sites and a large number of uncommon species at all the sites. This causes the diversity indices to be more similar than what they would be under circumstances with the evenness being higher. Nevertheless, Margelef, Shannon and Simpson diversity indices all show differentiation between the sites as far as biodiversity of the sites is concerned (Figure 4-20).

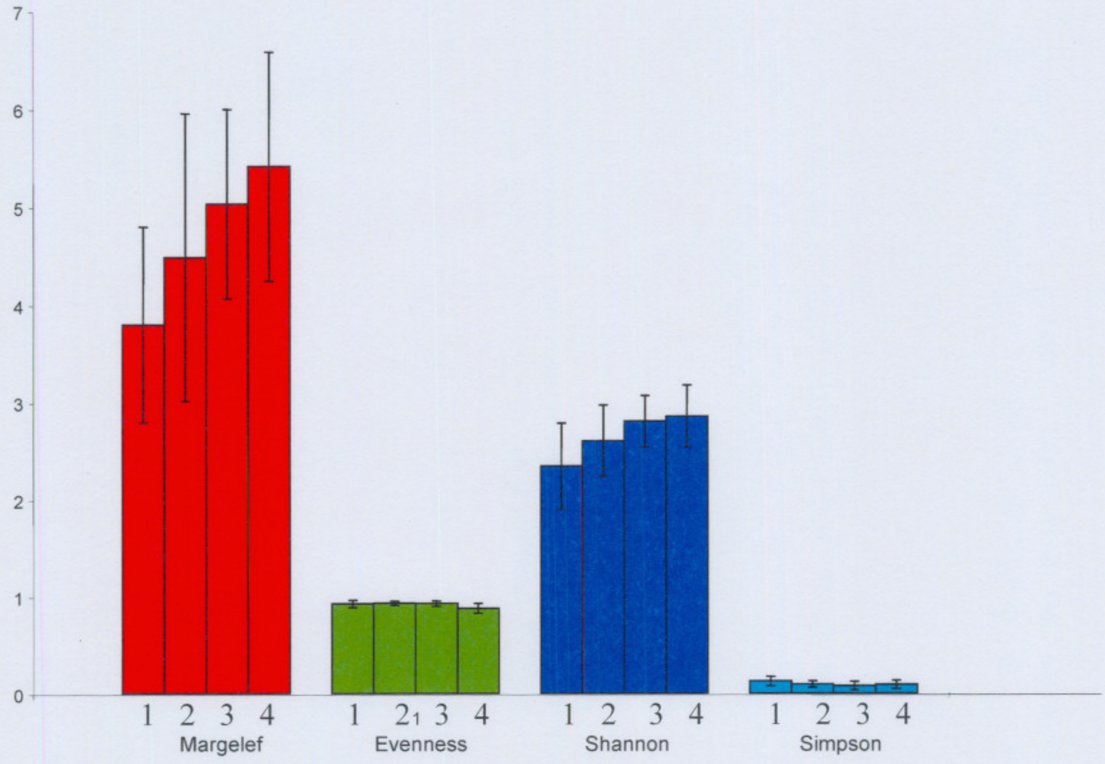

Figure 4-20: A graphical representation of the diversity indices. Sites are indicated by the numbers (1: Heuningvlei communal farm, 2: Lafras commercial farm, 3: Driefontein communal farm and 4: Molopo Nature Reserve.

4.2.2 Non-metric Multidimensional Scaling (NM MDS)

Non-metric multidimensional scaling (NM MDS) was done using Primer 5 and the data collected from the different sites over the four seasons. The plot was made by plotting the relative similarities, obtained from a similarity matrix of the survey data into 2, 3, 4 or more dimensions. The data was correlated with the various land use types to indicate whether or not the data from the various land use types showed any similarities with one another. The stress, indicated in the upper right corner of the plot (Stress: 0.09), refers to the possibility of the plot being misleading due to the program having to "squeeze" a plot into fewer dimensions than would give a true reflection of the ordination. A stress value of <0.1 (as is the case with the plot in question) corresponds to a good ordination with no real prospect of misleading interpretation. The figure obtained using NM

MDS is shown in Figure 4-21. The data was correlated with the various land use types to indicate whether or not the data from the various land use types showed any similarities with one another. The NM MDS showed a definite aggregation of the sites, even over the four seasons during which the data was collected. In Figure 4-21 Heuningvlei communal farm is indicated by the "very disturbed" icons, Lafras commercial farm is indicated by the "well managed" icons, Driefontein communal farm is indicated by the "disturbed" icons and Molopo Nature Reserve by the "natural" icons.

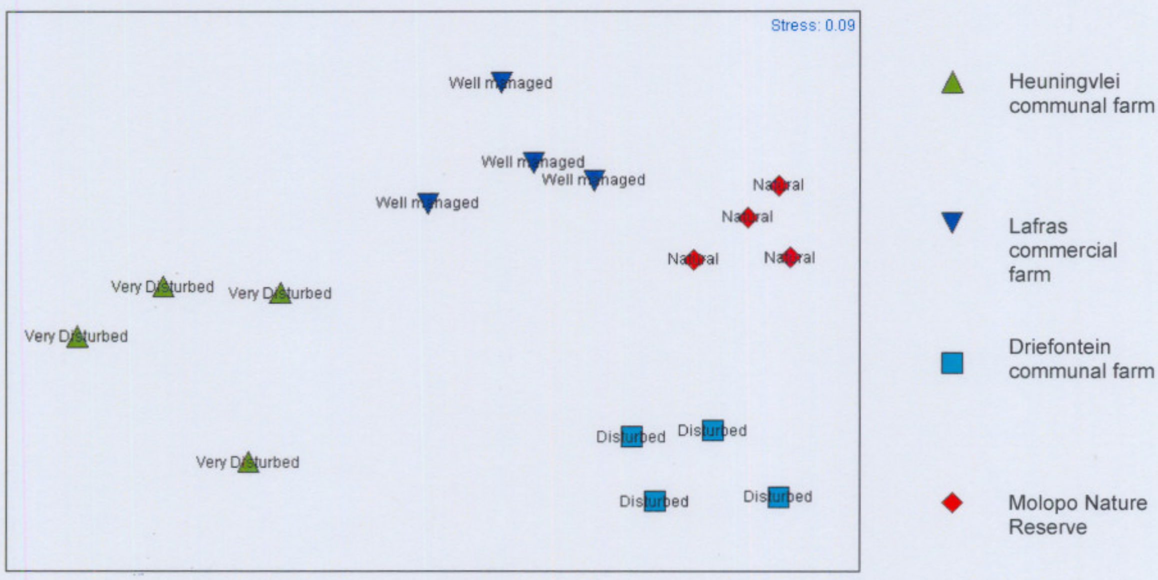

Figure 4-21: Non-metric Multidimensional Scaling plot using data obtained during the data collection and correlated with land use.

The aggregation of data points collected at sites over the various seasons indicates that the similarity of the sites persists over the four seasons although the data collected does vary with time. The NM MDS fits the samples according to their similarity and dissimilarity. The stress value in the upper right corner of figure 4-21 indicates how well the samples are fitted in the NM MDS. A stress value of <0.2 indicates a very true fit (i.e. a true reflection of the samples relative to each other, and little or no chance of misinterpretation), whereas a stress value of >0.5 will indicate that the NM MDS may be misleading in what it represents, with regard to the position of the samples relative to each other.

4.2.3 Multivariate Dispersion Indices (MDI)

Multivariate Dispersion Indices (MDI) calculate the Multivariate Dispersion Index (a measure of rank dissimilarity among replicates). MDI is used to investigate whether community structure has increased variability under disturbance. The Primer 5™ programme was once again used with the data collected at the various sites to calculate the MDI between the sites. Multivariate dispersion indices indicate the similarity or dissimilarity between sites with regard to a number of variables; in this case the variables used were the actual species composition, number of birds and number of birds representing each species. These variables were then used to compare the different land-use types, and MDI were calculated for each pair of land-use types. These indices can be used to give a tabular representation similar to the graphical representation of the NM MDS, however the MDIs for different land-use types lump data from all for seasons and then give an index of the dispersion between two sites. This dispersion is the theoretical distance that the plots would be away from each other if the sites were used to obtain a plot. The results of the MDI analysis are tabulated in Table 4-19. The smaller the value of the MDI (Multivariate Dispersion Index) the greater the dissimilarity between the sites, thus greater change in community structure with a change in disturbance. From this we can see that the much degraded site (Heuningvlei communal farm) is most dissimilar from the natural site (Molopo Nature Reserve), and that the greatest similarity is between the degraded site (Driefontein communal farm) and the natural site (Molopo Nature Reserve).

Table 4-19: MDI values calculated between various land use types

Factor values	MDI
Heuningvlei communal farm/Lafras commercial farm	0.177
Heuningvlei communal farm/Driefontein communal farm	0.343
Heuningvlei communal farm/Molopo Nature Reserve	0.085
Lafras commercial farm/Driefontein communal farm	0.160
Lafras commercial farm/Molopo Nature Reserve	0.226
Driefontein communal farm/Molopo Nature Reserve	0.398

4.2.4 Principal Component Analysis (PCA)

Primer 5 was used to do a Principle Component Analysis (PCA) of the sites. The PCA is a plot of the sites that, rather than giving a representation of geographical distance of the sites from each other, gives a representation of the similarity of their biological communities. PCA differs from NM MDS due to the fact that PCA uses Euclidian distance in order to derive the

plot whereas NM MDS uses a complex algorithm to refine the positions of the points, according to their dissimilarity, until they satisfy, as closely as possible, the dissimilarity relations between sites. The PCA (shown in Figure 4-22) indicates a clear grouping of the sites according to the principle components. Furthermore it was found that the sites Principle Components change over time causing the plot to shift towards the origin of the graph during the winter and spring months although this is not indicated on the graph. The similarity of the much degraded site (Heuningvlei communal farm) and the well managed farm (Lafras commercial farm), according to bird species composition and numbers,

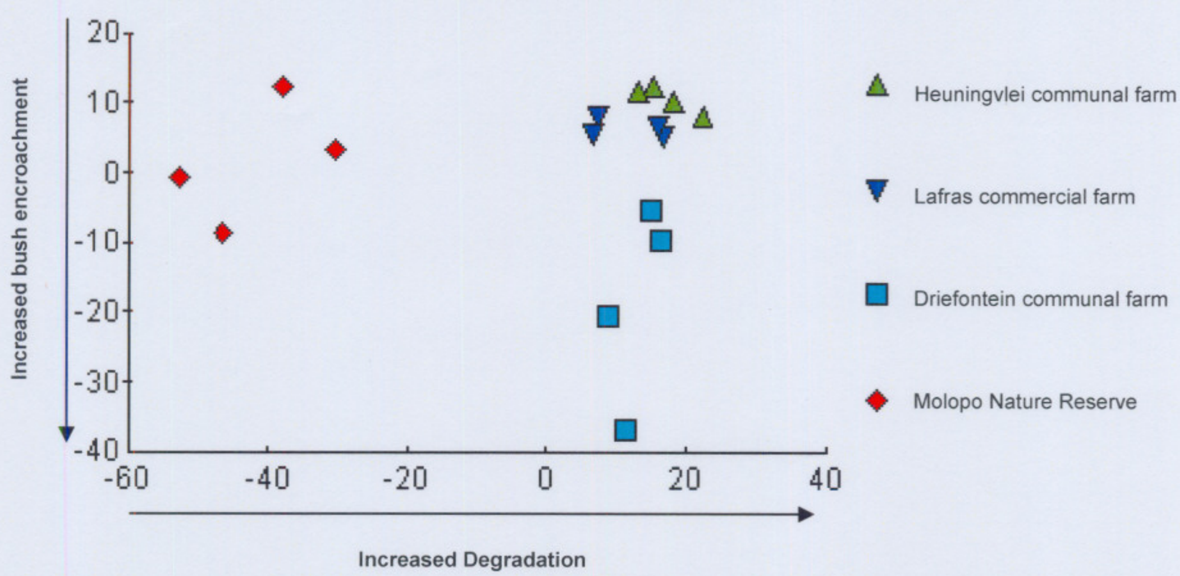

Figure 4-22. Principal Component Analysis (PCA) of the combined data of all four sites.

is also apparent through their grouping on the PCA plot (Figure 4-22).

4.2.5 ANALYSIS OF SIMILARITIES (ANOSIM)

ANOSIM uses the concept of a null hypothesis that similarities between sites and within sites are the same on average, in order to calculate similarities between and within sites and so generating an R-value that can be used to identify the similarity or differences between sites. If the R-value tends towards 0, it indicates support of the null hypothesis that the similarities between replicates of different and replicates within sites are the same on average. If the R-value tends toward 1, it indicates that the replicates within sites are more similar to each other than replicates from other sites. Support of the null hypothesis would, therefore, indicate similarities between sites whereas non-support of the null hypothesis would indicate greater differences between sites.

A Pairwise Analysis of similarities (ANOSIM), according to nesting guilds was done on all the sites using Primer 5 computer program (Table 4-20). The ANOSIM, once again, showed definite similarities between the much degraded site (Heuningvlei) and the well managed site (Lafras) with a significance level of 25.4%. the ANOSIM also shows a significance level of 14.0% for the well managed and degraded groups(Lafras and Driefontein). This analysis appears to contradict some of the other analyses, but the discrepancy can most probably be ascribed to the fact that only nesting guilds were used, because nesting guilds showed the greatest variation associated with land-use, as a measure by which the ANOSIM was done. Feeding guilds were also used in order to complete an ANOSIM, however the data obtained from this ANOSIM did not show significant trends and was thus omitted from this thesis.

Table 4-20: ANOSIM values calculated between various land use types

Pair compared by ANOSIM	R Statistic	Support null hypothesis
Heuningvlei communal farm/ Driefontein communal farm	0.241	YES
Heuningvlei communal farm/ Molopo Nature Reserve	0.741	NO
Lafras commercial farm/ Driefontein communal farm	0.056	YES
Lafras commercial farm / Molopo Nature Reserve	0.632	NO
Driefontein communal farm / Molopo Nature Reserve	0.472	NO

CHAPTER 5
DISCUSSION AND CONCLUSION

5.1 DISCUSSION

5.1.1 SITE CHARACTERISATION AND VEGETATION STRUCTURE ANALYSIS

Site characterisation and vegetation structure analysis was done by using the broad scale vegetation structure classification for practical purposes as set out by Edwards (1983). This vegetation structure classification was done by estimating vegetation cover and height classes of the vegetation and then using the dominant vegetation type(s) in order to determine the classification of the vegetation. The advantages of this classification system is it's ease and practicality in the field, as it eliminates the need for tedious, time consuming vegetation analysis using point transects, belt transects and quadrats. The shortcoming of this vegetation classification system is that it does not give a very good indication of species composition of the vegetation that is being surveyed and also does tend to give a very homogenous view of the landscape especially in this case where transects were chosen in similar vegetation. This study, however, did not attempt to investigate the effect of species composition on the distribution of birds, but rather the effect of land degradation. Based on the findings of previous studies (MacArthur & MacArthur, 1961; Roth, 1976; Kobal, Payne & Ludwig, 1999), the assumption was made that vegetation species composition would not have as great an influence on avian demography as vegetation structure (Refer to section 2.5.1).

The vegetation structure analysis showed a definite change in vegetation structure between the different land use types, ranging from what can be classified as natural vegetation structure at Molopo Nature Reserve to extremely altered vegetation structure at Heuningvlei communal farm.

Molopo Nature Reserve can be considered as the "natural vegetation structure" of the study area (Refer to Section 3.3.4., Table 4-13 and Figure 4-4).

Management on Molopo Nature Reserve is kept to a minimum; fire is not regularly used as a management tool, it is only used to reduce fuel loads after a number of years of good rainfall (S. Gore pers. comm.). This minimalistic approach with regard to the use of fire as a management tool is considered ideal in conjunction with the vegetation type of the area (Low & Rebelo, 1993). Game numbers are kept to just below the recommended stocking rate by means of hunting and the annual selling of game. All three vegetation strata are well developed at the study site on Molopo Nature Reserve, with tree cover of 10-1%, similar shrub cover of 10-1% and a well developed grass layer with cover of 100-10%. Tree height ranges between 5m and 10m, with shrub height of 1-5m and grass height of 0.5-1.0m. Areas around watering holes are more degraded than the majority of the vegetation due to increased concentrations of game, but these areas constitute less than 2% of the total area of the reserve (S. Gore pers. comm.). During the vegetation analysis no exotic species were observed on the nature reserve. According to Edwards (1983) the vegetation of Molopo Nature Reserve can be classified as Mixed Short Closed Grassland and Short Bushland.

Due to large scale overgrazing and unsustainable use of resources, such as wood for fuel, the vegetation at Heuningvlei communal farm has been reduced to Mixed Desert Shrubland and Desert Grassland (according to Edwards, 1983). No clear vegetation strata exist at the study site and tree cover has been reduced to <<0.1% and grass and shrub cover to <0.1%. The trees that do still exist in the area are less than 5m in height, while grass and shrubs are mostly less than 0.5m in height due to persistent grazing. Large areas (>1ha) totally denuded of vegetation also occur on Heuningvlei communal farm. No exotic species were observed during the vegetation analysis of Heuningvlei communal farm (Refer to Section 3.3.4., Table 4-13 and Figure 4-1).

Lafras commercial farm has also been altered by human intervention, management practices on Lafras commercial farm include control of bush encroachment by means of fire, herbicidal application and mechanical removal (P. Bruwer pers. comm.). The culmination of these management practices has led to greatly reduced tree and shrub strata and a very well developed grass strata. At the study site the tree strata can be described as having an average height of 5-10m with a total cover of <0.1%, the shrub layer has been affected to a greater extent by management practices and has a height of 1-2m and a cover of <<0.1%. Grass cover is 100-10% with a height of 0.5-1.0m. According to the classification system of Edwards (1983) Lafras commercial farm vegetation structure can be described as Short Closed Grassland (Refer to Section 3.3.4., Table 4-13 and Fig 4-2).

Driefontein communal farm is overgrazed, but not to the extent of Heuningvlei communal farm. The overgrazing is more prevalent in some areas than others due to the fact that cattle tend to be kept in the areas where water is available, thus these areas do not get time to recuperate. Land degradation is manifested by bush encroachment and denudification of the grass layer in large areas. At the Driefontein communal farm study site tree cover is 10-1% with a height class of 2-5m. The shrub layer is greatly exaggerated due to bush encroachment and covers 100-10% of the area of the site with a height class of 1-5m. Grass cover is reduced to 10-1% with a height class of <0.5m. Driefontein communal farm vegetation structure can be classified as Low thicket (Refer to Section 3.3.4., Table 4-13 and Fig 4-3) according to Edwards (1983).

From these vegetation analyses the change in vegetation structure due to land use is obvious (Refer to Section 3.3.4., Table 4-13 and Figures . 4-1 through 4-4). Factors such as rainfall were not taken into account due to the fact that reliable rainfall data could not be obtained for all the sites. The data that is available is also not relevant to the actual sites because 1) no rain meters have been positioned at the sites for an extended period of time and 2) the rainfall in the area is very patchy (S. Gore pers. comm.; Bruwer pers. comm.). The assumption was thus made that the areas had similar rainfall in the time leading up to the study and during the period of study itself.

The vegetation type and geological substrate are homogenous throughout the area (Low & Rebelo, 1998; Mangold *et al*, 2002), the topography of the study area is very flat and the climatic conditions throughout the study area are similar (Mangold *et al*, 2002) thus the only variable that differentiates between the sites is the vegetation structure of the different areas.

The main cause of change in vegetation structure is land degradation, the degree of which, in turn, is determined by anthropogenic and climatic factors (Kellner, 2002). Climatic conditions have been determined to be very similar throughout the study area (Mangold *et al*, 2002), therefore it can be deduced that the main factor determining land degradation, in the study area at hand, is anthropogenic. The finding that communal cattle farming is the main land-use in these degraded areas is consistent with the findings of Gonzalez (2002), Kellner (2000) and Van den Berg & Kellner (2001) that overgrazing is one of the leading causes of land degradation in the desert margin areas. Other factors that come into play are fire and water supplementation (Doherty *et al*, 2000). Fire is used extensively on Lafras commercial farm, the results of which can be seen in the altered vegetation structure, while water supplementation is used at all sites, the effects of which have been discussed and are also shown in Figure 3-4. The effects of pumping on the underground water (James *et al*, 1999) were not investigated during this study.

5.1.2 CHANGES IN AVIAN COMMUNITY COMPOSITION

The study showed avian community composition to vary considerably between sites. The number of species occurring at each site varies greatly as shown by Figure 4-8. Species numbers show the same trend as shown in Figure 4-5. From these results a definite difference in bird species and numbers can be seen between the sites. Land degradation increases in the following order of sites studied from least to most degraded: Molopo Nature Reserve < Lafras commercial farm < Driefontein communal farm < Heuningvlei communal farm. The expected result would be that bird species and numbers would decrease from the least degraded site to the most degraded site, due to the decreased biodiversity that is usually associated with desertification (Kellner 2000; Gonzalez 2002). However, although the trend is similar as to what is expected, Lafras commercial farm, which was assumed to be less degraded than Driefontein communal farm, had lower species numbers and lower numbers of birds than Driefontein communal farm. Common species at all sites were granivorous, especially generalists such as the Southern Greyheaded Sparrow

(*Passer diffusus*) and Cape Sparrow (*Passer melanurus*) (Refer to Tables 4-2, 4-5, 4-8 and 4-11).

Uncommon species vary from site to site (Refer to Tables 4-3, 4-6, 4-9 and 4-12); at Heuningvlei the uncommon species were mostly rarer granivores or ground gleaning insectivores, with an interesting find being the Cape Robin (*Cossypha caffra*) almost 300km outside its known range. Uncommon species at Lafras included a few raptor species and migratory tree-dwelling insectivores. Driefontein had a few uncommon species which included rarer tree dwelling birds, and ground nesting species. The bulk of the rarer birds at Molopo Nature Reserve were made up of larger raptors and migratory birds. The variation in the different types of data collected at each site clearly indicates a certain degree of variation in the avian communities at each site, even without doing a statistical analysis of the sites. Red data species were found at each site, except Heuningvlei communal farm. The number of red data species also increased with a decrease in degradation.

Feeding guild composition did not change as much as may have been expected over the different sites (Figures 4-12 to 4-15). It may have been supposed that in areas such as Lafras or Molopo, granivorous species would be more numerous due to the higher prevalence of grass and availability of seed. Dewalt *et al* (2003) and Johnson & Sherry (2001) found that increased food availability caused an increase in bird numbers and species utilising those food sources. The data collected in this study does, however, not agree with these findings. Although bird numbers appeared to be influenced by the amount of food available, food availability did not appear to influence the percentage of species belonging to a certain feeding guild present in an area. Guild assemblages remained similar between all the sites with slight variation with regard to raptors and frugivores; this assemblage trend, that remained stable throughout the different sites, may indicate stability at lower diversity levels in areas where degradation has taken place. Raptors did appear to be affected by degradation; this correlates with the findings of Casey and Hein (1994), that raptors are indirectly limited by vegetation because it affects the number of small mammals to a greater extent than birds (Bock *et al*, 1984).

Nesting guild composition, on the other hand, showed a much greater response to vegetation structure (Refer to Figures 4-16 through 4-19). At Heuningvlei commercial farm and Lafras communal farm the percentage composition of species according to nesting guild was dominated by ground nesting birds. Molopo Nature Reserve and Driefontein communal farm were, however, dominated by tree- and shrub nesting species. This data correlates with the vegetation structure of the different areas, with Heuningvlei and Lafras having a great deal less shrubs and trees than Molopo and Driefontein. One would however expect Lafras to have had more grass nesting species. It must be kept in mind, though, that very few grass nesting birds occur in the area (Refer to Appendix 1).

The deduction to be made from the analysis of breeding and nesting guilds is that bird species composition changes can be attributed to their nesting needs, to a much greater extent than their feeding needs.

The fact that birds appear to select sites according to nesting availability supports the suggestion of Lack (1933) and Beecher (1942) that birds identify proximate factors when selecting sites. In this case the availability of areas that would provide nesting sites would be very visible factors that could influence a birds' selection process. Although it was initially thought that competition could possibly be a factor influencing the distribution of birds in the study area, this was not apparent during the study. In order to test whether or not competition does play a role in the distribution of birds in the area, further studies will need to be carried out. Specialist species were affected to a much greater degree at all sites than generalist, which could be expected due to the specificity of the habitat or niche required by specialist species.

Predation was mentioned by Bider (1968), Collias & Collias (1984), Keyser (2002) and Maestas *et al* (2003) as a further factor that influences bird distribution. This study did not attempt to assess the effects of predation on bird distributions, but if anything the size of bird populations in areas was responsible for the distribution of their predators. African Wild Cat were spotted only on Molopo Nature Reserve (one of the areas with higher bird populations) with evidence of birds that it had been preying upon. Smaller raptors that prey upon birds were also most numerous in areas that had larger bird populations and absent from areas like Heuningvlei communal farm, which had low numbers of birds.

Water availability was mentioned by DeGraaf *et al* (1991) and Hockey (2003) as a factor that could limit bird distribution. Water availability was not regarded as a limiting factor with regard to bird populations in this study, due to the fact that none of the sites and transects were in excess of 5km from a watering point which, when taking into account their mobility, would give most birds access to daily water, if needed. The Molopo area of the North-West Province is an area where very few studies have taken place in the past and no long-term data on avian diversity of the area is available. Thus it is impossible to determine what influence, if any, the increase in water availability due to land-use has had on avian diversity. It is very possible that the increase in, more or less, permanent available water has given bird species that are dependent on free water, the opportunity to extend their ranges into areas that were previously unsuitable due to the lack of water.

While examining unpublished studies by the North-West Parks and Tourism Board (and speaking to members of North-West Parks and Tourism Board), it was noted, by them, that avian demography of the area is very variable, not only seasonally but also between years and over a number of years. Variable rainfall, drought, and the subsequent effect of climate on vegetation in the area may play an important role in the year to year variability of avian demography. A long term study to investigate the effects of years of drought and years of above average rainfall would be useful in determining the effects climatic conditions have on the avian diversity of the area, and also whether the effects of land-use on avian diversity are exacerbated or reduced by an increase or decrease in rainfall.

The importance of vegetation structure can not be ignored in the study of avian diversity; the most significant effect of the different land-uses was the change in vegetation structure that took place. Vegetation structure had an effect on all factors influencing avian diversity (with the possible exception of water availability) from nesting sites to feeding. The effects of vegetation structure on avian diversity has been the focus of a number of studies in the past, although findings varied from a strong correlation between vegetation structure and avian diversity (MacArthur & MacArthur, 1961), to no correlation at all between the two (Tomoff, 1974; Willson, 1974). This study supports the findings of MacArthur & MacArthur (1961) that there is a strong correlation between vegetation structure and avian diversity. A factor that was not sufficiently investigated during this study was the effect spatial heterogeneity had on avian diversity, Flather *et al* (1992) found that vertical height diversity alone could not account for the variation in avian diversity, this study does agree with this finding due to the fact that Molopo Nature Reserve had greater avian diversity than Driefontein communal farm, and the only visible difference in vegetation structure between the two sites was the greater spatial heterogeneity at Molopo Nature Reserve. The determination of which of these factors is more important in determining avian diversity is complicated by the fact that vertical height diversity is usually accompanied by spatial heterogeneity and *vice versa*, and it is, therefore, difficult to formulate an experimental design that will separate the two factors.

The numbers of birds occurring at the sites were still very high during the autumn survey as many of the migratory species (local and global) had not left by that time. The lowest numbers were recorded during the spring survey (Refer to Figure 4-6); this appears to be as a result of the survey being conducted in early spring before the summer rains. Therefore: 1) the migratory species had not as yet returned from their winter refuges and 2) the area was experiencing the driest period of the entire year, thus 3) biodiversity could be expected to be at its lowest in the area. A factor that was observed, at all the sites, was the dramatic decrease in bird numbers occurring in the areas between the autumn and spring surveys. At Heuningvlei communal farm the bird numbers decreased by 61.2%, at Lafras commercial farm there was a 50.4% decrease in species numbers, Driefontein communal farm showed a 62.6% decrease, while Molopo Nature Reserve showed only a 19.6% decrease in bird numbers. This gives a very different picture of the effect of land use on avian demography. The largest decreases in bird numbers appear to be in the communal farm areas namely

Heuningvlei communal farm and Driefontein communal farm. These areas both had a decrease in over 60% in the numbers of birds recorded. Lafras showed a decrease of just over 50% which appears to indicate that Lafras can maintain its bird numbers to a greater degree as resources decrease during the drier season. Molopo Nature Reserve showed a decline of only 19.6% in the number of birds between autumn and spring surveys. This indicates that, although there was a marked decrease in species numbers for that time, somehow numbers of resident species increased. This also appears to indicate an influx of birds to Molopo Nature Reserve during the drier months.

5.1.3 IMPLICATIONS FOR BIODIVERSITY

Although this study was not designed to investigate factors such as habitat complexity and habitat quality, it is obvious from the studies by Pimm (1984) and Doherty *et al*, (2000) that these factors are strongly linked to habitat heterogeneity. This study did investigate the effects of habitat heterogeneity on avian diversity and the postulation by Doherty *et al* (2000) is supported by the findings of this study. Habitat heterogeneity is described in Doherty *et al* (2000) as the spatial and temporal changes in habitat structure and species composition of a habitat. Due to the homogeneity of plant species occurring in the area and the assumption that plant species composition does not have a significant effect on avian population when compared to vegetation structure, this study concentrated on vegetation structure of the sites with regard to spatial heterogeneity. Habitat complexity as defined by Pimm (1984) refers to the richness, connectance, interaction strength and evenness. Species richness appears to be affected by land-use in the study area, due to the change in vegetation structure. Evenness is also affected, as shown in Table 4-18, although evenness still tends to be low at all sites. Although the other factors affecting habitat complexity were not measured in this study, the fact that land use affects both species richness and evenness, and habitat complexity is affected by (amongst others) these two factors, it can be deduced that habitat complexity will be affected by land use.

Habitat quality should be defined in a species-specific manner (Doherty *et al*, 2000), but this study appears to indicate that it could also be defined in a guild-specific manner. With regard to feeding guilds it is noticeable that, due to the absence of raptors in the area, the habitat quality at Heuningvlei communal farm appears to be far inferior for raptors than that at Molopo Nature Reserve.

Breeding guilds were also affected by habitat quality as seen by the dramatic reduction in tree- and shrub nesting guilds at Lafras commercial farm. These guilds appeared to have fewer representative species because of a reduction in habitat quality for these guilds, brought about by the reduction of the tree and shrub strata.

The ecosystem functions and processes that are affected by land-use are very complex and difficult to study especially in a study with the objectives stated in chapter 2 and were thus not investigated by this study.

The importance of diversity in ecosystem function is a much debated subject (Doherty *et al*, 2000), but according to Wardle, Bonner and Nicholson (1997), there is a definite link between species diversity and ecosystem function. The effect of species diversity on ecosystem stability is also addressed by Wardle, Bonner and Nicholson (1997) and findings thus far seem to indicate an increase in ecosystem stability with an increase in ecosystem function. The reduction in species diversity with an increase in degradation may therefore indicate a decreased stability in degraded areas of the desert margin areas; this was not investigated by the current study and requires further research for substantiation.

This study did investigate and support the findings of Abbott (1976), Braithwaite (1984) and Coops & Catling, (1997) that vertical height diversity of vegetation in an area influences species diversity of that area. The present study was not sufficiently robust to test all factors responsible for the increases in species diversity due to a more diverse vegetation structure.

With regard to the effects of disturbance on the avian diversity of the area, this study has undoubtedly supported the statement by Connell (1978, 1979) that species diversity is reduced by excessive disturbance. This is especially visible in the case of Heuningvlei communal farm where excessive disturbance by overgrazing has caused a definite decline in avian diversity, when compared to the other sites.

The effect of fire (as a management tool) on avian diversity is visible on Lafras commercial farm. Although fire serves to remove bush encroachment (which is seen as a form of degradation) it also causes a very homogenous landscape with regard to vegetation structure (Low & Rebelo, 1998). The link between vegetation structure and species diversity, as well as the well debated theoretical link between species diversity and ecosystem stability (Doherty *et al*, 2000), is cause for concern in this case. There is a need for further study as it is unclear whether or not the use of fire as a management tool is a sustainable practice, or whether it will eventually lead to a large scale increase in degradation and reduction in species diversity.

The effects of fragmentation were unclear in this study because the sizes of the fragments caused by the different land-use types were too large to have the effects usually associated with fragmentation. Although fragmentation does occur due to different land-use in the area under investigation in this study, the scale at which it occurs is very large. Fragment sizes in the area are usually greater than 3000ha and the size of the fragments were therefore, probably, too large to have the same visible effects that smaller fragments have, as found in the studies by Bennett (1987) Askins *et al* (1987), Hobbs (1993), Dunstan and Fox (1996), Doherty *et al*, 2000.

In this study the fundamental assumption was made that avian diversity was correlated to land degradation in order to identify avian diversity as a surrogate for degradation. This assumption was supported by the data collected during the study with a visible change (refer to Section 4.1) in avian diversity being recorded over the spectrum of land-uses, which in turn represented different stages of degradation. The use of avian diversity as a surrogate for degradation was thus supported by the findings of this study, although the data for Lafras commercial farm did present some cause for concern. According to Kellner (2002), little degradation occurring in the form of bush encroachment and denudification usually indicates a well managed farm. With this in mind, Lafras commercial farm can be considered a well managed farm. Because birds are good indicators of environmental variables (Adamus, 2002; O' Halloran *et al*, 2002), the data collected with regard to avian diversity, indicates some kind of disturbance on the commercial farm. The drastically reduced shrub layer on the Lafras commercial farm site appears to account for the reduced number of bird species in the area, because of the use many species have for the shrub layer with regard to foraging, nesting and protection from predators (Maclean, 1993). As mentioned before in this section, this may be cause for concern with regard to ecosystem stability in the area.

Variations in species diversity and bird numbers between sites followed the same trend over the different seasons during which surveys were done with the exception of the bird numbers during the winter survey on Molopo Nature Reserve. While bird numbers declined steeply from the autumn survey at the other three sites, there was an increase in the number of birds surveyed at Molopo Nature Reserve; this data seems to indicate that there is a flux of birds from other areas towards Molopo Nature Reserve as the dry season progresses. It could be speculated that Molopo Nature Reserve acts as a refuge for birds as the supporting quality of farms in the area decrease during the dry season. The reason for this flux is most likely food availability, as it was noticed during the surveys, that the amount of grass seed on the grass, and seed matter on the ground, was considerably more on Molopo Nature Reserve than the other sites during the dry season. This observation may be important for the conservation of bird species in the area, as studies may be done to identify and conserve refuge areas, such as Molopo Nature Reserve, in the region and in the DMP region in general. This section does bring up the question as to whether Molopo Nature Reserve can be recognized as an Important Bird Area (IBA). Depending on further studies, Molopo Nature Reserve may be classified as and IBA by means of the A3 classification. This classifies an area as an IBA due to the biome restricted assemblages that occur in that area (Fishpool & Evans, 2001), meaning that the area must contain a significant number of bird species that are largely or wholly restricted to that biome.

As long as such refuge areas exist it may be possible to conserve the species diversity of a larger surrounding area without excessive interference in farming practices of the area. Studies need to be carried out in order to determine:

- Whether Molopo Nature Reserve is, in fact, a refuge?
- The significance of a refuge such as Molopo Nature Reserve on the bird populations of the area,
- Which bird species would benefit by the establishment of refuges?
- Whether or not the conservation of similar refuges in the areas will have a considerable positive effect on the general bird populations in the area?
- The optimal size and distribution of such refuges in order to have a significant impact on bird populations.
- Whether or not Molopo Nature Reserve qualifies as an Important Bird Area (IBA)

Although the trip in February 2004 (Refer to section 3.4.2) did not include actual surveys for the purpose of data collection for this thesis, it did serve to validate how thorough the surveys until then had been by investigating whether or not any new bird species could be identified at any of the study sites. No new species were found during the February 2004 survey trip, which indicates that the surveys done for the purpose of the study were representative of the areas for which they were elected.

5.1.4 STATISTICAL ANALYSES

Diversity Indices

Shannon, Simpson and Margelef diversity indices of the sites are shown in Table 4-18, as well as the evenness index of each of the sites. Although the diversity indices do give an indication of a difference in species diversity of the sites, they do not appear to give a true reflection of the variations in species diversity of the sites. By looking at the graphical representations of the variations in bird species and numbers in Chapter 4 (Refer to Figures 4-5 through 4-9), a considerable difference can be observed in the numbers of birds, as well as the numbers of species, occurring at each site, while the species diversity indices do not appear to reflect as large a difference. The reason for this is the low evenness scores for all the data collected. The low evenness scores indicate that there are few species that occur in all the sites and many species that have a low occurrence at the sites; this is illustrated by Figure 4-11 which gives the occurrence of all the species noted during the study. The evenness of the sites implies that there are not many species which occur at all the different sites and that there are a relatively large amount of species that occur at only one or two of the sites. This lack of evenness, or dissimilarity between the sites with regard to species composition, makes it difficult to compare sites by means of species diversity indices. The lack of evenness does, however, in itself have significance in that it indicates the effect that degradation has on the dissimilarity of the species occurring at the different sites. Because different species may choose to inhabit different sites due to different factors inherent to those sites, it indicates that land-use, and the associated level of degradation, has had an impact on the suitability of the different for different species.

Non-metric Multidimensional Scaling (NM MDS)

The Non-metric Multidimensional Scaling (NM MDS) is a method of mapping the data obtained in a similarity matrix in order to show the relative similarity or dissimilarity between sites according to a specified number of dimensions. The Non-metric Multidimensional Scaling (NM MDS) in Figure 4-21 shows the NM MDS of the rank similarity of sites in two dimensions. There is a definite correlation between sites over the different seasons and there is a significant amount of difference (with regard to similarity) between the sites in different land-use types. The stress value of 0.09 indicates that the ordination in question is good and there is no real prospect of misinterpretation of the data. The discussion thus far has indicated that vegetation structure appears to be the most important factor in determining the distribution of birds, and the number of birds, occurring at each site. This ordination shows the similarities between data obtained in surveys at transects on the same land-use type, and the dissimilarity between the data obtained at transects with different land use types. The NM MDS was used to indicate the differences between the sites, taking into account species diversity and species numbers without being constrained by the lack of evenness between the sites as was apparent when using diversity indices.

The similarity of the data recorded at transects within the same site indicates that the methods used during the surveys did give an accurate representation of the *status quo* of the sites. The dissimilarity between the sites combined with the similarity of the transects at each of the sites indicates, once again, that there was a definite difference between the avian demography at the sites and that the variations were not just due to an error in methodology.

Multivariate Dispersion indices (MDI)

The results of the MDI (Refer to Table 4-19) showed that Molopo Nature Reserve and Heuningvlei communal farm were the most dissimilar and that Molopo Nature Reserve and Driefontein Communal Farm were the most similar with regard to these variables. Evenness, as with the diversity indices, once again comes into play with MDI and causes the data to be skewed as can be seen with the similarities between Molopo Nature Reserve and Lafras Communal Farm. Although the similarity score is relatively high it does not give an accurate indication of the actual similarity of these sites. As mentioned before, the lack of evenness (although it interferes with accurate statistical analysis) is significant in the sense that it indicates variation between sites, which in turn indicates a variation in environmental factors that influence avian demography on different land-use types.

Principal Component Analysis (PCA)

The PCA plot for the sites is shown in Figure 4-22. On the plot the sites are indicated by similar coloured and shaped markers and the four similar markers indicate the data collected over the four seasons. The PCA shows a definite grouping of sites according to their land-use, and does also indicate a similarity between Heuningvlei communal farm and Lafras commercial farm in the species composition and number of birds occurring at the respective sites.

Molopo Nature Reserve and Driefontein communal farm are not only different from the other two sites, but also from each other with regard to species composition and species numbers. The close grouping of the Heuningvlei communal farm and Lafras commercial farm plots over the seasons indicate less change in numbers or species composition with seasonality when compared with the more widely spaced plots of Molopo Nature Reserve and Driefontein communal farm. The more widely spaced plots indicate a more considerable change in species diversity as well as bird numbers, which are due to the larger number of migratory birds that occur at these two sites when compared with the former two, over and above the greater resident species diversity. The lesser degree of change at Heuningvlei communal farm and Lafras commercial farm may be due to a number of reasons. Firstly, the number of species that occur at more degraded sites are far less than the number of species at the less degraded sites, thus only a limited amount of change in species composition and numbers can take place. Secondly, species occurring at these sites are mostly generalist species that are well adapted to the increased level of degradation in these areas and are thus better able to cope with the harsher conditions in winter. Many of the specialist species at the Molopo Nature Reserve site may be ill equipped to cope with the harsher conditions during winter and need to migrate (locally or further afield) in order to find more suitable areas. Finally, from the data there appears to be a flux of birds towards Molopo Nature Reserve during winter. Although the number of species on the reserve decreases significantly (Refer to Figure 4-9), there is an increase in the number of birds observed on Molopo Nature Reserve between autumn and winter (Refer to Figure 4-6). This indicates that, although there is a loss of species due to the absence of migratory species, there is a gain in resident species from surrounding areas.

This observation at Molopo Nature Reserve could be seen from different points of view. Firstly it could be an indication of the ability of a less degraded area, such as Molopo Nature Reserve, to resist dramatic change due to environmental stress, thus still having sufficient resources to sustain the influx of resident species from more degraded areas that are less resistant to change.

Secondly, the outflux of migratory species may leave a "gap" which can be filled by less specialized resident species, when the resources at their usual ranges become reduced due to increased stress. Thirdly, the influx of species may indicate a change in the ecological role Molopo Nature Reserve plays, during the drier months, from an island of increased biodiversity with a large number of migratory bird species in summer, to a refuge for resident species in winter.
Component factors, as indicated on figure 4-22, are land degradation and bush encroachment. There appears to be a definite decrease in bird species richness and bird numbers with and increase in land degradation. Bush encroachment appears to cause an increase in bird species richness over the warmer wetter months but does not similarly increase the numbers of birds. This may be due to migratory birds that make more use of the wooded areas but then leave again in winter. This would explain the dramatic decrease in species richness in areas with considerable bush encroachment (such as Driefontein communal farm) during the winter months when migratory birds leave.

Analysis of Similarities (ANOSIM)

The analysis of similarities also analyses the similarity of different land-use types with regard to avian population dynamics. From the ANOSIM results we can see that the greatest similarities occur between the much degraded site at Heuningvlei communal farm and the well managed site at Lafras commercial farm. The second highest similarity according to the ANOSIM is between Lafras communal farm and Driefontein communal farm. The lowest similarity was once again found between Molopo Nature Reserve and Lafras Commercial Farm and between Molopo Nature Reserve and Heuningvlei Communal Farm. These are more consistent with the situation that was observed at the sites than the diversity indices indicate. ANOSIM takes into account the number of species occurring in the area, to a lesser extent than the actual species composition. Thus the evenness factor, that has been explained, does not come into play to such an extent with ANOSIM as it does with the species diversity indices. The ANOSIM results did not give any new insight into the observations made, but did confirm the unreliability of the species diversity indices in this case.

5.2 CONCLUSION

The conclusions of the study will be set out in this section according to the hypotheses set out in Chapter 2, as well as within the objectives of the broader framework of the Desert Margins Programme.

5.2.1 CONCLUSIONS WITH REGARD TO HYPOTHESES

HYPOTHESIS 1: Bird populations are noticeably influenced by the vegetation structure of the areas they inhabit in the Molopo area of the North-West Province.

Activity 1 Determine whether land-use types in desert margins areas have a significant influence on avian diversity the Molopo area of the North-West Province.

Activity 2 Determine which factors are most likely to influence bird diversity in the Molopo area of the North-West Province.

The first hypothesis of the study was supported by the findings of this study. The data collected during all four surveys showed that the sites varied greatly with regard to avian diversity and there was a dramatic decline in avian diversity with an increase in land degradation brought about by different land use types. Although diversity indices (Refer to Table 4-18 and Figure 4-20) did show a difference between the sites, they did not accurately reflect the extent of the variation of diversity between the sites. Other statistical analyses, such as the Analysis of Similarities (ANOSIM) (Refer to Table 4-20) and Multivariate dispersion indices (MDI) (Refer to Table 4-19), and plots such as Principal Component Analysis (PCA) (Refer to Figure 4-22) and Non-metric Multidimensional Scaling (NM MDS) (Refer to Figure 4-21) gave a clearer indication of the variation in avian diversity. The best indication of the variation in diversity was, however, graphical representations of species diversity.

The study clearly shows that objective one was achieved in that it was determined that avian populations are indeed influenced by land use types within the study area.

Vegetation structure was found to be a factor that definitely influenced avian diversity, mainly due to the fact that vegetation structure influences a number of the factors important to the survival of bird species such as nesting and feeding. It was found, during winter, that visible quantities of seed on the grass as well as on the ground appeared to be considerably more than at the other study sites; this also correlated with the increase in the numbers of birds on Molopo Nature Reserve during the winter survey, while all the other sites showed a decrease in bird numbers. Because bird numbers increased in areas where there appeared to be more available food during winter, it can be deduced that food is important in the determination of the numbers of birds found in an area rather than the species diversity of the area.

HYPOTHESIS 2: Bird species diversity, as well as bird numbers, will decline with an increase in land degradation, brought about by land-use in the Molopo area of the North-West Province, South Africa.

Activity 3 Determine whether land degradation caused by land-use types in desert margin areas cause a significant decline in avian diversity.

The second hypothesis was also supported by the data obtained during the study, although the observation at the Lafras commercial farm site did appear to contradict the hypothesis. This observation, however, highlighted the importance of more studies with regard to the ecosystem function and processes, as well as the concept of system integrity in the desert margins area. Land degradation brought about by land-use was found to be the major factor affecting avian diversity of the area. The processes affecting these declines are poorly understood and, due to the scope of this study, not much further knowledge was gained on these processes. The change in vegetation structure was brought about by different land-uses was, however, identified as having an important role to play in the change of avian diversity.

Another observation from the data was the high species diversity at Driefontein communal farm during the autumn survey, which did not support the hypothesis that avian species diversity decreased with an increase in degradation. This may have been caused by increased precipitation just before the start of the survey which, in turn, may have increased the number of species flocking to the area in order to make use of the increase in water, plant matter and arthropod activity that accompanies rain in the area.

Once again further study needs to be carried out in order to investigate the effects land-use, and the accompanying change in vegetation structure, has on the biodiversity in the desert margins area. Long-term studies on the effects of landscape alteration for the purposes of increasing grazing on cattle farms may also be needed, as the results of this study (although not verified due to the complexity such a study would entail) alluded to the probability that there may be a decline in ecosystem integrity, due to the simplification of the ecosystems, by management practices on commercial farms.

HYPOTHESIS 3: Bird species diversity will act as a good surrogate for assessing the degree of land degradation brought about by land-use in the Molopo area of the North-West Province, South Africa.

Activity 4 Determine whether avian species diversity can be used as a surrogate for land degradation of the land-use types studied.

Activity 5 Identify indicator species for both good and degraded habitats.

Bird species diversity was greatly influenced by the degree of land degradation brought about by land-use in the study area. This indicates that bird species diversity will act as a good surrogate for land degradation in the study area. (Refer to section 2.2.5). Once again, due to time available for this study and other logistical constraints, this study could not fully investigate the usefulness of bird species diversity as surrogates for land degradation, but the observations made show that there was a definite decline in bird species diversity which correlated with an increase in land degradation. It must also be noted here that the assumption was made here that the landscape alteration at Lafras commercial farm was tantamount to a form of land degradation.

Species were identified as indicators due to an increase in the numbers of birds occurring with a decrease in degradation. Birds that indicate high or low levels of degradation may be useful as well, but when comparing different areas, a species is needed that can indicate the relative levels of degradation in those areas. For this reason bird species were identified that occurred at all four (or at least three of the four) sites and then these were narrowed down to the species whose numbers appeared to be negatively affected with an increase in degradation (Refer to Table 4-14). These species are: Pale Chanting Goshawk (*Melierax canorus*), Forktailed Drongo (*Dicrurus adsimilis*), Pied Babbler (*Turdoides bicolor*), Desert Cisticola (*Cisticola aridulus*), Crimsonbreasted Shrike (*Laniarius atrococcineus*) and the Blackthroated Canary (Serinus atrogularis). Some of these species (Pale Chanting Goshawk (*Melierax canorus*), Forktailed Drongo (*Dicrurus adsimilis*) and Crimsonbreasted Shrike (*Laniarius atrococcineus*)) are absent from very degraded areas, but do increase in numbers in the other areas according to a decreasing level of degradation.

Other birds (Refer to Table 4-15) namely Redcapped Lark (*Chersomanes albofasciata*), Pinkbilled Lark (*Spizocorys conirostris*), Burchell's Courser (*Pterocles burchelli*) and Doublebanded Courser (*Smutsornis africanus*) could be investigated as being indicators of degraded areas due to their occurrence only at very degraded sites, while larger raptor species (such as Bateleur (*Terathopius ecaudatus*), Secretarybird (*Sagittarius serpentarius*) and Martial Eagle (*Polemaetus bellicosus*)) can be investigated as indicators of a much lower level of degradation, as they are usually associated with less degraded areas. Further study is, however, needed to identify and scientifically investigate bird species as indicators of degradation.

5.2.2 CONCLUSIONS WITH REGARD TO RELEVENCE WITHIN THE BROADER DESERT MARGINS PROGRAMME FRAMEWORK

The objectives of the Desert Margins Programme (DMP) according to Kellner (2000) are outlined in section 1.1.1.2. This study was designed to contribute towards the eventual objectives of the DMP. The objectives of this study as well as the design of the framework were set out in such a way as to adhere to these objectives. These objectives can be summarized as follows:

- Conservation and sustainable use of endemic biodiversity in dryland ecosystems where biodiversity is threatened by intensified land-use, drought and desertification.
- Prevention and control of land degradation through development of sustainable-use methods for biodiversity conservation.
- Integrated approaches to conservation, sustainable land-use systems and strategic interventions to rehabilitate degraded land.
- Public participation in project design and implementation.

At the outset of the study the parties involved with the study (private land owners and land users, conservation officials and other interested parties such as the Department of Agriculture, Conservation and Environment (DACE) as well as the North-West Parks and Tourism Board (NWPTB)) were consulted with regard to the design of the project and indigenous knowledge available through these sources was used to assist in the experimental design of the project.

The results of the project will undoubtedly help further studies with the aim of conservation and sustainable use of endemic biodiversity in the area. Although not discussed in this thesis, this study did also perform the role of compiling an inventory of bird-, frog- (5 species) and tree species (11 species) present in the area for further use in the conservation efforts of the DMP and NWPTB. In order to effectively conserve the biodiversity of the area, an in-depth understanding of the biodiversity, ecosystem functions and processes and effects of anthropogenic utilization of biodiversity are needed. This study was initiated with regard to the DMP, as the first phase in understanding these factors with effective conservation and sustainable utilization as the final goal. This study may also aid in the rehabilitation of degraded land by being the first step in identifying an efficient approach to the monitoring of rehabilitation efforts through the use of avian diversity as surrogate indicators.

5.2.3 RECOMMENDATIONS WITH REGARD TO FURTHER STUDIES

Further possible studies to clarify certain aspects of avian diversity in the area have been mentioned before in this thesis, but can be summarized as follows:

- Studies to determine the effects of vegetation structure on certain species in order to ascertain whether or not those species will be useful as indicator species.
- More studies need to be done to determine the relative importance of the factors known to influence avian diversity, and to investigate further factors that may have an influence on avian diversity.
- Further studies to determine the characteristics and causes and effects of local migrations as well as the presence or absence of refuges in the area may be important for future conservation in the area.
- Studies to investigate the functioning of ecosystems in the area as well as the effects of avian diversity on ecosystem functioning. The effects of system integrity on avian diversity may also be important in the understanding of the intricacies of the correlation between avian diversity and degradation.
- Common language indicators also need to be investigated. These are indicators that are useful to local people, decision makers and members of the general public (Schiller *et al*, 2001). This makes them far more useful for lay-people, due to their ease of identification and measurability, without employing complicated scientific jargon or methodologies. Because of their visibility, the ease with which they can be measured and the widespread knowledge many people already posses on birds, they can be very useful as common language indicators.

5.3 MANAGEMENT IMPLICATIONS

Vegetation structure was the factor that most influenced bird diversity and also happens to be the factor most influenced by management practices of land users. The implications of this for management are far reaching with regard to sustainable utilization of land by pastoral farmers. Bird species diversity can be used as an effective tool in assessing the sustainability of the practices implemented on farms, as well as assessing conservation efforts in the area. With further study, the use of birds as indicators of ecosystem integrity may play an important role in further refining the use of bird species diversity as an environmental assessment tool. The use of birds as such a tool is especially significant due to the ease of use, speed, and relative low cost of surveys on bird species diversity. Indicator species, once identified, may also further refine the use of birds for environmental assessment.

What can clearly be seen, during this study, was the far reaching effects land-use types can have on avian demography (refer to section 4.1). These changes can be indicative of changes in various environmental conditions, but it is obvious that some degradation must be taking place in order to be causing these changes in avian demography. The challenge for land users is to alter their management practices in order to reduce the impact on the environment. Because of the various importance of birds, as well as their mobility and sensitivity to environmental change (refer to section 1.1.2), birds can be very helpful to land-users in the assessment of existing degradation, as well as the monitoring of implemented restoration plans.

The fact that refuges such as Molopo Nature Reserve play an important part in the avian demography of the area, may also have important implications for management by land-users in the area. If such refuges are established at regular intervals in the area, they can help to conserve bird species diversity in the area without negatively affecting the productivity of the farms themselves. The position of some of the predatory birds in the food web (refer to section 1.1.2) will also ensure the inadvertent conservation of other species in these refuges. As mentioned, in section 5.2.3, more studies need to be done with regard to refuges, in this specific area, before they can be correctly implemented to have the desired effect.

CHAPTER 6
REFERENCES

Adamus, P.R., 2002. Methods for evaluating wetland condition: biological assessment for birds. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-023

Anderson, B.W., Ohmart, R.D. and Rice, J., 1983. Avian and vegetation community structure and their seasonal relationships in the Lower Colorado River Valley. *Condor.* 85:392-405

Andrewartha, H.G. and Birch, L.C., 1984. *The Ecological Web.* University of Chicago Press, Chicago

Anon., 2002. *Birds, Australian Terrestrial Biodiversity Assessment 2002.* Department of the Environment and Heritage, Canberra

Askins, R.A., Philbrick, M.J. and Sugeno, D.S., 1987. Relationships between the regional abundance of forest and the composition of forest bird communities. *Biological Conservation.* 39:129-152

Barnes, K.N., 2000. The Eskom red data book of birds of South Africa, Lesotho and Swaziland. Birdlife South Africa, Johannesburg.

Begon, M., Harper, J.L. and Townsend, C.R., 1996. *Ecology: Individuals, Populations and Communities.* 3rd Ed. Oxford, Blackwell Science Ltd.

Bennett, A.F., 1987. Conservation of mammals within a fragmented forest environment : the contributions of insular biogeography and autecology. 41-52 In: Saunders, D.A., Arnold, G.W., *Nature Conservation: the Role of Remnants of Native Vegetation.* Chipping Norton, NSW.

Beinroth, F.H., Eswaran, H., and Reich. P. F., 2000. Land quality and food security in Asia. In Press. *Proceedings of the 2nd International Workshop on Land Degradation*, Thailand

Bibby, C.J., Burgess, N.D. and Hill, D.A., 1993. *Bird census techniques.* Harcourt Brace & Company, London

Blydenstein, J., Hungerford, C.R., Day, G.I. and Humphrey R.R., 1957. Effect of domestic livestock exclusion on vegetation in the Sonoran Desert. *Ecology* 38: 522-526.

Bock, C.E., Bock, J.H., Kenney, W.R. and Hawthorne, V.M., 1984. Responses of birds, rodents, and vegetation to livestock exclosure in a semi desert grassland site. *Journal of Range Management* 37:63-89

Braithwaite, L.W., Turner, J. and Kelly, J., 1984. Studies on the arboreal marsupial fauna of eucalypt forests being harvested for woodpulp at Eden, N.S.W. III. Relationship between faunal densities, eucalypt occurrence and foliage nutrients, and soil parent materials. *Australian Wildlife Research* 10: 41-48

Brotons, L. and Herrando, S., 2001. Factors affecting bird communities in fragments of secondary pine forests in the North-Western mediterranean basin. *Acta Oecologica* 22: 1-11

Casey, D. and Hein, D., 1994. Effects of heavy browsing on a bird community in deciduous forest. *Journal of Wildlife Management.* 47: 829-836

Chapin, F.S., Torn, M.S. and Tateno, M., 1996. Principles of ecosystem sustainability. *The American Naturalist.* 148:1016-1037

Chase, M.K., 2002. Nest site selection and nest success in a song sparrow population: the significance of spatial variation. *The Condor* 104:103-116

Connell, J.H., 1978. Diversity in tropical rain forests and coral reefs. *Science.* 199:1302-1310

Connell, J.H., 1979. Tropical rainforests and coral reefs as open non-equilibrium systems. 141-163 in: *Population Dynamics.* The 20th Symposium of the British Ecological Society. Blackwell Science, Oxford

Coops, N.C. and Catling, P.C., 1997. Utilizing airborne multispectral videography to predict habitat complexity in eucalypt forest for wildlife management. *Wildlife Research.* 24: 691-703

Darwin, C., 1859. *The origin of the species.* Watts and Co. London

De Walt, S.J., Maliakal, S.K. and Denslow, J.S., 2003. Changes in vegetation structure and composition along a tropical forest chronosequence: Implications For Wildlife. *Forest Ecology and Management* 182:139-151

Dean, W.R.J. 2000. Factors affecting bird diversity patterns in the Karoo, South Africa. *South African Journal of Science* 96:609-616

Dean, W.R.J., Anderson, M.D., Milton, S.J. and Anderson, T.A., 2001. Avian assemblages in native *Acacia* and alien *Prosopis* drainage line woodland in the Kalahari, South Africa. *Journal of Arid Environments* 51:1-19

Dean, W.R.J., Milton, S.J. and Jeltsch, F., 1999. Large trees, fertile islands, and birds in arid savanna. *Journal of Arid Environments* (1999) 41:61-78

DeGraaf, R.M., Scott, V.E., Hamre, R.H., Ernst, L. and Anderson, S.H., 1991. *Forest and Rangeland Birds of the United States natural history and habitat use*. U.S. Department of Agriculture, Forest Service, Agricultural Handbook 688.

Doherty, M., Kearns, A., Barnett, G., Sarre, A., Hochuli, D., Gibb, H. and Dickman, C., 2000. The interaction between habitat conditions, ecosystem processes and terrestrial biodiversity – a review. *Australia State of the Environment, Second Technical Paper Series (Biodiversity)*, Department of the Environment and Heritage, Canberra

Dunstan, C.E. and Fox, B.J., 1996. The effects of fragmentation and disturbance of rainforest on ground-dwelling small mammals on the Robertson Plateau, New South Wales, Australia. *Journal of Biogeography.* 23:87-201

Edwards, D., 1983. A broad-scale structural classification of vegetation for practical purposes. *Bothalia* 14:705-712

Feeley, K., 2003. Analysis of avian communities in Lake Guri, Venezuela, using multiple assembly rule models. *Oecologia* 137: 104-113

Ferrier, S. and Watson, G., 1996. *An Evaluation of the effectiveness of environmental surrogates and modelling techniques in predicting the distribution of biological diversity.* Report to Environment Australia, Canberra

Fishpool, L.D.C. and Evans, M.I. eds. 2001. *Important bird areas in Africa and associated islands: priority sites for conservation*. Newbury and Cambridge, UK: Pisces Publications and Birdlife International (Birdlife Conservation Series No. 11)

Flather, C.H., 1996. Fitting species accumulation functions and assessing regional land-use impacts on avian diversity. *Journal of Biogeography* 23:155-168

Flather, C.H., Brady, S.J. and Inkley, D.B., 1992. Regional habitat appraisals of wildlife communities: A landscape-level evaluation of a resource planning model using avian distribution data. *Landscape Ecology*, 7:137-147

Fox, B.J. and Fox, B.J., 1986. The effect of fire frequency on the structure and floristic composition of a woodland understorey. *Australian Journal of Ecology.* 11:77-85

Gaston, K.J., 1996. What is Biodiversity?, *Biodiversity: a biology of numbers and difference.* Blackwells, Oxford

Ghilarov, A., 1996. What does "Biodiversity" mean – scientific problem or convenient myth. *Tree.* 11:304-306

Gibson, N. and Kirkpatrick, J.B., 1989. Effects of the cessation of grazing on the grasslands and grassy woodlands of the Central Plateau, Tasmania. *Australian Journal of Botany.* 37:55-63

Gonnet, J.M., 2001. Influence of cattle grazing on population density and species richness of granivorous birds (Emberizidae) in the arid plain of the Monte, Argentina. *Journal of Arid Environments* 48:569-579

Gonzalez, P., 2002. Program to monitor impacts of desertification and climate change in Africa. Famine Early Warning System Network (FEWS NET).

Gregory, R.D. and Baillie, S.R., 1998. Large scale habitat use of some declining British birds. *Journal of Applied Ecology* 35:785-799

Hansen, A.J. and Urban, D.L. 1992. Avian response to landscape pattern: the role of species' life histories. *Landscape Ecology* 7:163-180

Hendrix, P.F., 1996. Nearctic earthworm fauna in the southern USA: biodiversity and effects on ecosystem function. *Biodiversity and Conservation.* 5:223-234

Hobbs, R.J., 1993. The effects of landscape fragmentation on ecosystem processes in the Western Australian wheatbelt. *Biological Conservation.* 64: 193-201

Hockey, P., 2003. Land Invasions, *Africa Birds and Birding*, 8:35-41

James, C.D., Landsberg, J. and Morton, S.R., 1999. Provision of watering points in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments* 41:87-121

Johnson, M.D. and Sherry, T.W., 2001. Effects of food availability on the distribution of migratory warblers among habitats in Jamaica. *Journal of Animal Ecology* 70:546-560

Joubert, D.F. and Ryan, P.G., 1999. Differences in mammal and bird assemblages between commercial and communal rangelands in the Succulent Karoo, South Africa. *Journal of Arid Environments* 43:287-299

Kauffman J.B. and Pyke D., 2001. Range ecology, global livestock influences. 33–52 In: Levin, S. ed. *Encyclopedia of Biodiversity,* Vol. 5. San Diego: Academic Press.

Kellner, K., 2002. Desert Margins Program, Proceedings of a National Workshop: Appropriate Restoration Technologies in South Africa. Potchefstroom University for CHE. Potchefstroom. ISBN: 0-620-26424-1

Keyser, A.J., 2002. Nest predation in fragmented forests: landscape matrix by distance from edge interactions. *The Wilson Bulletin:* 114:186-191

Knick, S.T. and Rotenberry, J.T., 2000. Ghosts of habitats past: Contribution of landscape change to current habitats used by shrubland birds. *Ecology*, Jan 2000.

Kobal, S.N., Payne, N.F. and Ludwig, D.R., 1999. Habitat/area relationships, abundance, and composition of bird communities in 3 Grassland Types. *Transactions of the Illinois State Academy of Science* 92:109-131

Koford, R.R. and Best, L.B., 1996. Management of agricultural landscapes for the conservation of Neotropical migratory birds. 68-88 In: Tompson III, F.R. ed. *Management of agricultural landscapes for the conservation of Neotropical migratory birds.* U.S. Forest Service, General Technical Report.

Lack, D., 1933. Habitat selection in birds. *Journal of Animal Ecology.* 2:239-262

Liebezeit, J.R. and George, T.L., 2002. Nest predators, nest-site selection, and nesting success of the Dusky Flycatcher in a managed Ponderosa Pine forest. *The Condor.* 104:507-517

Low, A.B. and Rebelo, T.C., 1998. *Vegetation of South Africa, Lesotho and Swaziland.* Pretoria. Department of Environmental Affairs and Tourism.

MacArthur, R.H. and MacArthur, J.W., 1961.On Bird species diversity. *Ecology*, 42: 594-599

Maclean, G.L., 1993. *Roberts Birds of Southern Africa*, 6th Edition. Trustees of the John Voelcker Bird Book Fund, Cape Town.

Mangold, S., Kalule-Sabiti, M. and Walmsley, J. 2002. *State of the Environment Report 2002, North-West Province.* North West Province Department of Agriculture, Conservation and Environment. Directorate Environment and Conservation Management, Mafikeng.

Maesetas, J.D., Knight, R.L. and Gilgert, W.C., 2003. Biodiversity across a Rural Land-Use Gradient. *Conservation Biology*, 17:1425-1434

May, R.M., 1973. *Stability and Complexity in Model Ecosystems.* Princeton University Press, Princeton.

McNaughton, S.J., 1977. Diversity and stability of ecological communities: a comment on the role of empiricism in ecology. *American Naturalist.* 111:515-525

Meffe, G.K., and Carroll, C.R., 1997. *Principles of Conservation Biology* (2^{nd} ed.). Sinauer Associates, Sunderland.

Naddra, R. and Nyberg, D., 2001. Effects of afforestation of pasture on bird abundance. *Transactions of the Illinois State Academy of Science*, 94:243-250

O' Halloran, J., Walsh, P.M., Giller, P.S. and Kelly, T.C., 2002. Forestry and Bird Diversity in Ireland: A Management and Planning Guide. National Council for Forestry and Development, Dublin, Ireland.*Oikos.* 79:247-258

Parody, J.M., Cuthbert, F.J. and Decker, E.H. 2001. The effect of 50 years of landscape change on species richness and community composition. *Global Ecology & Biogeography* 10:305-313

Pimm, S.L., 1984. The complexity and stability of ecosystems. *Nature.* 307: 321-326

Powell, G.W., Cameron, K.J. and Newman, R.F., 2000. *Analysis of livestock use of riparian areas: literature review and research needs assessment for British Columbia.* Res. Br., B.C. Min. For. Victoria, B.C. Working Paper 52/2000.

Primack, R. B., 1998. *Essentials of Conservation Biology* (2nd ed.). Sinauer Associates, Sunderland.

Reich, P., Eswaran, H., Kapur, S. and Akca, E., 2000. Land degradation and desertification in the Desert Margins. *Bildiri Özetle*

Resource Assessment Commission (RAC), 2003. *The Use of Surrogate Measures for Determining Patterns of Species Distriburion and Abundance.* Research Paper No. 8. Australian Government Publishing Service, Canberra

Rodenhouse, N.L., Best, L.B., O'Connor, R.J. and Bollinger, E.K., 1993. Effects of temperate agriculture on neotropical migrant landbirds. In: Finch D.M. and Stangel P.W., eds. *Status and Management of Neotropical Migratory Birds*. U.S. For. Serv. Gen. Tech. Rep. RM-229. Rocky Mountain For. Serv. And Range Exp. Sta. Ft. Collins, CO.

Roth, R.R., 1976. Spatial heterogeneity and bird species diversity. *Ecology* 57:773-782

Saba, S.L. and Toyos, A., 2003. Seed removal by birds, rodents and ants in the Austral portion of the Monte Desert, Argentina. *Journal of Arid Environments* 53:115-124

Schiller, A., Hunsaker, C.T., Kane, M.A., Wolfe, A.K., Dale, V.H., Suter, G.W., Russell, C.S., Pion, G., Jensen, M.H. and Konar, V.C., 2001.Communicating ecological indicators to decision makers and the public. *Conservation Ecology* 5:19

Schluter, D. and Repasky, R.R., 1991. Worldwide limitations of finch densities by food and other factors. *Ecology*, 72:1763-1774.

Söderström, B., Kiema, S. and Reid, R.S., 2003. Intensified agricultural land-use and bird conservation in Burkina Faso. *Agriculture, Ecosystems and Environment*, 99:113-124

Stiles, D., 1995. Desertification is not a myth. *Desertification Control Bulletin*. Surrey Beatty and sons, Sydney, 26:29-36

Tainton, N.M., 1999. *Veld Management in South Africa*. Pietermaritzburg. University of Natal Press

Thiaw, I. and Chouchena-Rojas, M., 1999. Biological Diversity of Dryland, Mediterranean, Arid, Semi-arid, Savanna, and Grassland Ecosystems. IUCN-The World Conservation Union: *Fourth Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice*. Montreal, Canada, 21-25 June 1999

Tomoff, C.S., 1974. Avian species diversity in desert scrub. *Ecology*, 55:396-403

Turpie, J.K. and Ryan, P.G. 1999. What birders are worth: the value of birding in South Africa. *Africa Birds and Birding*, 4:64-68

U.S. E.P.A., 2002. *Methods for Evaluating Wetland Condition: Biological Assessment Methods for Birds*. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-023

Van den Berg, L. and Kellner, K., 2001. *Evaluation of Restoration Technologies Applied on Bare Patches in the Middelburg District*. Abstract of poster presented at The Arid Zone Ecology Forum 4-7 September 2001.

Valentin, C. and J.M. d'Herbes., 1999. Niger tiger bush as a natural water harvesting system. *Catena*, 37:231-256.

Walker, B.H., 1992. Biodiversity and ecological redundancy. *Conservation Biology.* 6:18-23

Wardle, D.A., Bonner, K.I. and Nicholson, K.S., 1997. Biodiversity and plant litter – experimental evidence which does not support the view that enhanced species richness improves ecosystem function. *Oikos,* 79:247-258

Waterhouse, F.L., Mather, M.H. and Seip, D., 2002. Distribution and abundance of birds relative to elevation and biogeoclimatic zones in coastal old-growth forests in southern British Columbia. *B.C. Journal of Ecosystems and Management* 2: 133-169

Whitford, W.G., 1997. Desertification and Animal Biodiversity in the desert Grasslands of North America. *Journal of Arid Environments* 37:709-720.

Williams, J., 2001. Biodiversity Theme Report: Disturbance Regimes and Biodiversity. *Australia State of the Environment Report 2001.* Commonwealth of Australia 2001, ISBN 0 643 06749 3

Williams, R.J. and Ashton, D.H., 1987. Effects of disturbance and grazing by cattle on the dynamics of heathland and grassland communities on the Bogong High Plains, Victoria. *Australian Journal of Botany.* 35:413-431

Wilson. B. A., 1994. Effects On Vertebrate Fauna And Implications For Fire Management And Conservation. In: *Fire and Biodiversity: The Effects and Effectiveness of Fire Management. Proceedings of the Conference held 8 - 9 October 1994*, Footscray, Melbourne Biodiversity Series, Paper No. 8, Biodiversity Unit

Willson, M.F., 1974. Avian community organization and habitat structure. *Ecology*. 55:1017-1029.

Wilson. E.O., 1992. *The Diversity of Life*. Belknap Press, Harvard.

Wimbush, D.J. and Costin, A.B., 1979. Trends in vegetation at Koscuisko. 1. Grazing trials in the subalpine zone, 1957-1971. *Australian Journal of Botany*. 27:741-787

Winter, M. and Faaborg, J., 1999. Patterns of Area Sensitivity in Grassland-Nesting Birds. *Conservation Biology*, 13:1424-1436

APPENDIX A: Bird list including new names, biological names and guilds

Roberts No	Common Name (OLD)	Common Name (NEW)	Biological Name	Feeding guild	Nesting guild
1	Ostrich	Ostrich	*Struthio camelus*	5	1
118	Secretarybird	Secretarybird	*Sagittarius serpentarius*	3	4
123	Whitebacked Vulture	Whitebacked Vulture	*Gyps africanus*	8	4
124	Lappetfaced Vulture	Lappetfaced Vulture	*Torgos tracheliotus*	8	4
127	Blackshouldered Kite	Blackshouldered Kite	*Elanus caeruleus*	3	4
136	Booted Eagle	Booted Eagle	*Hieraaetus pennatus*	3	6
140	Martial Eagle	Martial Eagle	*Polemaetus bellicosus*	3	4
146	Bateleur	Bateleur	*Terathopius ecaudatus*	3	4
149	Steppe Buzzard	Steppe Buzzard	*Buteo vulpinus*	3	6
161	Gabar Goshawk	Gabar Goshawk	*Melierax gabar*	3	4
162	Pale Chanting Goshawk	Southern Pale Chanting Goshawk	*Melierax canorus*	3	4
169	Gymnogene	African Harrier Hawk	*Polyboroides typus*	3	4
171	Peregrine Falcon	Peregrine Falcon	*Falco peregrinus*	3	6
181	Rock Kestrel	Rock Kestrel	*Falco [tinnunculus] rupicolis*	3	5
183	Lesser Kestrel	Lesser Kestrel	*Falco naumanni*	3	4
194	Redbilled Francolin	Redbilled Francolin	*Pternistes adspersus*	1	1
200	Common Quail	Common Quail	*Coturnix coturnix*	1	1
203	Helmeted Guineafowl	Helmeted Guineafowl	*Numida meleagris*	1	1
230	Kori Bustard	Kori Bustard	*Ardeotis kori*	1	1
237	Red-crested Korhaan	Red-crested Korhaan	*Eudopotis ruficrista*	1	1
239b	Northern Black Korhaan	Northern Black Korhaan	*Eudopotis afraoides*	1	1
255	Crowned Plover	Crowned Lapwing	*Vanellus coronatus*	1	1
297	Spotted Dikkop	Spotted Thick-knee	*Burhinus capensis*	1	1
299	Burchell's Courser	Burchell's Courser	*Cursorius rufus*	1	1
301	Doublebanded Courser	Doublebanded Courser	*Rhinoptilus africanus*	1	1
345	Burchell's Sandgrouse	Burchell's Sandgrouse	*Pterocles burchelli*	1	1
349	Rock Pigeon	Speckled Pigeon	*Columba guinea*	2	4
354	Cape Turtle Dove	Cape Turtle Dove	*Streptopelia capicola*	2	4
355	Laughing Dove	Laughing Dove	*Streptopelia senegalensis*	2	4
356	Namaqua Dove	Namaqua Dove	*Oena capensis*	2	4
375	African Cuckoo	African Cuckoo	*Cuculus gularis*	1	7
378	Black Cuckoo	Black Cuckoo	*Cuculus clamosus*	1	7
382	Jacobin Cuckoo	Jacobin Cuckoo	*Oxylophus jacobinus*	1	7
386	Diederik Cuckoo	Diderick Cuckoo	*Chrysococcyx caprius*	1	7
392	Barn Owl	Barn Owl	*Tyto alba*	3	4
397	Whitefaced Owl	Southern White-faced Scops-Owl	*Ptilopsus granti*	3	4
398	Pearlspotted Owl	Pearl-Spotted Owlet	*Glaucidium perlatum*	3	4
401	Spotted Eagle Owl	Spotted Eagle-Owl	*Bubo africanus*	3	4
406	Rufouscheeked Nightjar	Roufous-Cheeked Nightjar	*Caprimulgus rufigena*	1	1

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Roberts No.	Common Name (OLD)	Common Name (NEW)	Biological Name	Feeding guild	Nesting guild
411	Eurasian Swift	Common Swift	*Apus apus*	1	6
415	Whiterumped Swift	White-Rumped Swift	*Apus caffer*	1	5
417	Little Swift	Little Swift	*Apus affinis*	1	5
425	Whitebacked Mousebird	White-Backed Mousebird	*Colius colius*	4	4
426	Redfaced Mousebird	Red-Faced Mousebird	*Urocolius indicus*	4	4
437	Striped Kingfisher	Striped Kingfisher	*Halcyon chelicuti*	1	4
438	Eurasian Bee-eater	European Bee-Eater	*Merops apiaster*	1	1
444	Little Bee-eater	Little Bee-Eater	*Merops pusillus*	1	1
445	Swallowtailed Bee-eater	Swallow-Tailed Bee-Eater	*Merops hirundineus*	1	1
447	Lilacbreasted Roller	Lilac-Breasted Roller	*Coracias caudata*	1	4
449	Purple Roller	Purple Roller	*Coracias naevia*	1	4
451	African Hoopoe	African Hoopoe	*Upupa africana*	1	1
452	Redbilled Woodhoopoe	Green Wood-Hoopoe	*Phoeniculus purpureus*	1	4
454	Scimitarbilled Woodhoopoe	Common Scimitarbill	*Rhinopomastus cyanomelas*	1	4
457	Grey Hornbill	African Grey Hornbill	*Tockus nasutus*	2	4
459	Southern Yellowbilled Hornbill	Southern Yellow-Billed Hornbill	*Tockus leucomelas*	7	4
465	Acacia Pied Barbet	Acacia Pied Barbet	*Tricholaema leucomelas*	4	4
473	Crested Barbet	Crested Barbet	*Trachyphonus vaillantii*	1	4
474	Greater Honeyguide	Greater Honeyguide	*Indicator indicator*	1	7
481	Bennett's Woodpecker	Bennett's Woodpecker	*Campethera bennettii*	1	4
483	Goldentailed Woodpecker	Golden-Tailed Woodpecker	*Campethera abingoni*	1	4
486	Cardinal Woodpecker	Cardinal Woodpecker	*Dendropicos fuscescens*	1	4
487	Bearded Woodpecker	Bearded Woodpecker	*Dendropicos namaquus*	1	4
493	Monotonous Lark	Monotonous Lark	*Mirafra passerina*	1	1
495	Eastern Clapper Lark	Eastern Clapper Lark	*Mirafra fasciolata*	1	1
497	Fawncoloured Lark	Fawn-Coloured Lark	*Mirafra africanoides*	1	1
498	Sabota Lark	Sabota Lark	*Mirafra sabota*	1	1
505	Dusky Lark	Dusky Lark	*Pinarocorys nigricans*	1	6
506	Spikeheeled Lark	Spike-Heeled Lark	*Chersomanes albofasciata*	1	1
507	Redcapped Lark	Red-Capped Lark	*Calandrella cinerea*	1	1
508	Pinkbilled Lark	Pink-Billed Lark	*Spizocorys conirostris*	1	1
515	Chestnutbacked Finchlark	Chestnut-Backed Sparrowlark	*Eremopterix leucotis*	1	1
516	Greybacked Finchlark	Grey-Backed Sparrowlark	*Eremopterix verticalis*	1	1
518	Eurasian Swallow	Barn Swallow	*Hirundo rustica*	1	6
520	Whitethroated Swallow	White-Throated Swallow	*Hirundo albigularis*	1	5
523	Pearlbreasted Swallow	Pearl-Breasted Swallow	*Hirundo dimidiata*	1	5

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526	Greater Striped Swallow	Greater Striped Swallow	*Hirundo cucullata*	1	5
529	Rock Martin	Rock Martin	*Hirundo fuligula*	1	1
533	Brownthroated Martin	Brown-Throated Martin	*Riparia paludicola*	1	1
541	Forktailed Drongo	Fork-Tailed Drongo	*Dicrurus adsimilis*	1	4
543	European Golden Oriole	Eurasian Golden Oriole	*Oriolus oriolus*	1	6
547	Black Crow	Cape Crow	*Corvus capensis*	8	4
548	Pied Crow	Pied Crow	*Corvus albus*	8	4
552	Ashy Tit	Ashy Tit	*Parus cinerascens*	1	3
557	Cape Penduline Tit	Cape Penduline-Tit	*Anthoscopus minutus*	1	3
560	Arrowmarked Babbler	Arrow-Marked Babbler	*Turdoides jardineii*	1	3
563	Pied Babbler	Southern Pied Babbler	*Turdoides bicolor*	1	3
567	Redeyed Bulbul	African Red-Eyed Bulbul	*Pycnonotus nigricans*	1	3
580	Groundscraper Thrush	Groundscraper Thrush	*Psophocichla litsitsirupa*	1	4
583	Shorttoed Rockthrush	Short-Toed Rock-Thrush	*Monticola brevipes*	1	1
587	Capped Wheatear	Capped Wheatear	*Oenanthe pileata*	1	1
589	Familiar Chat	Familiar Chat	*Cercomela familiaris*	1	1
595	Anteating Chat	Ant-Eating Chat	*Myrmecocichla formicivora*	1	1
601	Cape Robin	Cape Robin-Chat	*Cossypha caffra*	1	1
615	Kalahari Robin	Kalahari Scrub-Robin	*Cercotrichas paena*	1	3
621	Chestnut-vented Titbabbler	Chestnut-vented Titbabbler	*Parisoma subcaeruleum*	1	3
651	Longbilled Crombec	Long-Billed Crombec	*Sylvietta rufescens*	1	3
653	Yellowbellied Eremomela	Yellow-Bellied Eremomela	*Eremomela icteropygialis*	1	3
664	Fantailed Cisticola	Zitting Cisticula	*Cisticola juncidis*	1	2
665	Desert Cisticola	Desert Cisticola	*Cisticola aridulus*	1	2
671	Tinkling Cisticola	Tinkling Cisticola	*Cisticola rufilatus*	1	2
685	Blackchested Prinia	Black-Chested Prinia	*Prinia flavicans*	1	3
689	Spotted Flycatcher	Spotted Flycatcher	*Muscicapa striata*	1	4
695	Marico Flycatcher	Marico Flycatcher	*Bradornis mariquensis*	1	4
697	Chat Flycatcher	Chat Flycatcher	*Bradornis infuscatus*	1	3
698	Fiscal Flycatcher	Fiscal Flycatcher	*Sigelus silens*	1	4
703	Pririt Batis	Pririt Batis	*Batis pririt*	1	3
713	Cape Wagtail	Cape Wagtail	*Motacilla capensis*	1	3
716	Grassveld Pipit	African Pipit	*Anthus cinnamomeus*	1	1
718	Plainbacked Pipit	Plain-Backed Pipit	*Anthus leucophrys*	1	1
719	Buffy Pipit	Buffy Pipit	*Anthus vaalensis*	1	1
731	Lesser Grey Shrike	Lesser Grey Shrike	*Lanius minor*	7	3
732	Fiscal Shrike	Common Fiscal	*Lanius collaris*	7	3
733	Redbacked Shrike	Red-Backed Shrike	*Lanius collurio*	7	6

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739	Crimsonbreasted Shrike	Crimson-Breasted Shrike	*Laniarius atrococcineus*	7	3
741	Brubru	Brubru	*Nilaus afer*	7	3
743	Threestreaked Tchagra	Brown-Crowned Tchagra	*Tchagra australis*	7	3
764	Cape Glossy Starling	Cape Glossy Starling	*Lamprotomis nitens*	5	4
779	Marico Sunbird	Marico Sunbird	*Cinnyris mariquensis*	6	3
788	Dusky Sunbird	Dusky Sunbird	*Cinnyris fusca*	6	3
798	Redbilled Buffalo Weaver	Red-Billed Buffalo-Weaver	*Bubalornis niger*	2	4
799	Whitebrowed Sparrowweaver	White-Browed Sparrow-Weaver	*Plocepasser mahali*	2	4
802	Great Sparrow	Great Sparrow	*Passer motitensis*	2	4
803	Cape Sparrow	Cape Sparrow	*Passer melanurus*	2	4
804	Southern Greyheaded Sparrow	Southern Grey-Headed Sparrow	*Passer diffusus*	2	4
805	Yellowthroated Sparrow	Yellow-Throated Petronia	*Petronia superciliaris*	2	4
806	Scalyfeathered Finch	Scaly-Feathered Finch	*Sporopipes squamifrons*	2	4
814	Southern Masked Weaver	Southern Masked Weaver	*Ploceus velatus*	2	4
821	Redbilled Quelea	Red-Billed Quelea	*Quelea quelea*	2	4
834	Melba Finch	Green-Winged Pytilia	*Pytilia melba*	2	4
845	Violeteared Waxbill	Violet-Eared Waxbill	*Granatina granatina*	2	3
846	Common Waxbill	Common Waxbill	*Estrilda astrild*	2	3
847	Blackcheeked Waxbill	Black-Faced Waxbill	*Estrilda erythronotos*	2	3
856	Redheaded Finch	Red-Headed Finch	*Amadina erythrocephala*	2	4
861	Shafttailed Whydah	Shaft-Tailed Whydah	*Vidua regia*	2	7
870	Blackthroated Canary	Black-Throated Canary	*Serinus atrogularis*	2	4
878	Yellow Canary	Yellow Canary	*Serinus flaviventris*	2	4
884	Goldenbreasted Bunting	Golden-Breasted Bunting	*Emberiza flaviventris*	2	3
887	Larklike Bunting	Lark-Like Bunting	*Emberiza impetuani*	2	3

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