Chapter 5

Discussion

5.1 Introduction

The results presented in Chapter 4 are based on the investigation of a combination of a number factors influencing avian distribution, one of which is land use. The research for this dissertation suggests that there are other factors affecting avian distribution, including climate, weather, vegetation, vegetation structure and disturbance. This is confirmed by Penry (1994), who suggested that there are a number of factors governing bird distribution and bird movements and that it is the variation of these factors which combine to affect bird distribution patterns (Penry, 1994). The title of this dissertation implies that it is land use alone that influences the distribution of birds, but land use is only one part of a complex interaction of a number of factors resulting in the distribution patterns and movements of birds. In order to investigate these interactions, four ways of analysing the data were used; geostatistics, univariate, bivariate analyses, and multivariate analyses. The discussion will focus on all four and integrate the findings with theory and published results.

5.2 Discussion

The vegetation structure of the study area followed the patterns suggested by Perkins (2006; and see Chapter 3). Interpolated information of the vegetation structure of the study area (Figures 4.41 - 4.45) follows the vegetation patterns, also suggested by Perkins (2006). Tree cover of the study area (Figure 4.42) and woody biomass of the Mopane Mine lease area (Figure 3.14) had similar patterns, with highest biomass on the rocky hills and in the riparian vegetation. Areas of reduced woody biomass in the study area (Figures 4.43 - 4.45) correspond with the areas of reduced woody biomass in the Perkins (2006) study (Figure 3.14), which was the savannah between the hill and riparian vegetation categories. Bare ground (Figure 3.13) (Figure 4.45) was mainly in the high intensity grazing area outside the fenced lease area, predominantly along the river courses. Grass cover in the study area (Figure 4.44) declined from east to west, while bare ground (Figure 4.45) declined from west to east, following the grazing intensity of the study area.

The vegetation structure of the current study (Figures 4.1 & 4.87) gives a clear indication of the different vegetation categories, with the woody biomass in the MLM and the RLM being significantly higher than both the ILM and CLM.

The information gained from the Perkins (2006) study suggests that there are clear differences in the vegetation structure and vegetation communities when comparing the vegetation of the rocky hills and riparian vegetation to the surrounding vegetation. This was very evident in the current study.

Trager and Mistry (2003) examined the effects of kopjes, which they describe as naturally occurring insular rock outcrops, on avian communities. What was evident from Trager and Mistry (2003) was that the kopjes formed a small portion of the study area in the Serengeti landscape, but hosted a diverse, yet poorly documented, set of biotic communities. The effect on avian communities will be discussed in greater detail in this chapter. The point being made is that the vegetation cover of the kopjes was significantly different when compared to the surrounding vegetation matrix, as suggested in Perkins's (2006) study.

Much of the MLM area is dotted with rocky hills, with a high ridge evident, running from north to south on the eastern section of the study area. These areas of high ground have a distinct vegetation structure and vegetation communities, as confirmed by Perkins (2006). Both the ILM and CLM have few rocky hills with the exception of the CLM, which has the highest outcrop in the study area, Ntimbali Hill, at the northern edge of the CLM (Figure 3.4). The effect of Ntimbali Hill on the results of birds recorded at C21 and C25 was evident and will be referred to when discussing distribution of avifauna.

The points drawn from the Perkins (2006) study, which are relevant in the current study, include:

1. There are three broad vegetation communities, namely riparian, rocky hill and savannah communities.
2. The change from one vegetation community to the next is very distinct over a short distance.
3. The woody biomass corresponds with the different vegetation communities.
4. The woody biomass of the savannah between the hill and riparian vegetations is considerably lower than these two areas.
5. Heavy stocking rates resulting in over-grazing and fuel wood collection had resulted in large areas of bare ground.

5.3 Avifauna distribution patterns

The results presented in Chapter 4 indicate a number of factors contributing to bird distribution patterns. These include climate and local weather patterns, vegetation structure of the region, and vegetation structure of the study area, as well as, of course, the different land use types. It is with this interaction of factors that the results of Chapter 4 will be discussed in more detail. Bird species richness, numbers of birds and guild distribution patterns will be examined combined with the climate and vegetation patterns already presented in Chapters 1 and 2.

All species cannot be treated in the same manner when assessing the impact of land use on birds and different bird groups (Blake & Karr, 1984). Knowledge of bird species ecology will assist when assessing the reasons why certain species are present, while others are not (Blake & Karr, 1984).

5.3.1 Bird species richness

The Geostatistical analysis provides a clear picture of species richness distribution over the entire study area (Figure 4.6). The trend was a decrease in species richness from the north-east to the south-west. This trend was stable in both summer (Figure 4.7) and winter (Figure 4.8), with slightly more species being recorded during the winter counts. Shannon diversity (Figure 4.15) indicates a similar pattern of diversity of species richness, with the trend of species diversity decreasing from the north-east to the south-west.

ANOVA confirmed (Figures 4.63 - 4.65) the results presented by the geostatistical analysis. There was significantly greater bird species richness when comparing both the ILM and RLM with the CLM (ANOVA: Bonferroni's multiple comparison tests; $p<0.05$). A very significant difference was recorded when comparing the species richness of the MLM and the CLM, (ANOVA: Bonferroni's multiple comparison tests; $p<0.001$) (Figure 4.63). The species richness of the summer counts produced a significant difference when comparing the MLM and the CLM, (ANOVA: Bonferroni's multiple comparison tests; $p<0.05$) (Figure 4.64). The winter counts produced a very significant difference when comparing the MLM and the CLM, (ANOVA: Bonferroni's multiple comparison tests: $p<0.001$) (Figure 4.65), while a significant difference was recorded when comparing species richness of the ILM and CLM, (ANOVA: Bonferroni's multiple comparison tests: $p<0.05$) (Figure 4.65). The seasonal differences suggested that winter counts were significantly different for the MLM and the ILM when compared to the CLM, suggesting the higher species richness may be a result of the species using the MLM and the ILM as areas of refuge in winter (Trager & Mistry, 2003). The summer differences when comparing the species richness were not as marked, suggesting that there was an even spread of species over the summer months.

A two-way ANOVA was used on the mean aggregated values of bird species richness. The results of the two-way analysis comparing land use and seasons on the distribution of species richness (Figure 4.73) indicate that there was a variance as a result of these two parameters. Land use accounts for 10.2% in the variance of species richness (ANOVA: Bonferroni's multiple comparison tests: $p=0.0002$) which is very significant. Likewise, the season accounts for a 12.03% difference in the variance of species richness (ANOVA: Bonferroni's multiple comparison tests; $p<0.0001$) which is also very significant (Figure 4.73). Both the land use and the seasons had a significant effect on species richness for each of the land use types.

Non-metric Multidimensional Scaling (NMS) was used to analyse the relationship between species distribution, using the presence / absence criteria and land use. The Monte Carlo tests recommended three axes (all axes $p<0.04$) (Figure

4.83). Species richness for the different land use types does follow a pattern, with the different census points for each land use having similar species richness (Figure 4.83). C21 was associated with RLM and MLM, which was understandable, as the point was at the base of a rocky hill with a vegetation structure of greater woody biomass and woody species richness when compared to the immediate surroundings of intensively grazed savannah. C25 was due west of C21 and also close to a rocky hill, which may also account for a different species richness compared to the other census points of this land use. The influence of the riparian vegetation and the small farm were less influential as these features were a kilometre away when compared to C21. As mentioned previously R17, although under RLM, was some distance away from the riparian vegetation, yet the species richness was similar to other points of RLM. The possible reason for this was that R17 was close to a rocky hill and a small farm with cattle, sheep, goats and fields of maize and some vegetables – therefore an ectone. The combination of the rocky hill and its vegetation structure, the close proximity to a small farm with its availability of food for birds and the close proximity to the river could contribute to the high species richness similar to the RLM points.

The statistical analysis confirmed that there were significant differences in species richness when comparing the different land use types and when comparing the seasons, but whether these results were influenced by grazing intensity is uncertain.

The increased complexity of vegetation showed a positive relationship between higher density, biomass, and energy requirements of the bird populations (Allan *et al*., 1997; Lack, 1986). Lack (1986) attributed this to the micro-climate created by trees and bushes. A factor that does emerge from Lack's (1986) study is that the species in the more open areas are not simply a subset of the denser habitats. There were a number of species that occurred in the entire study area, while there were those that occurred only in the areas of more dense vegetation, as well as those that occurred only in the openly vegetated areas (Lack, 1986).

Changes in vegetation type, from grassland to forest particularly, will affect grassland bird species and communities (Allan *et al*., 1997). Allan *et al.* (1997) used satellite imagery, which was then superimposed on bird atlas maps, using a similar grid system, making the comparison of forested areas and bird distribution possible. The reduction of grassland to forestation of alien trees had a marked negative effect on bird species diversity, but a positive effect on some species, to a much lesser extent. This positive effect is further reduced, on closer examination, as birds inhabiting the alien forest used it primarily for roosting, breeding or cover, while they had to forage at a distance in the surrounding natural areas (Allan *et al.,* 1997).

The current study clearly indicates that vegetation structure had an effect on the bird species richness, which was confirmed by other researchers who suggested that vegetation structure, as opposed to vegetation species composition, and the quantity of indigenous vegetation play a pivotal role in avian species diversity (Dean 2000; MacArthur & MacArthur, 1961). Trager and Mistry (2003) noted that habitat requirements of bird species differ in diverse avian communities, which in turn influences species assemblages when confronted by changes in vegetation. The conclusion reached by Trager and Mistry (2003) confirmed that the kopjes of the Serengeti National Park represented a unique habitat type, which influenced avian communities when compared to the surrounding vegetation matrix.

In the current study, the primary land use for all four areas was livestock farming, mostly cattle, but with some small stock being farmed on the CLM. The grazing intensity followed the opposite trend to vegetation cover (Figure 4.41), with the highest grazing pressure in the west and decreasing to the north-east of the study area.

An historical parallel can be used here. A unique set of circumstances was created by the previous Apartheid Government of South Africa, particularly during the 1960's, 1970's and 1980's. During this time, the government divided the country along racial lines with self-governing states, called homelands, governed by the Black population group. These were primarily subsistence farming areas. The areas of White government were areas of intensive farming and industrial practices (Fairbanks, 2004). Fairbanks (2004) drew comparisons between two different land use types, which adjoined one another. Kwa-Zulu Natal was a Black governed province, which experienced intensive subsistence land use, primarily resulting in the over-exploitation of the grasslands by overgrazing and destruction of woody vegetation for fuel and dwelling construction, as well as an agricultural production that offered little potential to bird species because of poor production (Fairbanks, 2004). However, there was a positive relationship between avian richness and intensive human development in the province of KwaZulu-Natal under White governance. The avian richness in these developed areas could be attributed to artificial land-use by the creation of dams, tree planting, planting crops and constructing buildings. The richness was not necessarily an increase in the indigenous bird species, but rather an increase in more generalist species (Fairbanks, 2004). By contrast, the subsistence management areas of the province showed a decline in species richness. Subsistence farming was primarily stock farming, which affects grasslands significantly as a result of overgrazing (Fairbanks, 2004). The results of this study, although on a smaller scale, confirm the effects of different land use on bird communities.

Taylor (1986) showed in his research that cattle grazing had a significant effect on passerine birds, with the intensively grazed areas having the most marked negative result on bird species richness. The numbers and species of birds decreased as grazing increased (Taylor, 1986). Birds use different strata of the vegetation structure from the upper canopy to the lower strata, all of which can be effected by grazing intensity. The lower strata are affected almost immediately by grazing as grasses are a large part of the food required for the lower stratum group of birds. Intermediate and upper strata of vegetation used by birds are affected by longer periods of grazing as young trees are either trampled or grazed inadvertently, with the result that few young trees grow to replace the older trees (Taylor, 1986). Hudson and Bouwman (2007) studied the impacts grazing intensity and management type on four different land uses in the North West Province of South Africa. The floristic composition for the four sites was similar but the different management approaches resulted in perturbations in the vegetation structure. Bird communities in the Kalahari varied between the different land use types. The natural area or control of the study had the highest bird diversity because of more niches being available (Hudson & Bouwman, 2007)

The current study focused on the effects of land use on the avian diversity in north-east Botswana, with reference to grazing. It is worth comparing the effects of over-utilisation of the vegetation in a natural environment, which could assist in the understanding of these impacts.

Herremans (1995) researched the change in vegetation structure by elephants in northern Botswana, particularly on the Chobe River waterfront. During the winter months there was a large concentration of elephants accessing water from the river, which resulted in a change in the vegetation structure of the area. Much of the bush and large trees were removed by the elephants and replaced by low scrub with considerable open ground and only scattered large trees. Herremans (1995) noted that avian species diversity remained constant – although there was a loss in the canopy and woodland bird species, there was a replacement by bird species utilising the emerging scrub and open areas (Chadwick *et al.,* 1995).

The statistical analysis confirmed that there were differences in avian species richness as a consequence of both land use and the seasons. The trend indicated higher species richness for the MLM and the ILM for the summer with species increasing in the winter. This is confirmed by the Shannon Diversity Index (Figure 4.15). The distribution of insular granite outcrops or kopjes may have influenced avian species richness. The increase in species richness during the winter suggests that the MLM, ILM and to some degree the RLM are areas of refuge during the winter months. The consistent pattern of species richness strongly suggests that different land uses will affect species richness relative to land use intensity.

Literature cited in chapter two suggests that IDH will positively influence species richness. The avifauna of MLM was positively influenced by the low intensity grazing regime on this land use. Bird species richness was highest in the MLM during the duration of this study but as the intensity of the disturbance (grazing) increased through the ILM and both the RLM and the CLM bird species richness dropped progressively.

5.3.2 Bird numbers

A trend similar to bird species richness was noted when compared with the numbers of birds per land use. The trend for both variables followed a decrease from the north-east to the south-west. The maps produced by the geostatistical analysis (Figures 4.9 - 4.11) confirm this trend, with the highest number of birds found predominantly in the ILM and the MLM, declining in a westerly direction, with the lowest recorded numbers in the CLM. The highest numbers of birds recorded in the summer (Figure 4.10) was 67.9 birds and the lowest in the summer was 46.7 birds. The winter counts (Figure 4.11) had a high of 99.5 birds and a low of 47.2 birds. The reason for the increased number of birds in the winter could be that birds were using the area as a refuge during the winter months.

The decrease in numbers in a westerly direction was confirmed when using ANOVA one-way analysis of bird numbers for the count. Bird numbers were significantly different when comparing the MLM and the CLM (ANOVA: Bonferroni’s multiple comparison tests: $p<0.001$). When comparing the bird numbers of the RLM and the CLM (ANOVA: Bonferroni’s multiple comparison tests: $p<0.01$) there was a significant change in bird numbers, while bird numbers of the ILM and CLM were also significantly different (ANOVA: Bonferroni’s multiple comparison tests: $p<0.05$) (Figure 4.66).

The trend when comparing species richness and bird numbers was further confirmed when analysing the summer and winter counts for the numbers of birds. In summer, there were no significant differences with the exception when comparing numbers of MLM and CLM (ANOVA: Bonferroni’s multiple comparison tests; $p<0.05$). Bird numbers, like species richness, were more evenly distributed over the land use types during the summer (Figure 4.67). The comparison of bird numbers of the different land use types during winter produced more significant differences. When comparing the numbers of birds during the winter counts, there was a very significant difference between MLM and the CLM (ANOVA: Bonferroni’s multiple comparison tests; $p<0.01$). The comparison of bird numbers during the winter between the RLM and the CLM was significant (ANOVA: Bonferroni’s multiple comparison tests: $p<0.05$)(Figure 4.68). These results clearly indicate significant differences between the MLM and the RLM when compared to the CLM throughout the count and between the seasons. The difference between the land use types during summer was not as marked as winter, possibly indicating that the land uses, particularly the MLM and the RLM, could be used as refuge areas for birds during the winter months (Hudson & Bouwman, 2007; Trager & Mistry, 2003).

A two-way ANOVA for mean numbers of birds and land use as variables showed that land use played a very significant role in the distribution of bird numbers, (ANOVA: Bonferroni’s multiple comparison tests; $p<0.0001$). Seasons also played a very significant role in the distribution of bird numbers, (ANOVA: Bonferroni’s multiple comparison tests; $p<0.0001$) (Figure 4.72).

The NMS bi-plot (Figure 4.82) shows the distribution of points according to the numbers of birds recorded at each point with the different land uses shown. The Monte Carlo tests were significant for all three axes (all three $p=0.04$). The grouping of the points was consistent with the land use types, with the RLM counts being very distinct. R17 appears as an outlier, which could be a result of the unique set of circumstances found at that point. As mentioned previously, R17, although grouped with the RLM points, falls some distance from the river, with a rocky hill within a few meters and a small farm very close to the point location. These factors could have caused the position to appear as an outlier, creating opportunities for bird numbers to differ when compared of the remaining RLM points. C21 and C25 had a different topography compared to the remaining CLM points (Figure 4.82). Again these points had rocky hills in close proximity, which, with their marked difference in vegetation structure, could have influenced the numbers of birds recorded at these points. Both C21 and C25 were positioned amongst MLM, which has a different vegetation structure as a result of the rocky hills. These are almost inaccessible to livestock, particularly cattle.

The current study attempted to assess the effect of land use on birds, but, as each land use is managed differently, the environment becomes fragmented, creating different vegetation structures. The edge effects that result from the transition of different ecological types have for many years been recognised by wildlife practitioners as areas of high biotic diversity (Harris, 1988). The scale of this study was also probably too large (1 X 1 km grid) to capture changes in avian parameters that probably occur over smaller distances across ecotones. Nevertheless, the changes in bird parameters noted above suggest that an ecotone effect was in play.

Fairbanks (2004) noted that the vegetation patchiness created by high human land transformation could have a positive result on species diversity, with generalist species migrating into these areas and the resident species remaining (Fairbanks, 2004).

The changes in vegetation as a consequence of agricultural land use result in fragmentation of the environment, impacting directly on some bird species, but also creating secondary impacts on some small mammals, insects and bird populations (Maitima *et al.,* 2009*).* Where two different plant communities come together (ecotone), there is normally an increase in species, both plant and animal. The increase in animal species can be attributed to the combination of the species of each of the two plant communities, including the species that use the ecotone as their preferred habitat (Gates & Gysel, 1978). The net result will be that these ecotones have a higher population of animals, particularly birds, and therefore more nests exposed to predation and parasitism when compared a homogeneous environment (Evans, 2004; Gates & Gysel, 1978).

Changes in habitat and predation can lead to population declines (Evans, 2004). There are a number of reasons that habitat fragmentation could result in increased predation affecting bird populations. Evans (2004) presented a number of interactions between habitat change / edge effects and predation rates. Habitat change could result in reduced food availability, which can lead to a chain of possible effects (Chapter 2 section 2.4)

Habitat change could force birds to nest in less suitable sites or in greater densities, thus exposing these nests to detection by predators. Evans (2004) suggested that it is possible that there will be declines in farm land birds as a result of anthropogenic alterations to ecosystems caused by farming methods. These declines may be the result of increased predation.

Cary and Temple (1988) used a computer model in their study on the effects of fragmentation on bird populations. They worked with fecundity as a variable of bird populations as a function of the distance from the ecological edge. As the landscape became more fragmented, the breeding success of the bird populations dropped significantly. There was a geometric increase in the populations of birds in the portion of forest habitat that is near the ecotone, which was a direct result of increased fragmentation. The consequence of continued fragmentation is that in time there will be little or no habitat interior (Cary & Temple, 1988). The effects of predation, competition and parasitism that are more evident at forest edges, become more meaningful as they have a direct effect on the dynamics of bird populations (Andren & Angelstam, 1988). The results of the computer model compared favourably with actual results made in fragmented forests in southern Wisconsin (Cary & Temple, 1988).

Despite the presence of more kopjes in the MLM the overall distribution patterns and statistical analysis confirm that bird numbers were affected by land use and the seasons. A similar scenario was evident with species richness, as bird numbers increased in winter in the MLM, ILM and RLM but remained constant in the CLM. The current study shows that land use intensity affects the numbers of birds with the magnitude of the affect being relative to the intensity of land use. Reference is made to the IDH suggesting that intermediate levels of disturbance will have a positive result on species richness and bird numbers. This has been the case in this study with bird numbers decreasing as grazing intensity increases.

5.3.3 Feeding guild distribution

Geostatisical interpolated maps in figures 4.16 – 4.35 represent the distribution patterns of avian feeding guilds for the entire census and the seasonal counts. The distribution patterns depicted some guilds increasing under different land management practices, while other guilds decreased.

Lack (1986) studied the effects of food availability as a consequence of erratic weather conditions in East Africa. Fruit, nectar and grass seeds were affected directly by rainfall, with peaks being soon after significant rain. Arthropods peaked at the end of each rainy season with numbers reaching five times those in the dry season. Although there were peaks in the food availability, all the food types for the different feeding guilds were available throughout the year (Lack, 1986) and this was presumed to be the case for the current study area as well.

The results of this study are confirmed by the findings of others (Perkins, 2006; Trager & Mistry, 2003) that the topography and, in particular, insular rocky outcrops have a very distinctive vegetation when compared to the surrounding matrix. The variation in the structure of the vegetation may have also influenced the distribution of the bird feeding guilds (Pearman, 2002). However, the statistical analysis confirmed that there were differences in the distribution of the different feeding guilds as a consequence of both land use and season. The different feeding guilds were impacted differently as a consequence of land use intensity.

5.3.3.1 Frugivores

The distribution of the frugivores is well illustrated using interpolated maps (Figures 4.16 - 4.20). The overall pattern (Figure 4.16) shows the distribution predominantly in the RLM, stretching eastwards into the MLM and the north-eastern portion of the ILM. The CLM showed very few to no frugivores throughout the area. Species richness for the summer and winter was fairly constant, but showed the highest number of frugivores in winter (Figure 4.19), more than double the number of frugivores recorded in summer (Figure 4.17). The RLM and the MLM had the highest tree cover index (Figures 4.42 & 4.87), with many of these trees being Figs *Ficus spp.* and Corkwood *Comiphora spp.*, which have fruits readily eaten by the frugivore feeding guild (Pulgrave, 1981).

The two-way ANOVA (Figure 4.76) showed that the effect of land use on frugivore distribution was significant (ANOVA: Bonferroni's multiple comparison tests; p<0.0001), while the seasons also had a significant effect on the distribution of frugivores (ANOVA: Bonferroni's multiple comparison tests; p=0.0461).

NMS bi-plot with a point count distribution by vegetation (Figure 4.85) has the feeding guilds clearly indicated. Monte Carlo tests were significant (all three axes p=0.004). The frugivore feeding guild was clearly associated with the vegetation of the MLM and the RLM, which conformed to the results of the tree cover (Figures 4.42, 4.87 & 3.12).

Others have also looked at frugivores and reported similar results. Lack (1986) found that frugivores were not recorded on the open grasslands and were generally found in wooded vegetation, with peaks occurring when a number of tree species produced fruit. Many of these frugivores, however, also included arthropods in their diet, with these arthropods also taking advantage of the fruiting trees (Lack, 1986). The interpretation from the interpolated map for the tree cover (Figure 4.42) compared favourably with the NMS plot (Figure 4.85) indicating vegetation cover and avian feeding guilds were associated with different vegetation cover. Woody biomass and woody species richness had high recordings in riparian and rocky out crop vegetation (Figures 3.13 & 3.14), as noted by Perkins (2006), which had the highest recordings of frugivore species richness and numbers of birds in this guild.

Borghesio (2007) studied the impacts of subsistence human activities on forest areas in northern Kenya. He suggested that these human activities favoured forest edge bird species at the expense of forest specialists. However, he did note that there appeared to be an increase in structural diversity of the vegetation, which provided a suitable habitat for some of the forest avifauna. The guilds that favoured the change in structure included nectarivores, insectivores, granivores and omnivores, while the frugivores were negatively affected (Borghesio, 2007; Kirika, *et al.,* 2007).

The findings of Trager and Mistry (2003) are confirmed by this study – that frugivores foraged in the dense and abundant vegetation of rock outcrops in the Serengeti. Tree species mentioned in the Trager and Mistry (2003) study include Figs and Corkwood, both of which are abundant on the kopjes of the study area.

The statistical analysis shows that there were differences in the distribution of the frugivores as a consequence of both land use and the seasons. Higher numbers of frugivores were recorded in the areas of higher woody biomass and woody species richness. These areas were mainly in the RLM, MLM and the east of the ILM. The frugivore numbers and species richness increased in these areas during the winter confirming that these areas were being used as areas of refuge during the winter. Frugivore numbers and species richness were low in the CLM and the west of ILM both for summer and winter where grazing intensity was highest.

5.3.3.2 Granivores

The distribution pattern of granivores is clearly indicated in the interpolated maps (Figures 4.21 - 4.25). The pattern of highest distribution of the numbers of the granivore feeding guild for the entire study period (Figure 4.21) was primarily from the northern portion of the RLM, across the south-western area of the MLM, to the eastern portion of the ILM. There was an even distribution of the granivore feeding guild over the balance of the study area. The highest count of 65.1 birds was at the RLM 17. This point was over 200 metres from the river's edge, but within close proximity of a small farm, which included cattle and grain crop farming. R17 was also very close to a rocky outcrop. The land use of the surrounding area of the R17 could have influenced its high granivore count. Reference can be made here of the IDH, as suggested by Connell (1978), which may have influenced the numbers of this feeding guild.

The summer counts for the numbers of birds of the granivore feeding guild produced a pattern where most granivores were recorded in the CLM and the ILM (Figure 4.22). The numbers of granivores for the winter counts were slightly higher than for the summer, with a distribution pattern from the northern area of the RLM, across the MLM, to the eastern portion of the ILM (Figure 4.24). The pattern of distribution of the species richness for the summer and winter was mainly over the ILM and the CLM (Figures 4.23 & 4.25), with a higher species richness in the winter.

The two-way ANOVA for granivores produced a result that indicated that land use had a very significant effect on the distribution of granivores (ANOVA: Bonferroni's multiple comparison tests; $p<0.0001$). The seasons had a very significant effect on the distribution of granivores (ANOVA: Bonferroni's multiple comparison tests; $p<0.0001$)(Figure 4.74).

NMS bi-plot incorporating vegetation structure indicates the association of granivores with the ILM and the CLM (Figure 4.85). Both ILM and CLM had reduced woody biomass and woody species when compared to the MLM and the RLM, suggesting that the grass cover was more evident in these areas (Figure 4.44). Grass coverage of 1.2 m was not evident in RLM, ILM and the CLM (Figure 4.87). The ILM, RLM and CLM had shorter grass cover, ranking from 1<0.5 m, possibly as result of grazing pressure.

The introduction of domestic stock has led to overstocking (Abel, 1997), which will impact the vegetation to an extent where perennial grasses will be replaced by annual grasses. Shrub and bush encroachment will also increase reducing the area available for grasses. The annual grasses produce more seeds than perennial grasses during their yearly cycle (Walker *et al.,* 1981). The availability of more seed may attract granivores species.

There are many factors influencing the changes in vegetation in the semi-arid areas as there are structural and environmental differences in these areas which, when combined with the different management practices, can lead to many different results (Perkins *et al.,* 1993). With the increase in domestic stock, the grass cover will be significantly reduced in these semi-arid areas. As a result, the soil will be exposed at the onset of the rains and water infiltration will be reduced to such an extent that there will be extensive water run-off and sheet erosion results (Walker *et al.,* 1981). Kelly and Walker (1976) calculated that the rate infiltration was reduced tenfold on bare ground when compared to grass covered ground. This feedback of overgrazing further compounds the impacts on the vegetation structure of grasslands, with predominantly perennial sward being reduced to annual grasses together with extensive bush encroachment (van Vegten, 1983).

When comparing bird numbers and bird species richness of the granivore feeding guild, there appears to be conformity between this guild and grazing intensity. The summer counts for the numbers of birds ranged between 13.4 - 24 birds over much of the ILM, RLM and the CLM. The species richness for the summer counts was 3.85 - 7.10 birds for the same area. Winter counts showed lower numbers in the CLM, ranging between 22.4 - 31.3 birds in an area from R17 across the MLM to the eastern portion of the ILM (Figure 4.24). Species richness in the winter was highest in the ILM with between 5.80 - 93 species and 5.80 - 6.59 species in the CLM (Figure 4.25).

The statistical analysis confirmed that there were differences in the distribution of the granivore feeding guild as a consequence of both land use and season. The trend is indicated by a lower number of birds and species richness of the granivore feeding guild during the summer, possibly because of the more even distribution of grasses, both annual and perennial. The scenario altered in winter, with a higher number and species richness of granivores in the area of less intensive grazing where more perennial grasses, less bare ground and presumably more seeds were available for this guild. The compounding influence of the farm at R17 has been mentioned, which could account for the high numbers of granivores at this point in the winter. The numbers of birds and species richness of the granivore feeding guild in the east of the ILM during winter would suggest that there was suitable habitat for this guild. The current study shows that land use intensity will affect the distribution of avian granivores, a finding that is supported by others. The magnitude of the affect will be related to the intensity of the land use.

5.3.3.3 Insectivores

Insectivores had the highest numbers in the north-east of the study area, declining to the south-west (Figures 4.26 - 4.30). The pattern remained fairly similar for the summer and winter for numbers of birds and for species richness (Figures 4.27 - 4.30). What was noticeable was that the numbers of insectivore birds increased significantly in winter. The maximum number of insectivore feeders in summer is 40.2, while the winter numbers for the same guild was 57.6. The species richness of this guild for the summer and winter remained constant at 15 and 14.8 species respectively. The possible reason for the increase in numbers was that the insectivores were using the RLM and MLM as areas of refuge during the winter months.

The two-way ANOVA for insectivores showed that land use had a very significant effect on the distribution of insectivores (ANOVA: Bonferroni's multiple comparison tests; $p<0.0001$). The effect of the seasons on the variance of the insectivore feeding guild is insignificant, (ANOVA: Bonferroni's multiple comparison tests; $p=0.7991$) (Figure 4.75).

The NMS bi-plot including vegetation structure clearly indicates the association of insectivores with the MLM and, to a reduced extent, the RLM (Figure 4.85). As has been noted with the frugivore feeding guild, there was an association of the insectivore feeding guild with the high woody biomass and high woody species (Chettri *et al.,* 2005) on the RLM and MLM. Monte Carlo tests for NMS were significant (all three $p=0.004$).

Studies on the effects of agricultural practices on the environment have been conducted predominantly in industrialised countries where intensive farming is practiced. Although the farming techniques in these industrialised countries were very different to those of the current study area, it is worth noting the impacts on the environment with particular reference to birds.

Some insects require a vegetation structure with a high density of trees and a good basal cover (Chettri *et al.,* 2005), as they favour the moist conditions and dense foliage which these habitats provide (Erwin 2001). A study by Britschgi *et al.* (2005) in the northern hemisphere found that the different land management practices of the Whinchat (*Saxicola ruberta*) habitat had affected the arthropod abundance available for chick rearing. The more intensive management practice involving the mowing of grass fields, and resulted in a marked reduction of arthropods (Britschgi, *et al.,* 2005).

Mowing could be compared with the extensive grazing regimes in the current study. As the intensity of grazing increases, the grass cover reduces to a point where the palatable perennial grasses are replaced by less palatable annual grasses (Walker *et al.,* 1981). Britschgi *et al.* (2005) recorded that Whinchat parents had to travel further to find suitable prey items in intensively managed fields and also substituted less favourable prey items when feeding their chicks. The net result was higher fledgling mortality in intensively managed fields (Britschgi *et al.,* 2005). The reduction of the grass cover and its replacement by bush and/or bare ground could be a cause of reduced insect population in the heavily grazed areas of the ILM and CLM, which in turn could affect the distribution of the insectivore feeding guild (Figures 4.26 - 4.30).

- The study in Botswana by Barker (1985) analysed the effect of grazing on *Acridoidea* (grasshoppers) and found that there was a predictable decrease in total herbage biomass from non-overgrazed to overgrazed areas*. Acridoidea* was a major herbivorous component of the grassland ecosystem and, as a result, the grasshoppers were affected by overgrazing.
- Contrary to the work by Barker (1985), Weese (1939) found that overgrazing had resulted in increases rather than decreases in some grasshopper population numbers. Barker (1985) however, found that although most species of *Acridoidea* were adversely affected by overgrazing, some species were less affected than others.
- Seymour and Dean (1999) noted that there were many factors influencing invertebrate assemblages in the Namaqualand region of South Africa, with grazing intensity being one. The study found that there was greater invertebrate species richness in the moderately grazed areas of the study, but that invertebrate abundances were consistently higher in heavily grazed areas. Insect populations will increase exponentially in response to disturbance, resulting in a high abundance of a few species (Schowalter, 1985). Seymour and Dean (1999) found that there was a marked increase in granivorous insects because of the seed made available by the annual plant cover. Increases in soil temperature during the day as a result of less vegetation cover favoured eurythermal invertebrates, while stenothermal invertebrates were found in areas of more vegetation cover. Invertebrate diversity showed a marked decrease with decreasing plant cover and the reduction of perennial grasses. The feedback of grazing intensity on vegetation degradation has been mentioned. Seymour and Dean (1999) noted that the greater abundance of invertebrates in severely degraded areas may further compound the effects of overgrazing, as the large

numbers of invertebrates may hinder the recruitment of palatable perennials.

- The study in the northern hemisphere of land use by Ambrosini *et al.* (2002) found evidence that livestock farming and the architecture on rural farms had an effect on the distribution and abundance of barn swallows (*Hirunda rustica*). When analysing farms with and without livestock, they found that 91% of those with livestock had barn swallows nesting, while only 44% of those without livestock had breeding barn swallows. The causes were not entirely as a result of the livestock, but also as a result of the buildings, which provided opportunity for nesting sites, and the hayfields, which provided areas to forage for insects. With regard to the buildings, Ambrosini *et al.* (2002) confirmed that the barn swallows nested in the older type farm buildings, rather than the more modern farm buildings.
- Moller (2001) also found that dairy farms had five times more insects than farms without dairy cattle. The reason for this could be that livestock could buffer the effect of sudden weather changes on insects. In the past, dairy cattle were housed in buildings, which, combined with the warmer temperature created by the cattle being housed indoors, created a suitable micro-climate for swallow nesting (Moller, 2001).

The current study and studies by others suggest that the intensity of land use will impact on the avian insectivores - some impacts being beneficial and others detrimental. The statistical analysis of the current study confirms the findings of others regarding the affects of grazing intensity on insectivorous birds with the land use playing a significant role in the distribution of this feeding guild. The effect of the season on the distribution of insectivores was insignificant possibly because of the location of the study area being well within the tropics and having mild winters. The winters would have less impact on insects when compared to an area south of the tropics.

5.3.3.4. Omnivores

The distribution of the omnivores is shown in the interpolated maps (Figures 4.31 - 4.35). The distribution of this guild was predominantly in the MLM and the RLM, with lower numbers recorded in the ILM and the CLM. The numbers of the omnivore feeding guild in the summer (Figure 4.32) was centred in the RLM and the MLM, where the numbers were also substantially higher in the winter (Figure 4.34). Species richness was found to be highest in the MLM, the northern portion of the RLM, and the eastern portion of the ILM during the summer (Figure 4.33). Species richness was higher in winter (Figure 4.35) in the MLM, with a large number of species found in the CLM.

The two-way ANOVA showed that land use had a very significant effect on the distribution of this guild**.** The mean number of omnivores for each land use type and for the seasons shows that numbers increased in all areas in the winter (Figure 4.77). The effect of land use on the variance of the omnivore feeding guild was very significant, (ANOVA: Bonferroni’s multiple comparison tests; p<0.0005). The effect of the seasons on the variance of the omnivore feeding guild was also very significant (ANOVA: Bonferroni’s multiple comparison tests; p<0.0001).

The NMS bi-plot including vegetation structure indicates the association of omnivores with the MLM and RLM (Figure 4.85). As has been noted with the omnivore feeding guild, there was an association of the guild with the high woody biomass and high woody species found on the RLM and MLM. Monte Carlo tests were significant (all three p=0.004).

The Southern Yellow-billed Hornbill was recorded extensively throughout the study area, over all land uses and during both seasons. The Southern Yellow-billed Hornbill was regarded as an omnivore in this study. When considering the large and even distribution of numbers recorded, it may have influenced the statistical analysis of this guild by outweighing other omnivores. It consumes a wide range of food, including seeds, fruit, insects, lizards, small mammals and birds (Kemp, 1976). Their diverse dietary range permits omnivores to adapt when their favoured food sources become difficult to find (Azman *et al.,* 2011). During the winter months, when their preferred food becomes scarce, the Southern Yellow-billed Hornbill resorts to different searching techniques, such as hawking and levering under bark and dung to source food (Kemp, 1976). The Southern Yellow-billed Hornbill will travel in excess of 10 km at dawn to source food, returning to its preferred habitat in the evening (Hockey *et al.,* 2005). This was supported by Folse (1982), who suggested that habitat requirements, rather than food requirements, regulated the niche segregation of birds on the Serengeti.

The distribution of omnivores in this study suggested and is confirmed by others, that the even distribution over the study area implies that this guild consumes a wide variety of food adapting to other food forms when shortages of the favoured food was reduced. Statistically there were differences in the distribution of omnivores both as a consequence of land use and season. The distribution of the species richness of omnivores showed a more even distribution over the study area in winter while the summer species richness was not as even. The implication was that the winter omnivores were accessing food from a wider geographical range while the summer birds were accessing a food source that was more specific to certain areas.

5.3.4. Nesting guild distribution

5.3.4.1. Tree nesters

The distribution of tree nesters for the study area is shown in Figure 4.36. The highest numbers of tree nesters was recorded in the RLM, most of the MLM and the central area of the ILM. The tree cover (Figure 4.42) should be seen in conjunction with bare ground (Figure 4.45) and total cover (Figure 4.41). Bare ground is most evident in the CLM, while total cover, which includes trees, shrubs and grasses, follows a pattern of highest cover in the north-east of the study area, reducing to the south-western portion. Woody biomass distribution and woody species distribution for the Mupane Mine lease area (Figures 3.13 & 3.14) follow similar trends to those found in the current study. Although the woody biomass is similar for the riparian vegetation and the vegetation found on the rocky hills, the woody species differ (Perkins, 2006).

The distribution of tree nesting species conformed (Figure 4.36) to the distribution of trees (Figure 4.42) being predominantly in the RLM, MLM and a portion of the ILM. The distribution of the numbers of the tree nesters was further confirmed in the two-way ANOVA (Figure 4.78). The effect of land use on the distribution of tree nesters was significant (ANOVA: Bonferroni's multiple comparison tests; p=0.0005). The effect of the seasons on the tree nesting guild was not significant, (ANOVA: Bonferroni's multiple comparison tests; p=0.9771). During the summer, the number of tree nesters was highest in the MLM and RLM. During the winter, the MLM had the highest number of tree nesting species, while the RLM and ILM had a similar number of tree nesters.

NMS bi-plot representing the distribution of points by land use with the nesting guilds is clearly indicated in Figure 4.86. Tree nesters were indicated mainly in the MLM and the RLM, and markedly not in the CLM, and, to a lesser extent, the ILM.

The distribution of tree nesters predictably conformed to the pattern that they will be located in areas where there are more trees. The land use of the current study area could adversely affect the distribution of tree nesters. The CLM area had management practice with high grazing pressure sustained throughout the year. Added to the grazing pressure is the use of the woody vegetation for fuel and dwelling construction, as living trees are chopped down for the construction of houses and kraals. Dead trees and dead branches are harvested for fuel for cooking and warmth. This can affect bird variables.

- Chadwick *et al.* (1986) studied the effects of the collection of wood as an energy source in the state of New England, USA, where the removal of primarily dead wood for fuel was principally an unmanaged exercise with no regard for future growth. The composition of a forest used for fuel wood collection had a different composition and structure when compared to an unharvested forest, which could affect bird communities (Chadwick *et al.,* 1986). The study showed that the canopy, although present in cut stands, was significantly reduced, while the shrub layer was increased in the cut areas (Chadwick *et al.,* 1986). As the vegetation was altered by the fuel wood removal, the bird species found here could be identified as species that could differentiate between cut and uncut forests. The unharvested forests recorded bird species identified within forest canopies (Chadwick *et al.,* 1986).
- However, degraded woody areas that do have some remnants of tree structure, will allow for some woody vegetation birds to survive (Fairbanks, 2004).

Land use in both the ILM and the CLM could adversely affect tree nesters, due to wood collection for fuel, construction and grazing. Birds use different strata of the vegetation structure, from the upper canopy to the lower strata all of which can be effected by grazing intensity. Intermediate and upper levels of vegetation are affected by the longer periods of grazing as young trees are either trampled or grazed inadvertently, with the result that few young trees grow to replace the older trees (Taylor, 1986).

Tree nesting birds conformed to the pattern of tree density. The principle areas of tree nesters were in the MLM and the RLM while there was a marked reduction in the ILM and CLM where tree harvesting was practised.

5.3.4.2 Cavity nesters

The distribution of cavity nesters (Figure 4.38) conformed to the distribution of total cover and trees (Figures 4.41 & 4.42). The mean distribution of cavity nesters (Figure 4.79) indicated by the two-way ANOVA of cavity nesters in summer and winter for the different land use types showed that the effect of land use on the cavity nesting guild was significant (ANOVA: Bonferroni's multiple comparison tests; p=0.0005), while the seasons also had a significant effect, (ANOVA: Bonferroni's multiple comparison tests; p<0.0001). The MLM had the highest mean number of cavity nesters in both summer and winter, which could be accounted for by the number of rocky hills and resultant woody biomass of the MLM. The distribution of cavity nesters for the ILM, RLM and CLM follow a similar pattern, although the mean numbers were higher in the winter.

The possible reason for the fairly even distribution of this guild is due to the distribution of the Southern Yellow-billed Hornbill, the Red-billed Hornbill and the African Grey Hornbill, which was classified as cavity nesters for this study. They were recorded throughout the study area in high numbers. Although the interpolated map (Figure 4.38) could appear to contradict the results of the mean numbers of cavity nesters (Figure 4.79), the distribution in total number of cavity nesters (Figure 4.38) was patchy and the mean results (Figure 4.79) conformed to the distribution over the different land use types and across seasons.

The NMS bi-plot (Figure 4.86) indicates the distribution of census points by land use with nesting guilds compared to each landuse. The cavity nesting guild does appear to be associated with the MLM, RLM and ILM, while the association with the CLM decreased. This can be explained by the following:

- In southern Africa as much as 35 - 50% of forest species, both animal and bird, rely on cavities for either roosting or nesting (Du Plessis, 1995). Du Plessis (1995) compared a forest that was utilised by the surrounding human population for firewood harvesting and a forest that was not. He found that both vertebrates and invertebrates, that required dead wood for survival, would be under threat in the forest that was not. Du Plessis (1995) showed that primary cavity nesters created cavities in mainly dead wood, whereas secondary cavity nesters used cavities that had already been created. Birds, particularly cavity nesting birds, are seriously compromised by reduction of deadwood, but there was a further affect on the foraging substrata, which compromises the bird species that glean from this stratum of dead wood. Du Plessis (1995) recorded that not only were the primary and secondary cavity nesters influenced by fuel wood collection, but that those species that feed amongst the dead wood strata were also negatively influenced.
- Primary and secondary cavity nesters were recorded in fewer numbers in cut forests when compared with uncut forests in a study conducted by Chadwick *et al.,* (1986). The forests were open after fuel collection, with the lower vegetation of the forests increased, resulting in a much denser shrub level, which attracted species that thrived there. Depending on the time lapse between the fuel wood removal, different bird species took advantage of different emerging vegetation strata, resulting in a positive effect on species diversity, with the result, when bird species richness was combined for early, middle and late harvests, that there was a significant increase in bird species richness (Chadwick *et al.,* 1986). Chadwick *et al*. (1986) added that when fuel wood is harvested, living trees could be damaged, exposing these damaged areas to fungal and insect attack, which could be of benefit to cavity nesters.

The pattern of distribution of cavity nesters (Figure 4.38), which includes both primary and secondary nesters, conformed to a pattern similar to tree distribution (Figure 4.41). The Black-collared Barbet, Cardinal Woodpecker and the Green Wood-Hoopoe, for example, will all be adversely affected by the removal of dead wood, which could be used for roosting or nesting and also used when gleaning for insects and other invertebrates. It is worth noting that the Black-collared Barbet has been recorded as having thirteen birds in a single roosting cavity (Hockey *et al.,* 2005) which implies that areas of wood collection may influence the distribution of cavity nesters. The use of trees for fuel, construction and fencing could impact substantially on cavity nesting birds.

5.3.4.3 Shrub nesters

The distribution of shrub nesters (Figure 4.37) does conform to the pattern for the distribution of shrub cover (Figure 4.43). There appears to be a difference between shrub nesters and shrub distribution. Shrub nesters appear to be poorly represented on the CLM, while shrub distribution is evident in a large part of the CLM. The possible reason for this absence is that the shrubs recorded were at the lower end of the shrub size category (Figure 4.1, 4.5 & 4.87).

Two-way ANOVA for mean shrub nesting species for each land use for the summer and winter (Figure 4.80) had higher numbers of shrub nesters in winter than in summer. The mean summer shrub nesting values indicated higher mean values for the ILM and the CLM, while the mean values for all land use types increased in winter, with the highest mean values on the CLM and the MLM. The effect of the land use on shrub nesting distribution was significant (ANOVA: Bonferroni's multiple comparison tests; p=0.0192) while the seasons also had a significant effect on shrub nesting distribution (ANOVA: Bonferroni's multiple comparison tests; p<0.0001).

The results of the NMS bi-plot for the distribution of nesting guilds measured plotted with vegetation structure indicated a trend with shrub nesters favouring the MLM and ILM (Figure 4.86). The trend of the NMS bi-plot (Figure 4.86) follows a pattern similar to the geostatistical interpolation (Figure 4.37), with shrub nesters predominantly recorded in the MLM and the ILM. When analysing shrub distribution (Figure 4.43), it appears that most shrubs were found in the CLM but, on closer examination, shrubs in the one to two metre category were scarce in the ILM and the CLM.

The Blue Waxbill (*Uraeginthus angolensis*) was recorded extensively throughout the study area in both summer and winter (Tables 4.21 & 4.22). As a shrub nester, the distribution could be effected by a shortage of food, being mainly seeds, and nesting material as a result of heavy grazing and drought conditions. The shrubs for nesting that are exploited by the Blue Waxbill nests are approximately 1.7 metres above the ground, with favoured shrubs being *Acacia tortilis* and *Dichrostachys cinerea* (Hockey *et al.,* 2005). The lack of shrubs at this height in the CLM may have affected the distribution of these shrub nesters. Although overgrazing does reduce perennial grass cover, which was replaced by annual grasses which produce more seeds (Walker *et al.,* 1981), the extent of the grazing could be such that annual grasses were reduced, resulting in bare ground that is very evident in the CLM (Figure 4.5).

The Kalahari Robin (*Cercotrichas paean*), which is also a shrub nester, can be positively affected by heavy grazing as Acacia *(Acacia mellifera)* and bare ground are favoured areas of this species. The Kalahari Robin is found in association with cattle watering points and extensively trampled areas where cattle dung provides a source for arthropods (Hockey *et al.,* 2005).

The Stierling's Wren-Warbler (*Calamonastes stierlingi*), on the other hand, is also a shrub nester with favoured shrubs of Buffalo Thorn (*Ziziphus muronata)* and Terminalia (*Terminalia sericea)*. Both these species of shrub are found throughout the study area. The Sterling's Wren-warbler is sensitive to disturbance and will abandon its nest if disturbed (Hockey, *et al.,* 2005).

Shrub nesters were found in the MLM and ILM with reduced numbers in the RLM and the CLM. The intensity of grazing in the CLM and the western section of the ILM was intense reducing the shrub layer to very low shrub and a significant amount of bare ground. Although shrubs were recorded in these areas of the CLM and the ILM these shrubs were reduced to such a level as to be unsuitable for shrub nesters. Land use therefore had a marked impact on shrubs and shrub nesters.

5.3.4.4 Ground nesters

The distribution of ground nesters indicates an reduced number and even absence of birds in the CLM and large portions of both the ILM and MLM (Figure 4.39). The ground nesting guild should be viewed simultaneously with total grass cover (Figures 4.44) and the vegetation structure (Figure 4.87). It is noticeable that the grass category from one to two metres (Figure 4.87) was absent from much of the ILM and CLM areas and bare ground was most evident in these areas (Figure 4.45) which conforms with ground nester distribution (Figure 4.39). The implication is that where there was less grass cover and more bare ground there were reduced numbers of ground nesters.

Two-way ANOVA for mean ground nesting species for the summer and winter counts and for the different land uses (Figure 4.81) indicates a small increase in mean numbers for all land use types in the winter. The effect of the land use on the results was very significant (ANOVA: Bonferroni's multiple comparison tests; p=0.0002) while the effect of the seasons on the result was also very significant (ANOVA: Bonferroni's multiple comparison tests; p=0.0006).

The results NMS bi-plot for the distribution of nesting guilds against vegetation structure (Figure 4.86) indicates a trend where ground nesters favoured the MLM and ILM. The trend follows a pattern, with ground nesters being predominantly recorded in the MLM and the ILM, which was confirmed by the geostatistical analyses in Figure 4.39. The mean ground nesters followed a trend similar for the summer (1 – 2.5), but the winter months had the greatest mean number distribution in the ILM and the RLM (2.5 – 3.0), with the lowest mean numbers in the MLM during the winter (Figure 4.81). The reason for this change in distribution in the winter could be that nesting takes place in the summer months, while in winter the ground nesting species range further. The mean ground nesting species summer distribution may be as a result of the high grazing intensity in the RLM and CLM during the ground nesting season. The grazing intensity could result in disturbance, as well as the destruction of nests by trampling of livestock. It is worth reiterating that grazing intensity was highest in the CLM and RLM by livestock, which included cattle, goats and sheep. The combined effect of this grazing pressure is noted in the distribution of ground nesting species. The following is advanced as additional explanations for the results:

- Perhaps one on the most influential factors that may affect the distribution of ground nesting birds, amongst others, is that ground temperatures can reach as high as 70^0C in the summer months (Tietema *et al.,* 1991). The distribution of bare ground was evident in Figure 4.45. These two factors could have an effect on the habitat use by ground nesters.
- The Boulder Chat (*Pinarornis plumosus*) could be affected by grazing pressure, which often leads to bush encroachment. This has been noted by Tree (1997a), who suggested that where there is an increase in Lantana (*Lantana camara)*, a known bush encroacher, the Boulder Chat, would desert these areas.
- The Cinnamon-breasted Bunting (*Emberiza tahapisi*), unlike the Boulder Chat, which is also a ground nester, favours over-grazed savannah (Hockey *et al.,* 2005).
- Bush encroachment has been regarded as favourable for the Red-crested Korhaan (*Lophotis ruficrista*) (Allan, 1987), although over-grazing can negatively affect their numbers (Irwin, 1981).
- The Crested Francolin (*Dendroperdix sephaena*) was negatively affected by clearing natural vegetation for agriculture and also by over-grazing and the results hereof (Little & Crowe*,* 2000).
- Habitat fragmentation and overgrazing also had a negative effect on Helmeted Guineafowl (*Numida meleagris*) numbers (Ledger, 1980).
- The Natal Spurfowl (*Pternistis natalensis*), on the other hand, was tolerant of some modification of land use, often being seen on the edges of these areas, adjacent to good cover and was often recorded along firebreaks made in commercial forests. Bush encroachment can be beneficial to the Natal Spurfowl, but numbers are threatened as a result of burning and fragmentation of habitat. The Natal Spurfowl was inclined to move away from drought stricken areas (Little & Herremans, 1997).
- The Swainson’s Spurfowl (*Pternistis swainsonii*) is also tolerant of man-modified habitats and adapts to encroachment, but excessive hunting

can reduce populations to levels that render them unviable (Little & Crowe, 2000).

Ground nesting species of the study area had different degrees of tolerance of grazing pressure, as mentioned above, but as a nesting guild they could be adversely affected by high levels of grazing pressure and the results over-grazing. Many ground nesters find nesting difficult because of the intense pressure on grasses. Statistically ground nesters were affected by both land use and season with much of the CLM and the ILM having reduced numbers. Where woody vegetation has been removed, resultant grassland patches could have a positive effect on bird species richness (Fairbanks, 2004).

5.3.5 Indicator species

Indicator species (Table 4.24) distribution patterns are illustrated in the interpolated maps (Figures 4.46 - 4.62). There have been a number of references made to the use of biological indicators during this study. Hudson and Bouwman (2007) confirmed that birds are useful indicators of perturbations in vegetation structure in the Kalahari.

The most noticeable distribution patterns for indicator species coincide with the RLM. The riparian habitat was one of the preferred habitats for the Yellow-bellied Greenbul (*Chlorocichla flaviventris*) (Figure 4.50) (Maclean, 1993), Orange-breasted Bush-Shrike (*Telophorus sulfureopectus*) (Figure 4.52) (Parker, 1997), Brown-hooded Kingfisher (*Halcyon albiventris*) (Figure 4.53) (Clancey, 1997), Tropical Boubou (*Laniarius aethiopicus*) (Figure 4.62) (Harris *et al.,* 2000), Hadeda Ibis (*Bostrychia hagedash*) (Figure 4.60), African Green Pigeon (*Treron calvus*) (Figure 4.58) (Goodwin, 1983), Jameson’s Firefinch (*Lagonosticta rhodopareia*) (Figure 4.61) (Davidson, 1986), African Paradise Flycatcher (*Terpsiphone viridis*) (Figure 4.55) (Johnson *et al.,* 1997*)* and the Three-banded Plover (*Charadrius tricollaris*) (Figure 4.54) (Tree, 1997).

The Yellow-bellied Greenbul uses well-wooded Mopane *(Colophospermum mopane)* and Brachestygia woodlands (Oatley, 1997). The Yellow-bellied Greenbul is known to peck at the ears, nostrils and pre-orbital glands of the Common Duiker *(Sylvicarpa grimma)* and Klipspringer (*Oreotragus oreotragus)* (Roberts, 1995), both of which are common in the rocky hills of the study area.

As has been explained previously, the RLM, although regarded as a separate management practice, has the same grazing practice as that of the CLM. The reason for this was that there were no fences restricting the movement of livestock from the CLM into and across the Tati River. The fences however, of the MLM and ILM followed the river course, excluding the riparian vegetation from these management practices. There was therefore no separate grazing management practice of the riparian vegetation with livestock, such as cattle, sheep and goats, moving and grazing freely in the riparian vegetation throughout the year.

It is also important to remember that there were only four census points for the RLM, while the remaining land use types had eight census points each. However, R17 fell some distance from the riparian vegetation (Figure 3.4), although included under RLM. In reality therefore, the RLM had three census points that were in the riparian vegetation. The influence of the grazing can be seen in RLM when noting the absence of grasses in the 1–2 m category (Figure 4.87).

Of the ten indicator species recorded in the RLM, seven were tree nesting species, two were ground nesting and one was a shrub nester. There were seven insectivores, two frugivores and one granivore. The majority of RLM indicator species were tree nesters and insectivores. The tree species and woody biomass of the riparian vegetation was confirmed by Willson (1974) and Lack (1986) as complex environment creating a suitable habitat that is conducive to an increase in numbers and species of birds.

- Two indicator species, the Brubru (*Nilaus afer*) (Figure 4.47) and the Grey-headed Bush-Shrike (*Malaconotus blanchoti*) (Figure 4.57), were recorded predominantly in the MLM. Both species are tree nesters, with one insectivore (Brubru) and one carnivore (Grey-headed Bush-Shrike). The habitat frequented by the Brubru is generally tall Acacia and Mopane trees, often as a combination of both dominating vegetation groups. In arid parts, the Brubru is found in clumps of trees (Fry *et al.,* 2000; Tarboton, 1984). The Grey-headed Bush-Shrike was also found in well-wooded areas, including bush clumps and wooded, rocky hills (Harris & Franklin, 2000).
- The two indicator species for the ILM were the Swainson's Spurfowl and the Harlequin Quail (*Coturnix delegorguei*) (Figures 4.46 & 4.51). Both species were ground nesters and, while the Swainson's Spurfowl was a granivore

and the Harlequin Quail was predominantly an insectivore. This distribution would suggest that the grass cover (Figures 4.44 & 4.87) was suitable for nesting and feeding. The Swainson's Spurfowl is very tolerant of habitat modified by man (Hockey, *et al.,* 2005), which was the case in the ILM and was generally found where there is sufficient cover offered long grass and natural bush.

- The Harlequin Quail is less tolerant of grazing pressure as it requires good cover for both breeding and feeding (Dudley, 1971). The grazing gradient decreased as the distance increased from the river where the watering point was situated in the ILM. In southern Africa the Harlequin Quail is found in more wooded areas when compared to other parts of Africa, where it was found in more open grasslands (Little & Crowe, 2000). The terrain and grazing pressure in the ILM would suggest that the habitat would be suitable for both the Swainson's Spurfowl and the Harlequin Quail. The vegetation cover (Figures 4.41 - 4.45 & 4.87) clearly indicates that the vegetation to the east of the ILM was more suitable for Harlequin Quail habitat. The water point on the ILM was at the Tati River, which has resulted in the vegetation being degraded (Nsinamwa, 2005; Perkins & Thomas, 1993) within proximity of the water, but improves as the distance from the water point increases to the east. The topography of the CLM was similar to the ILM, but the grazing intensity was greater, possibly making the vegetation structure (Figure 4.41-4.45 & 4.87) unsuitable for both the Swainson's Spurfowl and the Harlequin Quail as neither of these species distributed to any extent into the CLM.
- The Red-chested Cuckoo (Figure 4.56) is indicated for the CLM and the RLM. Both of these land use types had an intense uncontrolled grazing program. It appeared that the distribution of the Red-chested Cuckoo did not overlap with resident avian insectivores during the summer (Figures 4.27 & 4.28) as their distribution was primarily in the MLM. Lack (1986) did suggest that competition between residents and intra-Africa migrants was not significant.
- The African Paradise-Flycatcher (Figure 4.55) distribution indicated for the RLM and the MLM. Its preferred habitat is forest and woodland, but it was

absent from arid savannah (Johnson & Herremans, 1997*)*. In arid areas the African Paradise-Flycatcher was confined to riparian vegetation (Winterbottom, 1967). Perhaps one of the major reasons for failure of nests was cattle bumping trees, causing the eggs and fledgling to be dislodged (Skead, 1967). The distribution of the African Paradise-Flycatcher could be as a result of the higher numbers of cattle in the CLM and ILM impacting on egg and fledging success.

Many of the indicator species would have been distributed in their current positions if there was no intensive land use in the area. The RLM had a significant number of indicators indicating for this land use. The important indicators that were influenced by grazing intensity were the Swainson's Spurfowl and the Harlequin Quail which were distributed some distance from the Tati River on the ILM. This area had a reduced grazing intensity because of the distance from the river and the watering point. The implication was that the vegetation was more suitable for these two species because of reduced grazing intensity. Both species were not recorded in the CLM and RLM where grazing pressure was intense throughout this land use suggesting the vegetation was reduced to such a level that the habitat was unsuitable for these species. Although the grazing intensity was reduced in the MLM the terrain with the numerous kopjes may also have been unsuitable for these two species.

The Red-chested Cuckoo was distributed almost entirely in the CLM and RLM. Both these land uses had an intensive grazing program which may have resulted in a bloom of hairy caterpillars which are a favoured food item. The grazing intensity would have affected the distribution of the Red-chested Cuckoo. The Red-chested Cuckoo parasitizes robin nests with a number of robins been recorded during this study. The White-browed Scrub-robin (*Cercotrichas leucophrys*) which favours grazed areas, was recorded (Table 4.20) in both the RLM and CLM summer when the Red-chested Cuckoo breeds. The presence of this host species which was affected by grazing intensity, may have influenced its distribution of the Red-chested Cuckoo.

The African Green Pigeon and African Grey Hornbill were distributed exclusively out of each others territories. The reason is unclear and more research is required to test the competition between these species.

5.4 Reasons for bird distribution patterns

It should be remembered when using birds as indicators of land use, that birds may use one or more habitat type over space and time (Bouwman *et al.,* 2009). Birds could use different habitats for different reasons and at different times and seasons and it is the interaction of these different reasons that create the bird's profile, which can differ from the clear cut distribution patterns found in some literature (Bouwman *et al*., 2009).

5.4.1 Natural factors affecting avian distribution

Habitat structure and rainfall are perhaps the most important factors that contribute to bird species diversity (Hockey *et al.,* 2005; Sinclair 1978). Habitats that have the least structure and are dry generally have the fewest species, which means that there is a west to east trend of increasing bird species in southern Africa. The more heterogeneous the vegetation the greater the species diversity (McGarigal & McComb, 1995). A heterogeneous landscape implies an area, which is made up of interacting patches, which affect the distribution of a species, in this case birds (McGarigal & McComb, 1995).

There are exceptions:

- Although deserts have fewer species than savannahs, mesic savannahs tend to have more species than forests (Hockey *et al.,* 2005). The soil type also plays a significant role in the structure of the vegetation, with the nutrient rich clay soils supporting *Acacia* species, which support high bird species richness, while low nutrient sands support broad-leaved trees and lower densities of birds (Monadjem, 2002).
- Herremans (1993), in his study of the seasonal dynamics in sub-Kalahari bird communities, believed that resident bird diversity correlated well with the structure of the vegetation, particularly in the dry season. Herremans (1993) found that the more diverse the structure of the vegetation, the greater the diversity of the birds which is supported by Willson (1974).

- Hockey (2005) mentioned that rainfall, as well as vegetation structure, plays a major role in bird distribution. The rainfall for Botswana and the study area is low and erratic, with a co-efficient of variation as high as 100% (Tietema, 1991). The rainfall in the semi-arid areas of the tropics shows considerable changes over short periods, with a consequent effect on the birds in these areas (Lack, 1986).

The broad-scale classification, as suggested by Edwards (1983), was used to categorise the vegetation of the four land use types. The diagrammatic representation of the vegetation structure is clearly illustrated (Figure 4.1) and should be considered in tandem with figures taken from Perkins (2006) (Figures 3.13 & 3.14) and geostatistical analysis of the vegetation structure (Figures 4.41 - 4.45). Patches of vegetation created by natural features such as kopjes and riverine vegetation with affect bird distribution patterns. NMS provides a clear picture of the vegetation structure (Figure 4.84 & 4.87), while also confirming the uniformity of the vegetation structure of the different land use types.

Knowledge of bird species ecology will assist when assessing the reasons why certain species are present, while others are not in different sized forest patches (Blake & Karr, 1984).

Before the implications of land use are investigated, the natural factors that can influence avian distribution are summarised below:

1. Vegetation structure (Hockey *et al.,* 2005*;* Monadjem 2002; Penry, 1994).
2. Temperature and rainfall (Hockey *et al.,* 2005; Lack, 1986; Penry, 1994)
3. Bird profiles (Bouwman *et al.,* 2009)
4. Soil type (Monadjem, 2002)
5. Patchy vegetation created by kopjes and riverine vegetation (Perkins, 2006).

5.4.2 Land use as a factor influencing avian distribution

The matrix of natural factors that can influence bird distribution was considered in combination with different land uses in contiguous areas. The relationship between birds and anthropogenic features were complex over time and space, with bird distribution being affected by their daily requirements. Bird distributions are therefore not governed by a given set of features, but a combination of features, which permit individuals of these species to make use of differing environments (Bouwman *et al.,* 2009).

Before considering the effects of land use on the birds of the study area, the direct effect of the different management practices on the environment will be considered. This in turn will be discussed in relation to the effect of these changes on the avifauna of the study area.

- The distribution of bird numbers and species richness of the frugivores (Figures 4.16 - 4.20 & 4.85) conformed fairly well to the tree cover pattern (Figure 4.42), with most frugivores being recorded predominantly over the RLM and the MLM. The eastern portion of the ILM also recorded significant numbers of this feeding guild. Grazing intensity varied over these three land uses. The RLM had the highest and most intense grazing program, which was sustained throughout the year. The ILM had an intense grazing program with a period of reprieve when the cattle were removed during the winter months and only returned at the establishment of the grass after the onset of the summer rains. The MLM had a grazing program of a reduced number of cattle that were rotated to different parts of the farm. The most noticeable impact on the frugivores by the grazing intensity would be the inadvertent consumption of young trees by livestock as grass was consumed (Taylor, 1986) and the removal of trees for construction (du Plessis, 1995).

- The distribution of the granivores was impacted significantly by the grazing intensity (Figures 4.21 - 4.25 & 4.85). The most noticeable feature of this guild's distribution was the number and species richness of the guild in summer (Figures 4.22 & 4.23). The even distribution over the ILM, RLM and CLM during the summer presumably was the result of the more open grass terrain between the kopjes and riparian vegetation providing grass seeds produced by perennial and annual grasses. The distribution pattern changes in the winter (Figures 4.24 & 4.25) with a high recording in the ILM where perennials would be more evident because of the reduced grazing regime (Abel & Blaikie, 1989) when compared to the CLM. The granivore feeding guild was well represented in the birds found only in the ILM (Table 4.8) during the summer. Reduced numbers of birds and species richness for the CLM suggest that grass seed quantity would be reduced as the cover would be predominantly annual grasses, producing more seed than the perennials in summer, but less availability in the winter (Gonnet, 2001; Perkins & Thomas, 1993). The exposed terrain of the CLM (Figure 4.45) may lead to seeds being blown away, which may further influence the distribution of granivores in the winter (Lack, 1986).

- There should be a high density of trees with a good basal cover for insects to thrive (Chettri *et al.,* 2005) under moist conditions and dense foliage (Erwin, 2001). The distribution of the insectivores (Figures 4.26 - 4.30), when compared to tree cover (Figure 4.42), conformed very well. The bird species recorded only in the MLM in summer (Table 4.3) were a mix of the different feeding guilds, while the list for winter species only recorded in the MLM (Table 4.5) showed a marked shift to the insectivores implying that high vegetation cover index provided a suitable habitat for insects and insectivores during the winter.

  Although the tree cover in the RLM was high (Figure 4.42), the insectivore representation was poor (Figure 4.26). The RLM had an intensive grazing program on the same level as the CLM. The basal cover was significantly reduced by grazing, removing the moist, dense conditions conducive for insects as suggested by Chettri *et al*. (2005) and Erwin (2001). Reduced grass cover (Figure 4.44) and increased bare ground (Figure 4.45) are also conditions not entirely favourable as insect habitat.

  Exponential growth in some insect populations as a consequence of disturbance (Schowalter, 1986) can impact on avian distribution patterns. The distribution of the Red-chested Cuckoo (Figure 4.56) clearly indicates for the RLM and the CLM where grazing intensity was high. A favoured insect (presumably hairy worms) of the Red-chested Cuckoo’s diet could have bloomed as a consequence of the intensive grazing pressure, dramatically influencing the distribution of this species.

- The distribution of the omnivore feeding guild (Figures 4.31 - 4.35 & 4.85) shows a strong association with R17 of the RLM and the MLM. The opportunities offered by the diverse vegetation of the nearby kopjes, riparian vegetation and mixed farm at R17 could have influenced the high numbers recorded at this point.

The impacts of the grazing gradient may have influenced the distribution of some of the nesting guilds.

- The tree nesting guild distribution (Figure 4.36) conformed to the distribution pattern of highest woody biomass (Figures 4.41 & 4.42). Perhaps the most influential impact of land use on avian tree nesting guild was the direct removal of trees for fuel, construction and fences (du Plessis, 1995). The most intense areas of these activities were the CLM, western area of the ILM and the RLM. The impact of these activities was evident, strongly suggestive, and supported by numerous other studies.

- The distribution of shrub nesting guild (Figure 4.37), when compared to the shrub distribution (Figure 4.43), suggests that there was a reduction in shrub nesters in the CLM, although there was a high concentration of shrubs in the CLM. The shrub size as a consequence of land use on the CLM (Figure 4.5) may have influenced the distribution of the shrub nesting guild.

- The distribution of the cavity nesting guild (Figure 4.38) conformed to the distribution of woody cover (Figure 4.42) with the exception of the RLM, which had a high woody biomass, but a reduced number of cavity nesters. The RLM had a similar grazing program to the CLM, which included harvesting of wood for fuel, construction and fencing. The reduced numbers of cavity nesters in an area of high woody biomass confirms that the impact, although not directly connected to the grazing program, was significant when compared to areas in the MLM with similar woody biomass, but with little collection of wood.

- The distribution pattern of ground nesters (Figure 4.39) conformed to a similar pattern when compared to grass cover (Figure 4.44), but the trend was reversed when compared to bare ground (Figure 4.45). The reduced grass cover and increased bare ground as a consequence of grazing intensity may have influenced the distribution of the ground nesting guild. Reduced grass cover and increased bare ground will result in increased surface temperatures, which can reach temperatures of 70^{o}C (Bhalotra, 1985).

Different land uses will have different effects on the environment. The current study analysed the effects on the environment as a result of four different grazing regimes. These different management practices have been shown to result in altered vegetation with a fragmented landscape being the result.

5.4.2.1. Fragmentation

An edge or ecotone, which is the result of two vegetation types coming together, is either a clearly defined boundary or a zone of transition, where plants and animals from both vegetation types blend into one another (Harris 1988; Yahner 1988). Conservationists have for many years managed appropriate landscapes with the objective of increasing the amount of edges between vegetation types, with the net result that there will be higher animal populations.

The different management practices of the current study produced vegetation edges. These edges included the fence line between the MLM and the ILM (Figure 3.6) and the marked change in vegetation between the riparian vegetation of the RLM and the CLM (Figure 3.8).

There were also natural vegetation edges (Figures 4.1 & 4.87) in the study area (kopjes and riverine), which have been mentioned previously. The difference in woody biomass and woody species composition was evident when comparing the riparian vegetation and the vegetation found on the rocky outcrops. When these two vegetation types are compared to with vegetation matrix between the river and rock outcrops, there are marked differences (Perkins, 2006; Trager & Mistry, 2003).

The increase in animal species at vegetation edges or ecotones can be attributed to a combination of the species of each of the two plant communities, including the species that use the ecotone as their preferred habitat (Gates & Gysel, 1978). The net result will be that these ecotones have a higher population of animals, particularly birds (Gates & Gysel, 1978).

Induced fragmentation as a result of human activities however, may not have the desired effect of creating edges that are suitable for increased biodiversity. Created edges may result in decreased species composition and richness (Malan, 2001). The created edges at R17 include the farm with small fields of crops and livestock combined with the natural edges of the riverine vegetation and kopjes which contributed a patchy environment at this point.

When habitats are fragmented there is an alteration in the patterns of distribution of the vegetation, which can lead to dividing of the populations of animals. This division may affect the viability of the population being examined (McGarigal & McComb, 1995). Newmark (1991) found in his study in the Usambara Mountains of Tanzania that species extinction occurred as a result of forest fragmentation and that forest fragments contained a larger number of species before fragmentation. The area studied by Newmark (1991) was utilised by the surrounding human population for farming and wood collection. Vertebrate populations were found to be reduced as a result of fragmentation to a level after which extinction was likely. Extinction may result from genetic or environmental fluctuations (Newmark, 1991). It is the forest interior bird species that are particularly prone to extinction as a result of forest fragmentation (Laurance, 1991; Newmark, 1991).

5.4.2.2. Bush encroachment

Walker *et al.* (1981) suggested that semi-arid savannah, when undisturbed, can be viewed as being in equilibrium with grasses and trees in a competitive balance. The controlling factor of this balance was the availability of water. The trees draw water from deeper subsoil, while the grasses draw water from upper layers of the soil. When rain does fall, sufficient water infiltrates to the subsoil, permitting trees to grow, but not an excessive amount that permits the growth of woodland. Grass draws water from the upper layers of the soil as the root system is shallow. Grass cover is critical in regulating the amount of water that infiltrates into the soil because grass removal exposes the soil to direct rain drop impact which seals of the soil. This process is known as “capping”. Water runs off this sealed grassless surface, causing erosion (Walker *et al.,* 1981*)*.

Trees, on the other hand, can facilitate the flow of water to the subsoil layer by reducing the impact of the rain drops on its leaves and branches. The water then flows slowly down the stem of the tree into the soil at the base of the tree, then down into the subsoil (Tainton, 1999; Walker *et al.,* 1981*)*. Pressland (1973) studied the effects of tree cover on the infiltration of water in an arid area of south-western Queensland, Australia and found that there was a six-fold increase in the infiltration of water below a tree when compared to open ground.

The competitive edge between grasses and trees will shift in favour of trees as a consequence of overgrazing (Nsinamwa, 2005; Walker *et al.,* 1981). The end result of excessive stocking is the drastic reduction in grass biomass resulting in less infiltration of water into the upper layers of the soil after rain, which leads to even less water available for the remaining grass. The reduction in the grass biomass was followed by a significant increase in woody vegetation, often resulting in bush encroachment. In his study in eastern Botswana, van Vegten (1983) found that in a relatively short time bush encroachment, as a result of overgrazing, changed the landscape significantly with an increase in woody biomass tripling in the space of 25 years. In their study in the southern USA, Buffington and Herbel (1965) noted that there was very little woody vegetation, which they called mesquite, on the open grasslands prior to grazing by livestock in the early 1880s. Intensive grazing resulted in a considerable increase in the woody vegetation and a reduction in grass cover. Erosion increased, resulting in less water infiltration into the topsoil, thereby making it more difficult for grasses to grow.

Intensive grazing, whether controlled or uncontrolled, will have an effect on the fodder availability, which can lead to bush encroachment (Joubert & Ryan, 1999; Walker, *et al*., 1981). The net result was an increase in the ratio of bush to grass, with bush species, such as Sickle-bush *(Dichrostachys cineria)* and Acacia (*Acacia melifera)* being very common encroachers, and palatable perennial grasses decreasing and being replaced by unpalatable annual grasses Although of minor significance, it is worth noting that under low grass cover conditions moderate hoof action can have a beneficial effect on the infiltration of water into the topsoil (Savory & Butterfield, 1999; Walker *et al.,* 1981).

The change in vegetation structure as a result of intensive grazing will have an effect on the ecology of the area and ultimately affect the natural fauna (Nsinamwa, 2005). The differing grazing intensities of the current study confirmed these finding with changes in vegetation cover affecting the distribution of bird species, bird numbers and different guilds.

5.4.2.3. Wood collection for fuel and construction

Kalapula (1989) reported on a chain of events as a result of uncontrolled fuel wood collection in Zambia: soil erosion, causing sedimentation of dams and rivers, which will lead to flooding and drought, with wood for fuel being in short supply, ultimately resulting in widespread malnutrition. Previous reference has been made to the study by du Plessis (1995) confirming the high incidence of fuel wood in Africa. Mwampamba (2007) noted that the effects of wood collection on the environment for the manufacture of charcoal production in Tanzania was significant, but suggested that more research in this field was required.

It has been noted previously that 35 - 50% of animal forest species, vertebrates and invertebrates, in southern Africa need cavities for either nesting or roosting (du Plessis, 1995). Du Plessis (1995) found that cavity requirements for animals would be under threat in the forest that was heavily utilised for providing fuel wood. Du Plessis showed that primary cavity users created cavities in mainly dead wood whereas secondary cavity nesters used cavities that had already been created. Foley (1985) noted that the removal of trees in forested areas of Kenya was restricted to trees with a smaller circumference. Large trees were not removed as these had no value commercially as transport was limited in these rural areas. Foley (1985) suggested that the impacts removal of smaller trees would allow for certain avian species to survive in these areas of subsistence farming.

Many cleared fields in Botswana will have scattered numbers of Marula (*Sclerocarya birrea*) trees in the fields. These trees are not removed because of the valued fruit they produce (personal observation) which may benefit frugivores and insectivores.

5.5 Conclusion

There were a number of factors affecting bird distribution in the current study, both natural and anthropogenic. Avifauna reacts to these factors differently and it is these behavioural responses measured as distribution patterns that were the focus of this study. The matrix of patches found naturally and created by land use and seen in the context of the IDH suggests that bird distribution patterns were influenced a combination of these factors. The conclusion of this study will be discussed in light of the hypotheses listed in Chapter 2.

Hypothesis 1: Bird numbers, species richness, and indicator species will be affected by different land uses.

The survey methods and data treatments were able to detect meaningful distribution patterns, despite the presence of kopjes. That the presence of kopjes did not influence the distribution patterns at the scale of this study is indicative of the robustness of the study. At scales smaller than 1 x 1 km, a more detailed distribution pattern is likely to provide a clearer picture of the effects of the kopjes on bird distribution patterns. A consistent pattern of bird distributions were observed, strongly suggestive that both bird numbers, indicator species, and species richness was affected by different land uses.

Literature cited by some authors suggests that biota, in this case avifauna, are good indicators of different land uses. The results of this study strongly support the findings of many others. Bird numbers, species richness, and indicator species were therefore influenced by the intensity of grazing, the major difference between the land uses investigated.

The Intermediate Disturbance Hypotheses (IDH) and patchy environment explanations were both investigated as theoretical explanations of distribution patterns. Here, it was found that both influenced bird numbers, indicator species, and species richness.

Hypothesis 2: Avian guilds will respond to different land uses.

The impact of grazing on vegetation has been discussed throughout this dissertation. This study found that the effects of changes in vegetation on avian guilds varied according to the intensity of grazing.

- Feeding guilds responded to grazing intensity either directly, such as granivores, or indirectly, such as insectivores.
- Frugivores were mainly associated with woody vegetation, but the effects of grazing were influential on the distribution of this guild indirectly over a long period of time as young growth is severely reduced by grazing.
- Omnivores had access to a favourable diet in summer, but when these diets were reduced or changed during the winter the omnivores presumably reverted to a diet of insects and other items associated with cow dung.
- Grazing intensity directly impacted ground nesters, shrub nesters, tree nesters, and cavity nesters. The distribution of tree and cavity nesting guilds were further also affected as a consequence of wood harvesting due the presence of subsistence farmers.

Literature cited under hypothesis one above suggested that avian guilds would be more suitable as indicators of different land uses than avian species. This study found ample evidence that species as well as guilds were both good indicators. It is therefore suggested here that both avian species and the different avian guilds can be used in conjunction when studying the impacts of different land uses.

5.6 Implications for conservation

Biodiversity across all scales, from genes to species to ecosystems, is affected by land use (Present study; Walker, 1992). The homogenisation of habitat as a consequence of degradation will result in a few winner species within a general scenario of losers (Carrete *et al.,* 2009). The most effective way to minimise species loss is to maintain ecosystem function (Walker, 1992).

The present study reconfirms two very important points when addressing the conservation implications:

- The value of the rocky outcrops or kopjes as areas of high avian diversity and areas of refuge for many bird species particularly in the winter months. These outcrops should be regarded as islands of biodiversity and be managed in such a way as to conserve their biodiversity.
- The impact of grazing intensity, if managed correctly, could be beneficial to avian communities.
- Botswana’s human population is not large, but the rural community, in particular extends over most of the country and is encouraged by government to farm livestock. Most of the cattle herds draw water from communal points resulting in areas of environmental damage which diminishes as the distance from the water point increases. There are no fences to control cattle movements in the rural areas, as noted in the current study for the CLM. If the intensity of grazing was reduced to permit recovery of the vegetation, the impacts on the vegetation would be reduced.
- The results of this clearly confirm the impact of cattle farming as a land use, on bird communities. The importance of trees particularly on rocky outcrops and riparian vegetation are important for avufauna was evident. Cattle farmers should be made aware of the importance of trees and farm accordingly.
- Overgrazing in both commercial and communal farming will affect grass cover resulting in bush encroachment and soil erosion. The affect in bird communities was made evident in this study and the implications should be made available in order that conservation measures can be implemented.