CHAPTER 4

Effects of habitat fragmentation on the wildlife of the northern Drakensberg Afromontane region, South Africa.

ABSTRACT

This study aims to determine the effects of degree of isolation, edges, fragment size and fragment characteristics (such as rainfall, elevation and geology) on the faunal and floral communities of twenty-four grassland fragments in the northern Drakensberg Afromontane region, South Africa. In addition, sampling plots of different sizes were used to determine whether fixed-size sampling plots yield community structure estimates representative of the community structure of fragments of different sizes. The results were used to assess the conservation status of each fragment. No significant edge effects as a result of afforestation on the faunal communities 10, 20 and 50 metres from the fragments' edges were evident from the analyses. Fragment size influenced bird species richness, bird species diversity and general faunal diversity significantly, insects marginally and plants very little. Small, isolated fragments found within afforested areas have high conservation importance since they often remain the only representatives of particular plant communities – it is concluded that the fragments studied remain largely representative of the non-fragmented grasslands in the area.

Keywords: habitat fragmentation, fragment size, afromontane, population dynamics

Introduction

An ever-increasing human population and the resulting resource utilisation and fragmentation of the remaining natural habitats are the most critical and serious threats to the extant biodiversity (Thomas *et al.* 1997, Turin 1988, Sotherton 1998). The afromontane grassland of the escarpment region in Mpumalanga, South Africa, is no exception. Extensive afforestation in the area has destroyed and/or fragmented large parts of the largely unique grassland in the region (Deall 1985, Matthews 1991, Matthews *et al* 1993, Foord 1997). In some areas on the escarpment, the remaining patches of mountain grassland are mostly small, isolated and at risk of being affected or destroyed through forestry management activities.

Isolation in itself is a serious threat, for individual populations of many insect and plant species that are less mobile can be considered as island populations. Loss of genetic variation through genetic drift and inbreeding depression and can cause higher extinction rates in island than in mainland populations (Frankham 1998). For birds, the problems associated with island populations may be fewer because of greater mobility, but loss of habitat is probably the greatest threat to avian diversity (Allan *et al.* 1997, Haig *et al.* 1998, Vickery & Gill 1999, Pasitschniak-Arts, *et al.* 1998).

Other dangers often associated with habitat destruction and fragmentation, especially by afforestation (Richardson 1998), such as invasion of natural vegetation by aggressive exotic species could be important for the conservation of the montane grassland (Thiollay & Probst 1999). An understanding of the ecological factors influencing distributions of grassland plants and animals, as well as their interactions, is essential if the remaining biodiversity of the fragmented grassland of the Mpumalanga escarpment region is to be conserved successfully.

Forestry management is aware of these problems, and this project is in collaboration with Safcol, to assess the remaining biodiversity of these grasslands, its distribution patterns and vulnerability and to make recommendations to managers about the future conservation of the remaining patches of natural grassland.

Aims

- To quantify the effect of several environmental characteristics (slope, rainfall, geology, etc) on the faunal community structure of the grassland fragments.
- To quantify the effects of degree of isolation on species richness, species diversity and assemblage structure of plants, insects and birds in grassland remnants.
- To test for the effects of edges on the extant insect biodiversity in the grassland fragments inside plantations.
- To quantify the effects of fragment size on species richness, species diversity and assemblage structure of plants, insects and birds.
- To rank the grassland fragments in an order of conservation importance using factors such as biodiversity and uniqueness of the floral community.

Study Area

In the study area, represented by North-eastern mountain sourveld (Acocks 1988, Matthews 1991), twenty-four grassland fragments were chosen because of their accessibility, variability in geology and physiographical distribution. The study area includes grassland patches between the Drakensberg escarpment cliffs near Sabie and Graskop in the east and the Long Tom Pass in the west, the Blyderiverspoort Nature Reserve in the North and the Sudwala Caves in the south, covering 535 km^2.

The fragments range between 0.5 and 500 Ha and are between 1130 and 1980 metres above sea level. Six of the fragments are larger than 500 Ha, and were used as control sites. Only two of the twenty-four fragments are officially protected, and most of the fragments are under forestry control, with a few under private or government ownership.

Management of the grassland fragments range from burning and grazing to cutting and no management at all, and is inconsistent in timing and coverage. The study area is mountainous with many peaks, deep valleys and gorges with their associated streams. Geologically, the area is underlied by the Transvaal sequence (Geological Survey 1986). The underlying rocks of the area consist mainly of dolomite, lime, shale and quartzite (Geological Survey 1986).

Materials & Methods

- Field Survey:

Plants:

Each fragment was sampled using a 100 by 100 m sampling plot, the position of which was determined from aerial photographs and ground observations to be representative of the fragment being investigated. A 200-nearest-neighbour step-point survey presented adequate quantitative data to measure the frequency of dominant species (Bosch & Janse van Rensburg 1987). An inventory of all plant species encountered, using a semi-quantitative assessment of the cover-abundance of each species according to the Braun-Blanquet cover-abundance scale (Muller-Dombois & Ellenberg 1974, Werger 1974) detected rare species within the sample plot (Kamffer 2001, Chapter 2).

Insects and Birds:

Eight insect surveys during October/November and February/March during 1998 and 1999 were performed at each sample plot, two surveys for each of the four sampling periods. Sweep netting was used to calculate the species composition and relative abundances of the Coleoptera and Orthoptera of the twenty-four study fragments (Kamffer 2001, Chapter 3). Sweep netting comprised 200 sweeps with a 30 cm sweep net covering a representative proportion of the total surface of each fragment. In addition, presence/absence data was collected for Lepidoptera and Neuroptera during four sampling periods of fifteen minutes duration for each of the four seasons, while actively collecting adults with a hand net (Kamffer 2001, Chapter 3). This was performed between 10:00 in the morning and 14:00 in the afternoon, on days with less than 50% cloud cover.

During each of the above four sampling periods, one hour of bird identification was performed; comprising four fifteen minute periods during which all of the birds sighted (using binoculars) and heard were listed (Kamffer 2001, Chapter 3).

- Effects of sample size and spatial organisation of samples:

To test if the size of the area actually sampled within each fragment influences the resultant samples, the following experimental procedure was followed:
Nine fragments falling in three size classes were chosen: three small fragments (fragment 3 – 1.9 Ha, fragment 12 – 2.1 Ha and fragment 13 – 0.9 Ha), three medium-sized fragments (10 – 34 Ha, 14 – 64 Ha and 18 – 33 Ha) and three large fragments (1 – 106 Ha, 6 – 210 Ha and 19 - 500+ Ha). Within each sample plot, Coleoptera and Orthoptera were sampled by sweep netting. A series of six sweeps of 200 steps, each within a seperate100m by 100m sampling plot, were performed within each sample plot by placing sweep locations at even-spaced intervals in such a way as to cover the grassland component of each fragment in as representative a way as possible. Areas of the cumulative sweeps ranged between 0.819 Ha and 6.105 Ha. Each of these sweeps roughly corresponded to the normal sample size used in other parts of this study within each of the fragments. However, in small fragments each sweep was spatially restricted in order to fit six sweeps within a single fragment, and the 100m x 100m layout could not be used.

The insect assemblage structures (resultant from above sampling) of the nine fragments were statistically compared to the areas actually sampled (0.819 Ha – 6.105 Ha) and to the true fragment sizes (0.9 Ha – 500+ Ha). Two diversity indices were calculated, both of these being independent on the number of observations in the data set: Fisher's α (Fisher 1954) and Simpson's Index of Concentration (Simpson et al. 1960). Regression analyses were used to test for significant interactions between area sampled (number sample plots used in calculation) and true area (fragment size) on these diversity estimates.

- Edge effects on invertebrate assemblage structure:

Twelve of the twenty-four fragments were surrounded by mature plantations, and were each sampled six times, twice at distances 10, 20 and 50 metres from the edge of the fragment, using the sweep netting techniques described above. For analyses, fragments were grouped into the three major plant community groups, Wetter North (fragments 1,4,7,8,9), Transitional (fragments 6, 10,11,12) and Drier South (fragments 15,17,18)

(Kamffer Chapter 2). Multi-dimensional scaling (MDS), two-way nested ANOSIM (fourth-root transformed abundance values) and RELATE (testing matched distance matrices, Clarke & Gorley 2001) were used to test for the effects of habitat edges on the insects studied, and to discern possible trends in their abundance patterns in relation to distance from the habitat edge. Analyses were performed separately for each of the three major community groups (Wetter North, Transitional and Drier South). One-way analyses of variance (ANOVA, fixed effects) were performed for comparing the abundances of each individual species with respect to distance-from-edge in each of the three major community groups.

- Effects of distance to nearest grassland:

One-way analysis of similarity (ANOSIM) was performed to compare the faunal community structure of two groups of fragments: those closer than one kilometre to the nearest grassland (nine fragments) and the fragments further away than one kilometre from the closest grassland (eight fragments). All the analyses of similarity (fourth-root transformed abundance values) were performed on the number of individuals of each species encountered within each sample plot. The demarcation of one kilometre was chosen to have similar-sized sample sizes of fragments - for all the fragments together, and separately for the three major plant community groups (Wetter North, Transitional and Drier South). A SIMPER analysis was done to assess the individual contribution of species and their abundances to the variation between the faunal communities of the two groups of fragments (closer/further than one kilometre from nearest grassland neighbour). In addition, distance to nearest grassland was used as a variable in a gradient analysis using redundancy analysis (RDA; Jongman et al. 1995).

- Effects of fragment size:

I plotted fragment size against species richness (total number of species) and Shannon-Wiener species diversity (MacArthur & MacArthur 1961) for the different faunal groups (birds, Coleoptera, Orthoptera, Neuroptera and Lepidoptera), and for the faunal diversity as a whole, before performing non-linear regression analyses on the data, using the computer software NLREG (Sherrod 2003).

- Comparison of control sites and grassland fragments:

One-way analyses of similarity (ANOSIM, Clarke & Gorley 2001) - were used to test for significant differences between the faunal community structures of experimental fragments and control sites. A presence/absence transformation was used to statistically include the rare and single occurrence species. Of the three plant communities (Kamffer Chapter 2), separate analyses were performed for two communities for which control plots could be included in the experimental layout.

- Environmental characteristics affecting community structure:

The influence of various environmental characteristics (distance to nearest grassland neighbour, elevation, fragment size, lithology, rainfall, temperature, aspect and slope) on the faunal community structure of the fragments was tested, using redundancy analysis (CANOCO; Jongman et al. 1995). A square root transformation was performed on the species abundance data.

- Conservation evaluation:

Unfortunately there was no obvious quantitative way to compare the fragments. Therefore several qualitative criteria were used to make a comparison in order to assign a conservation importance to each fragment, ranked in increasing order of species richness for Lepidoptera, birds and plants, and in increasing order of Shannon-Wiener species diversity of Coleoptera and Orthoptera. Each fragment received a rank from 1 to 24 for each of the five groups used. If two fragments had the same level of species diversity, the fragment with more endemic animal species received the higher rank. The fives scores/rank were totalled and the twenty-four fragments were assigned a conservation score according to its total score. For example, fragment no. 6 scored 23 for plants (2nd highest), 22 for birds, 8 for butterflies, 8 for beetles and 15 for grasshoppers, scoring a total of 76. The total score (76) was the sixth highest total score, assigning the conservation rank of 6 to fragment no. 6. Since species-poor fragments may in reality have a high conservation importance because of the presence of endemic or rare taxa, this

approach may be simplistic. However, the results suggest that this problem does not apply to this particular data set.

Results:

- Effect of sample plot size on biodiversity estimates:

No clear relationship between, either true area of the fragments and area sampled and species richness and/or – diversity was evident. The smallest area sampled (fragment 13 – 0.82 Ha) had the fourth highest species richness (23 species) and the largest area sampled (fragment 1 – 6.11 Ha) had the fourth lowest species richness (22 species) and species diversity (Fisher's $\alpha = 7.84$). The largest fragment (500+ Ha) had the third lowest species richness (Fisher's Alpha = 8.560, Table 1). Regressions results (Table 2) did not show any significant effects of the geographical area sampled on the biodiversity estimates of the fragments. Therefore I assume that the estimates arrived at for the area sampled within each fragment is representative of that of the complete fragment.

- Environmental characteristics affecting community structure:

Detrended correspondence analysis (DCA), using square root transformed abundance data, indicated the gradient length of the first canonical axis was 1.46383 (total sum of squares in species data = 14913.8). As a result, gradient analysis was performed using a redundancy analysis (RDA). The permutation test resulting from this analysis revealed a non-significant value for the first canonical axis (Eigenvalue = 0.08, F-Ratio = 1.255 and P = 0.3050), but a significant value for the first four canonical axes together (Trace = 0.477, F-Ratio = 1.184 and P = 0.0150). The ten species contributing the most to above-mentioned result include two Scarabs (Scarabaeidae – *Aphodius* sp 1 and Melolonthinae sp 2), two weevils (Curculionidae – *Eudraces* sp 1 and Curculionidae sp 42), one leaf beetle (Chrysomelidae – *Asbecesta* near *capensis*), one darkling beetle (Tenebrionidae – *Lagria* sp 1), one longhorn beetle (Cerambycidae – *Anubis scalaris*), one jewel beetle (Buprestidae – Buprestidae sp 1), one ladybird (Coccinellidae – Coccinellidae sp 4) and one Dor beetle (Bolboceratidae – *Mimobolbus maculicollis*). Of these ten beetles only

three are not restricted to the Drier South Region (*Anubis scalaris* – Wetter North and Drier South, *Lagria* sp 1 – throughout and *Eudraces* sp 1 – throughout).

The associated stepwise multivariate regression showed distance to the nearest grassland to be the only environmental characteristic to significantly influence the faunal community structure of the fragments (F-Ratio = 1.79, P = 0.01, Figure 1, Table 3). Slope was the environmental characteristic with the smallest effect.

- Effects of distance to nearest grassland:

In contrast with the results from redundancy analysis, the analysis of similarity (ANOSIM) and t-tests did not reveal significant differences in the faunal community structure of fragments closer to – and further than one kilometre from the nearest grassland neighbour (Table 5, Figure 2). This trend was the most evident for fragments of the Transitional region (p = 0.457) and the least obvious for the fragments of the study area as a whole (p = 0.054). The SIMPER analysis (Table 4) showed that of the ten species contributing most to the dissimilarity between insect communities of fragments closer/further than one kilometre from the nearest grassland neighbour, eight were also in the group of ten species characterizing the faunal communities of either/both groups (contributing towards similarity).

- Edge effects:

The insect communities found at 10, 20 and 50 metres from the edge of the grassland fragments did not differ significantly (RELATE – Table 6), nor did an ANOSIM performed separately for each of the three major plant communities reveal any significant edge-related differences (Table 6, Fig. 3). The ANOVA results for the individual species revealed only one (of 57 - in the Transitional region) having a distribution that differs significantly with respect to distance from the habitat edge: *Eremnus* sp. 2 was only found at 10 metres from the edge of the fragment, close to the plantations.

- Effects of fragment size:

Fragment size only had a significant influence on bird species diversity, bird species richness and general faunal diversity (Table 7, Figure 4).
There was a non-significant trend for insects to biodiversity to be reduced in very small fragments (Figure 4). Most of the botanical data exhibited no significant relationship with fragment size (Table 7).

- Comparison of control sites and grassland fragments:

The species composition of control sites were compared to that of experimental fragments, and were not found to be significantly different for all the faunal groups pooled together (ANOSIM significance level $p = 0.891$), or for the fragments of the Transitional Region (significance level $p = 0.400$) and the Wetter North Region (significance level $p = 0.978$;Table 5). Unfortunately there are no control sites in the Drier South Region to compare with the fragments.

- Conservation evaluation:

Using the four separate scores for birds, butterflies, beetles and grasshoppers, each fragment was assigned a total conservation score. The twenty-four fragments were then ranked in order of conservation importance (Table 8). Fragments of the Wetter North (community 1.1) had an average score of 65.3, fragments of The Transitional Region (community 1.2) 66.6 and fragments of the Drier South (community 2) 52.3 (Table 8).

Discussion

- Effects of sample size and spatial organisation of samples:

This work focused on the grassland component of indigenous vegetation and specifically excluded indigenous forest or bush associated with the grassland. At the start of this study, it was decided to use sample plots one Ha in size within the homogenous unit floristically most representative of that specific grassland fragment. Although these sample plots would not include finer variations in grassland within each fragment, and therefore possibly not include all the animal and plant species within each fragment, it provides for units that are statistically comparable for all of the twenty-four fragments

used in this study. Inclusion of more sampling plots in the larger fragments would have brought about an unbalanced statistical design. Fortunately the survey work incorporating six sampling plots per fragment suggested no strong effects of increasing the number of sampling plots within a fragment (Table 1). The survey layout of this study therefore appears representative of the community structure of each of the fragments.

- Environmental characteristics affecting community structure:

Degree of isolation was the only environmental variable that appeared to have a significant influence on the faunal community structure of the grassland fragments. The fact that this relationship was not evident from the ANOSIM results is probably due to the effect that a single comparison was made: closer than 1 km *versus* those further away from grassland. The SIMPER analysis (Table 4) indicated that 8 of the top ten species accounting for dissimilarity between the two distance classes are also included in the top ten species characterising either/both of the distance classes, suggesting that there are few differences between the faunal community structures (species composition) of fragments closer/further than one kilometre from the nearest grassland neighbour, and most of the differences are a result of differences in the relative abundances of the same species. The 1 km demarcation was used because it facilitated approximately equal numbers of fragments in each if the two distance classes.

In contrast, the redundancy analysis detected gradient effects across a whole range of distances. Therefore, distance from grasslands does not appear to affect faunal community structure at distances in the order of 1 km, but does have a significant effect at larger distances from grassland. However, only two of the ten species correlating most closely with distance from grassland were found in all three regions (Wetter North, Transitional and Drier South) of the study area. Seven of the species were only found in the Drier South region and one species was present in the Drier South and Transitional regions. Fragments of the Wetter North and Transitional regions were, on average, 0.3025 km and 0.61875 km respectively from the nearest grassland neighbour. In contrast, fragments from the Drier South were on average 2 km from their nearest grassland neighbour, at least three times further. It is therefore possible that the

significant result of the RDA is due to differences in faunal communities of the different regions that incidentally correlate with significant differences in degrees of isolation between these regions, and not resulting from community differences between fragments resulting directly from increasing degrees of isolation.

Although elevation, rainfall and aspect all impacted reasonably on the faunal community structures of the grassland fragments, the one environmental characteristic not used in the analyses likely to influence the community structures to a large degree, is management regime. The influence of management on grasslands is well known (Greatorex-Davies & Sparks 1994, Whelan 1995, Bond & Wilgen 1996, Swengel 1996, Welch 1998, Gross et al. 1998, Katoh et al. 1998 and Swengel 1998). Unfortunately no information was available on the management of the grassland fragments used in this study, and the effect of grassland management on the fauna and flora of the twenty-four fragments remains unknown.

The effects of degree of isolation was the most evident in fragment 15, the most isolated of all the fragments (4.8 km to nearest grassland neighbour). The TWINSPAN-based interpretation of the faunal communities indicated the obvious differences in faunal community structures between fragment 15 and the other fragments (Kamffer Chapter 3) – it was only one of two fragments studied where the weevil Eudraces sp 1 was not encountered (Eudraces sp. 1 was by far the most dominant animal encountered during the survey with more than 5400 specimens sampled).

- Edge effects:

The assemblage structure of two invertebrate groups (Coleoptera and Orthoptera) was not significantly affected by edges. Although edge effects are usually more pronounced in vertebrate groups (Stevens & Husband 1998), even birds are sometimes not affected by edges (Pasitschniak-Arts et al. 1998). Ingham & Samways (1996) showed that grasshoppers vary greatly in degree of stenotopy, with many species being distributed regardless of landscape boundaries while others do, indeed, respond to the landscape pattern as perceived by human observers. They state one very important fact: as a

consequence of the considerable variation in degree of stenotopy, the results should rather be viewed at species level than at higher taxonomic levels. They also mention that gradual ecotones/edges are likely to improve diversity compared to sharp ecotones as found in this study. In another study patterns of grasshopper distribution patterns are also attributed to edge effects (Samways & Moore 1991), while bush crickets in southern France show an affinity for ecotones (Samways 1989). The bush crickets seem to use these ecotones as areas in which they commonly develop, before moving to adjacent areas. So-called 'edge species' have also been shown to make important contributions to the diversity patterns of remnant patches (Quinn & Robinson 1987). It is therefore possible that the non-significant influence of edges on the coleopteran and orthopteran assemblages of the fragments is a result of three factors: the abruptness of the edges, the fact that these edges are independent of landscape boundaries and the fact that plants and animals might be influenced on a different scale. Invertebrates are mostly influenced by microclimatic and other factors on a small scale, and it is therefore not surprising that they are seemingly uninfluenced by effects on a larger scale.

- Effects of fragment size:

The effects of fragment size were seemingly linked to the direct influences of the surrounding habitat experienced by each taxonomic group. Plants showed no detectable response to fragment size, probably because each plant is only influenced by a small area surrounding its position within the grassland fragment, i.e. the moisture, soil condition, shade, etc. directly influencing each individual plant. Insects were affected (albeit non-significantly) by fragment size, possibly because they are influenced by a larger area than plants (feeding sites, ovipositioning sites, areas covered in search of mating opportunities, etc.). Birds was the only group significantly influenced by fragment size, most probably because they are influenced by factors on a much larger scale than insects and plants, resulting in the absence of many species from most of the very small fragments (even though the smaller, isolated fragments compare well floristically to the sites in large, relatively undisturbed grasslands). We would expect that most vertebrates, e.g. amphibians, reptiles as well as small mammals found in the fragments would be affected in a way similarly that birds are.

- Conservation evaluation:

The qualitative method used to assess the conservation status of each fragment has many limitations. It does, however, provides a basic understanding of the distribution and rarity of certain geological features, animal and plant species important to conservation and uses these factors in combination to form a basis for further investigations. The geologically and floristically unique plant communities 1.1.2 and 1.2.2 also have faunal characteristics that emphasise their conservation importance. The fauna and flora of the *Eragrostis sclerantha – Panicum natalense* grassland (community 1.2.2) is especially important for conservation – it is only found on Black Reef Quartzite between 1260 and 1590 metres above sea level, hosting various rare, endangered and endemic plants and animals (Kamffer Chapters 2 and 3). Generally speaking, fragments situated further south enjoy less conservation priority, with the Drier South Region being of least importance (Table 8).

Conclusion

The following conclusions emerge from this study:

- Isolated grassland fragments in this study represent largely unaffected natural plant and insect communities, differing little from large unfragmented grasslands in the study area.
- Fragments found within afforested areas therefore have a high conservation importance, since they represent 'natural' grassland areas and are often the only representative of a particular plant community left in the area
- No significant edge effects on the faunal communities 10, 20 and 50 metres from the fragments' edges exist as a result of afforestation in the area.

- Birds (and probably other vertebrates in these grasslands) are affected by fragment size, while invertebrates are much less affected and plants do not show any measurable effect of fragment size.

- Fragments in the wetter northern part of the study area, characterised by high levels of plant endemicity, have a higher conservation importance as judged by faunal biodiversity.

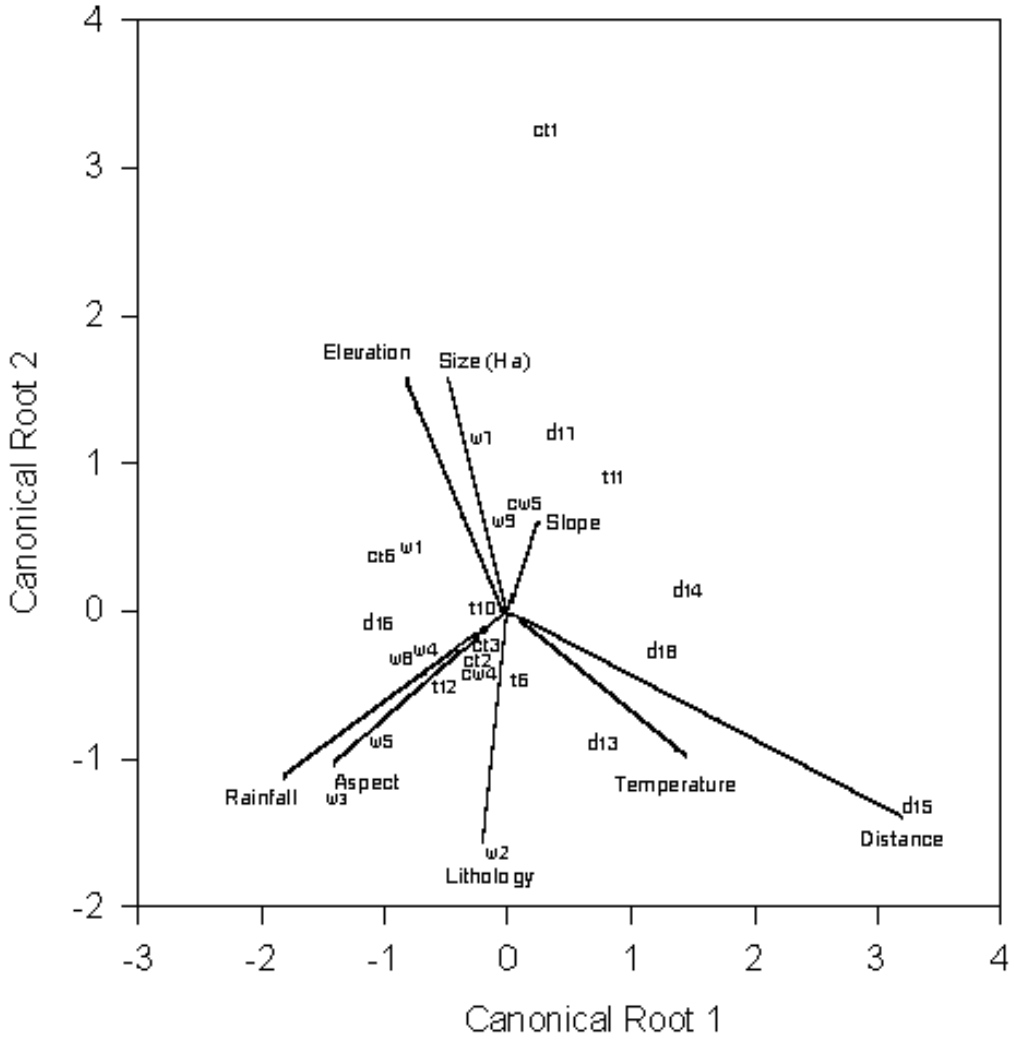


Figure 1. Results of the Redundancy Analysis (RDA) on the faunal community structure of the twenty-four grassland fragments. The plot of canonical root 1 vs. canonical root 2 shows the relative influences of fragment characteristics (distance to nearest grassland neighbour, elevation, fragment size, lithology, rainfall, temperature, aspect and slope) on the faunal community structure of the twenty-four grassland fragments. Degree of isolation (Distance) had the greatest influence (cf. Table 3).

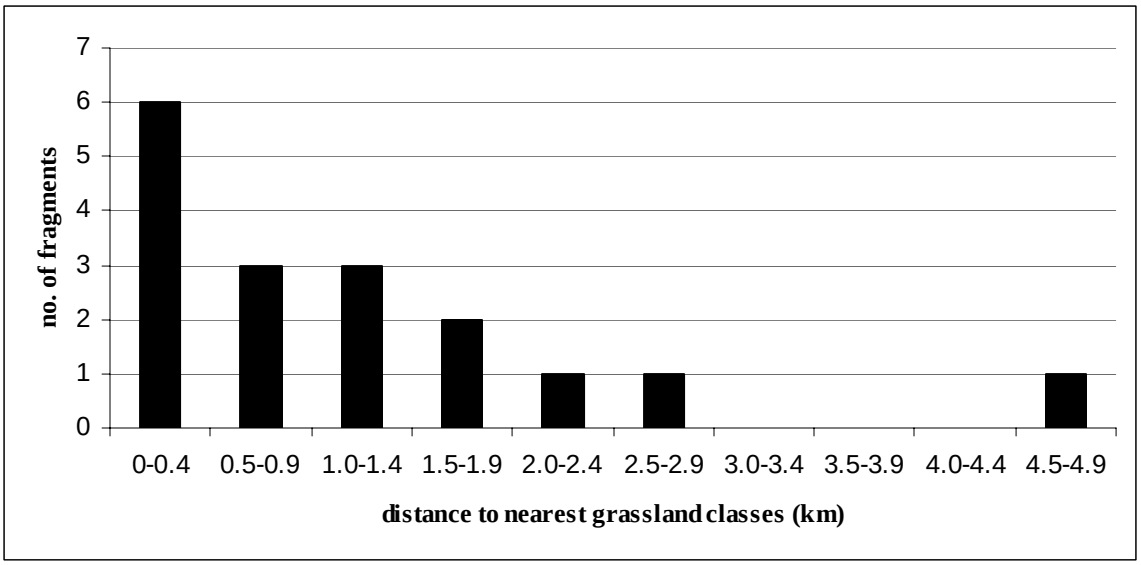


Figure 2. Histogram to show distance to nearest grassland classes. Fragments were divided divide into two groups, those closer than one kilometre (nine fragments) to the nearest grassland, and those further than one kilometre (eight fragments) for data analysis.

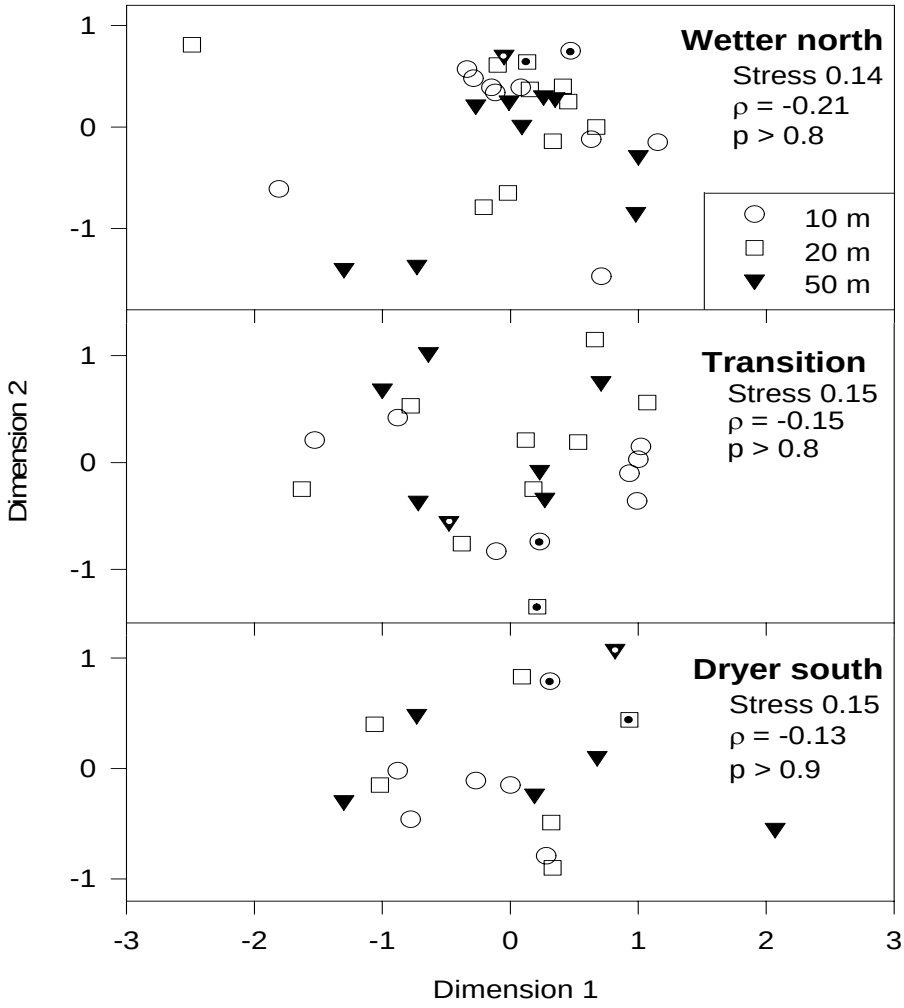
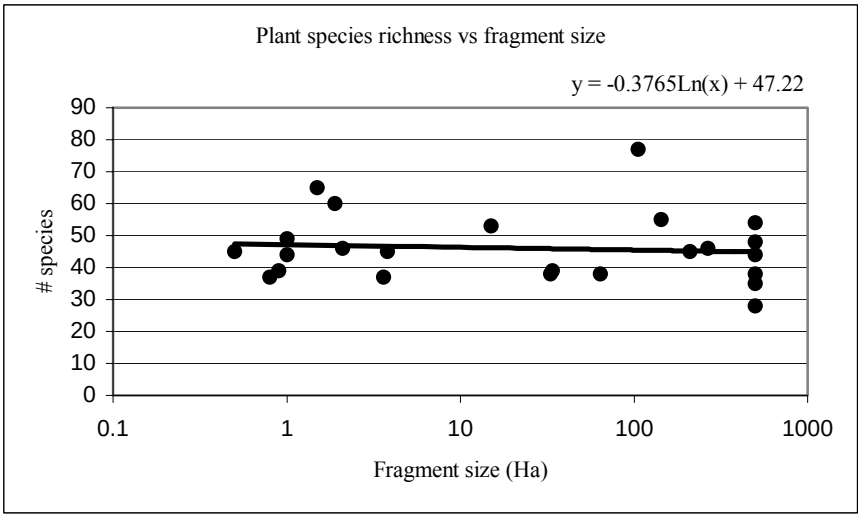
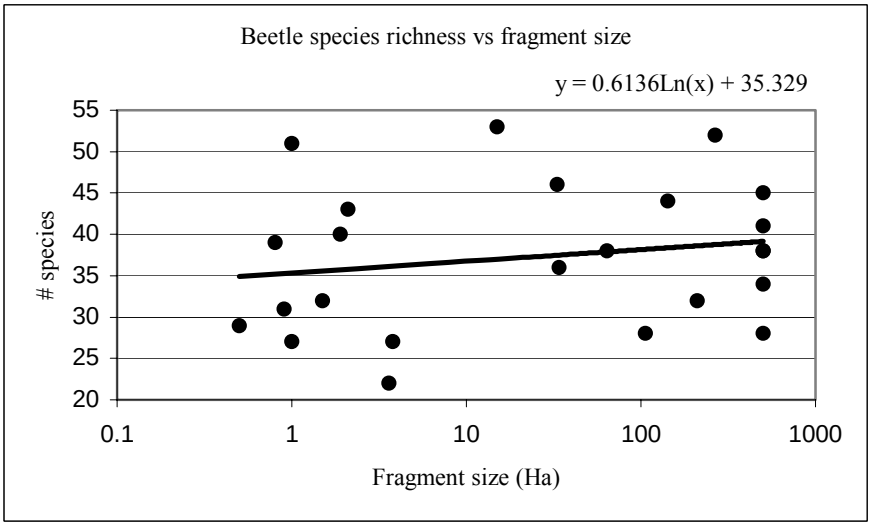
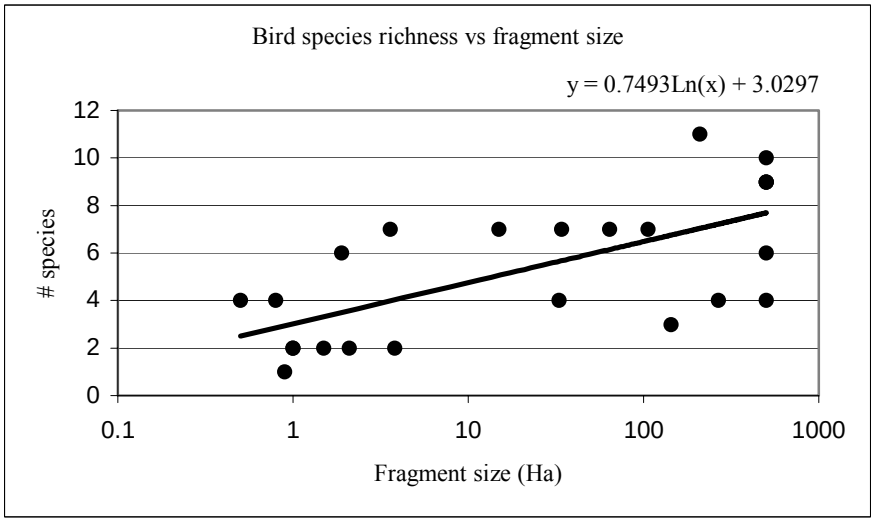


Figure 3. Multi dimensional scaling (MDS) of the fragments with distinct habitat edges in the three major plant communities (Wetter North – 1,4,7-9; Transitional – 6, 10-12 and Drier South – 15, 17,18). The insect assemblages found at 10, 20 and 50 metres from the habitat edge do not differ significantly, and do not cluster separately in any one of the three major floral community groups.


Plant species richness vs fragment size
y = -0.3765Ln(x) + 47.22
# species
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
1000
Fragment size (Ha)


Beetle species richness vs fragment size
y = 0.6136Ln(x) + 35.329
# species
55
50
45
40
35
30
25
20
0.1
1
10
100
1000
Fragment size (Ha)


Bird species richness vs fragment size
y = 0.7493Ln(x) + 3.0297
# species
12
10
8
6
4
2
0
0.1
1
10
100
1000
Fragment size (Ha)

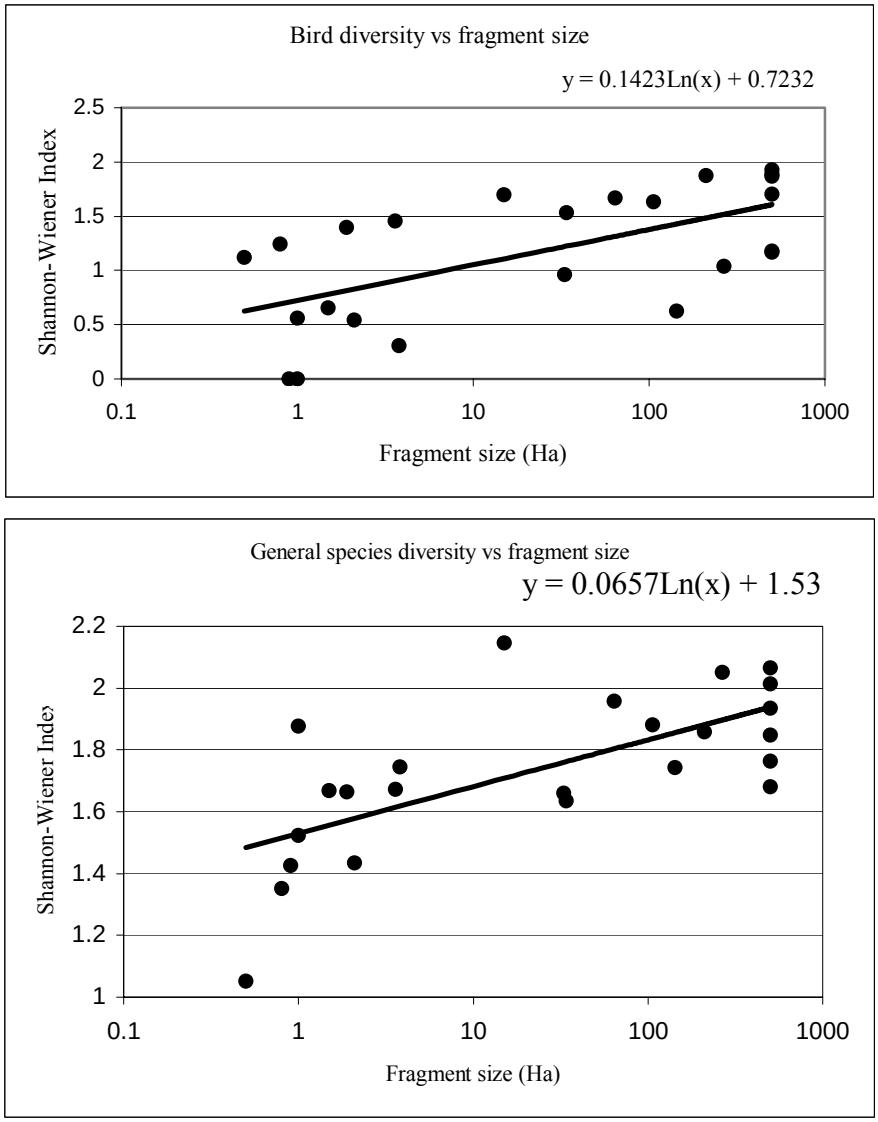


Figure 4. Scatter plots of plant species richness (# of species), beetle species richness, bird species richness, bird diversity and diversity of al the faunal groups in relation to fragment size. The Shannon-Wiener Index for diversity was used, and only bird species richness, bird diversity and general faunal diversity were significantly related to fragment size (cf. Table 7).

Table 1. Biodiversity as a function of the sampling extent. Areas are given in Ha, and the last two rows gives two species diversity indices for the relevant samples of each plot.

FRAGMENT ID	3	12	13	10	14	18	1	6	19
Size class	SMALL			MEDIUM			LARGE		
Fragment size (ha)	1.9	2.1	0.9	34	64	33	106	210	500+
Combined area sampled (ha)	1.43	2.05	0.82	2.44	2.06	2.44	6.11	5.44	6.61
Species richness	23	16	23	10	27	27	22	25	20
Ave no. of species added/sweep	2.8	1.6	2.6	1.2	4.2	4.2	3	4	3
Simpson's Index	0.378	0.566	0.353	0.290	0.352	0.338	0.324	0.076	0.113
Fisher's alpha	10.532	5.031	6.436	3.427	7.983	7.983	7.836	14.873	8.560

Table 2. Regression results of the comparisons between true area (the total fragment area), area sampled and species richness and species diversity (Fisher's α). No significant differences between the species richness and - diversity of true area and area sampled are evident.

	Regression Statistics				
	Multiple R	R Square	Adjusted R Square	Standard Error	Observations
Area sampled vs species richness	0.0522	0.0027	-0.1397	5.8744	9
True area vs species richness	0.03162	0.001	-0.14171472	5.87950547	9
Area sampled vs Fisher's α	0.4208	0.1771	0.0595	3.1819	9
True area vs Fisher's α	0.3462	0.1199	-0.0059	3.2906	9
			ANOVA		
	df	SS	MS	F	P
Area sampled vs species richness	(1,7)	0.6610	0.6610	0.0192	0.8938
True area vs species richness	(1,7)	0.24213	0.242130257	0.007004344	0.9356
Area sampled vs Fisher's α	(1,7)	15.2489	15.2489	1.5062	0.2594
True area vs. Fisher's α	(1,7)	10.3235	10.3235	0.9534	0.3614

Table 3. Results of the multivariate regression of the different environmental variables on the canonical axis values associated with each fragment. The P-values indicate that distance followed by elevation and rainfall had the most significant influence on the faunal communities of the fragments.

Fragment Characteristic	P	F-Ratio
Distance	0.0100*	1.79
Elevation	0.1250	1.29
Rainfall	0.1300	1.23
Aspect	0.2100	1.20
Size	0.2700	1.12
Lithology	0.3400	1.10
Temperature	0.4080	1.05
Slope	0.6700	0.95

Table 4. Results of the SIMPER analysis. Of the ten top species contributing to the differences between the two distance classes, eight (in bold) are shared as being within the ten most common species that characterise either/both of the distance classes.

GROUP 1 - Average similarity: 26.88					
Species	Average Abundance	Average Similarity	Similarity/Standard Deviation	Contribution %	Cumulative %
Eudr sp1	170.25	9.71	0.87	36.1	36.1
Xiph con	61.38	6.07	0.93	22.59	58.7
Macr aur	23.5	1.39	0.88	5.17	63.87
Alle sp1	25	1.21	0.68	4.49	68.36
Alle sp4	21.5	1.04	0.64	3.88	72.23
Chae sp1	43.13	0.81	0.77	3.03	75.26
Cola aca	18.75	0.5	0.42	1.85	77.11
Elat sp9	5.25	0.44	0.79	1.63	78.74
Clav sp2	6.38	0.27	0.49	0.99	79.73
Alti sp2	6.5	0.26	0.49	0.97	80.7
GROUP 2 - Average similarity: 23.33					
Species	Average Abundance	Average Similarity	Similarity/Standard Deviation	Contribution %	Cumulative %
Eudr sp1	254.38	6.36	0.75	27.25	27.25
Xiph con	33.88	3.23	1.38	13.86	41.11
Chae sp1	45.25	2.39	0.65	10.25	51.35
Alle sp1	36.38	1.44	0.48	6.15	57.51
Curc s16	20.69	0.89	0.61	3.81	61.32
Alti sp2	10.44	0.7	0.57	2.99	64.31
Macr aur	27.31	0.67	0.35	2.86	67.16
Cola aca	14.31	0.62	0.4	2.66	69.83
Chry sp9	14.44	0.58	0.37	2.5	72.33
Curc s17	14.88	0.54	0.68	2.33	74.66

GROUPS 1 & 2 - Average dissimilarity: 74.09						
Species	Ave Abundance (gr 1)	Ave Abundance (gr 2)	Ave Dissimilarity	Dissimilarity/SD	Contribution %	Cumulative %
Eudr sp1	170.25	254.38	18	1.02	24.3	24.3
Chae sp1	43.13	45.25	6.06	0.68	8.18	32.48
Xiph con	61.38	33.88	4.19	1.03	5.66	38.14
Alle sp1	25	36.38	3.2	1.04	4.32	42.46
Macr aur	23.5	27.31	2.93	0.87	3.95	46.41
Alle sp4	21.5	23.75	2.48	0.87	3.34	49.75
Curc s16	11.5	20.69	2.2	0.69	2.97	52.72
Cola aca	18.75	14.31	2.16	0.76	2.92	55.64
Alti sp5	9.63	13.69	1.88	0.57	2.54	58.18
Gale sp5	7.38	14.44	1.42	0.46	1.92	60.1

Table 5. One-way analyses of similarity (ANOSIM) comparing community structure of experimental fragments with those of control sites; and those of fragments closer than one kilometre to the nearest grassland with fragments further than one km from the nearest grassland. Analyses show no significant differences between experimental fragments and control sites of all groups together, or separately for the Wetter North or Transitional floral community groups (There were no control sites in the Drier South region). Distance to the nearest grassland also has no significant effect on the faunal community structures of the fragments. T-tests for independent samples showed no significant differences between the Shannon-Wiener species diversity of experimental fragments and control sites, or between fragments closer and further than one kilometre from the nearest grassland neighbour.

Groups	Fragments *vs.* control sites					Fragments < 1km *vs.* fragments >1km				
	t-test			Anosim		*t*-test			Anosim	
	t	df	p	Rho	p	*t*	df	p	Rho	p
All	1.7725	22	0.098	0.200	0.891	-0.002	22	0.99	0.152	0.054
WN	-2.008	8	0.079	0.504	0.978	-	-	-	0.167	0.400
T	-1.38	6	0.216	0.042	0.400	-	-	-	0.019	0.457
DS	-	-	-	-	-	-	-	-	0.393	0.200

Table 6. Two-way nested ANOSIM for trends in insect community distributions compared to distance (10, 20 and 50 metres) from habitat edge (RELATE). ANOSIM and RELATE for all three groups show no significant differences in insect community structure in relation to distance from habitat edge.

	Anosim		Relate	
	Rho	P	Rho	P
Wetter North	-0.137	1.000	-0.038	0.715
Transitional	-0.153	0.878	-0.034	0.712
Drier South	-0.21	0.836	-0.084	0.817

Table 7. Non-linear regression results for the different taxa, between species richness/diversity and fragment size. The model used was: species richness/diversity = a*fragment size**b. Only bird diversity, bird richness and general faunal diversity showed significant relationships with fragment size.

Group	Regression Coefficients		F	Df	P
	a	b			
General faunal species diversity	1.53	0.0657	17.52	(22; 1)	0.00038**
General faunal species richness			0.48	(22; 1)	0.49777
Bird species diversity	0.7232	0.1423	13.18	(22; 1)	0.00148*
Bird species richness	3.0297	0.7493	17.16	(22; 1)	0.00043**
Butterfly species diversity			0.03	(22; 1)	0.87071
Butterfly species richness			0.01	(22; 1)	0.90906
Beetle species diversity			2.31	(22; 1)	0.14271
Beetle species richness			0.79	(22; 1)	0.38505
Grasshopper species diversity			2.27	(22; 1)	0.14604
Grasshopper species richness			0.57	(22; 1)	0.4597
Plant species richness			0.18	(22; 1)	0.67310

Table 8. Conservation scores of the twenty-four fragments. Each fragment (ID's in column 1, and plant comm. no's in column 2) is awarded five scores for the different groups that score equally towards the total score – for plants, fragments were scored for plant endemism and rarity of plant community, for birds and butterflies endemism and diversity, and for beetles and grasshoppers diversity. Each of the five different scores is a rank (1 to 24) with 24 the highest score. The final conservation rank is given in the final column.

Frag. No.	Plant Comm.	Plants Rank	Birds Rank	Butterflies Rank	Beetles Rank	Grasshoppers Rank	Total Score	**Conservation Rank**
21	1.2.2(T)	22	21	15	20	7	85	**1**
20	1.2.2(T)	21	19	13	10	20	83	**2**
22	1.1.2(WN)	18	16	19	2	24	79	**3**
23	1.1.2(WN)	17	15	21	12	13	78	**4**
3	1.1.2(WN)	16	23	24	9	5	77	**5**
6	1.2.2(T)	23	22	8	8	15	76	**6**
2	1.1.2(WN)	20	7	23	17	8	75	**7**
24	1.2.1(T)	8	20	20	16	10	74	**8**
19	1.2.1(T)	7	10	18	19	19	73	**9**
1	1.1.2(WN)	19	17	11	7	17	71	**10**
7	1.1.2(WN)	14	8	6	18	23	69	**11**
17	2.1.1(DS)	2	9	9	24	22	66	**12**
14	2.2(DS)	6	11	14	15	18	64	**13**
4	1.1.1(WN)	24	13	10	11	4	62	**14**
15	2.1.2(DS)	5	12	2	23	12	54	**15**
16	2.1.2(DS)	4	4	12	22	11	53	**16**
5	1.1.2(WN)	12	2	3	14	21	52	**17**
9	1.1.2(WN)	15	18	16	1	2	52	**18**
11	1.2.1(T)	10	6	5	21	9	51	**19**
10	1.2.1(T)	11	24	4	4	6	49	**20**
18	2.1.1(DS)	3	5	17	6	16	47	**21**
12	1.2.1(T)	9	3	22	5	3	42	**22**

8	1.1.2(WN)	13	14	7	3	1	38	**23**
13	2.1.1(DS)	1	1	1	13	14	30	**24**

References

ACOCKS, J.P.H. 1988. Veld Types of South Africa. *Mem. Bot. Surv. S. Afr* 40: 1-128.

ALLAN, D.G., HARRISON, J.A., NAVARRO, R.A., VAN WILGEN, B.W. & THOMPSON, M.W. 1997. The impact of commercial afforestation on bird populations in Mpumalanga province, South Africa – insights from bird-atlas data. *Biological Conservation* 79: 173-185.

BOND, W.J. & VAN WILGEN, B.W. 1996. *Fire and Plants*. Chapman & Hall, London.

BOSCH, H.J.A. & JANSE VAN RENSBURG, F.P. 1987. Ecological status of species on grazing gradients on the shallow soils of the western grassland biome in South Africa. *Journal of the Grassland Society of South Africa* 4: 143-147.

CLARKE, K.R. & GORLEY, R.N. 2001. *Primer v5.* Plymouth Marine Laboratory. Plymouth, United Kingdom.

DEALL, G.B. 1985. *A plant-ecological study of the Eastern Transvaal escarpment in the Sabie area.* M Sc. Thesis, University of Pretoria, Pretoria.

EVANS, E.W. 1988. Community dynamics of prairie grasshoppers subjected to periodic fire: predictable trajectories or random walks in time? *Oikos* 52: 283-292.

FOORD, S.H. 1997. *Effects of afforestation on selected invertebrate taxa and their use in a habitat fragmentation experiment.* M Sc. Thesis, University of Pretoria, Pretoria.

FRANKHAM, R. 1998. Inbreeding and Extinctions: island populations. *Conservation Biology* 12(3): 665-675.

FISHER, R.A. 1954. *Statistical Methods for Research Workers*. 12th ed. Oliver & Boyd, Edinburgh.

GEOLOGICAL SURVEY. 1986. *Geology map 1:250 000 geological series. 2430 Pilgrim's Rest.* Government Printer, Pretoria.

GREATOREX-DAVIES, J.N. & SPARKS, T.H. 1994. The response of Heteroptera and Coleoptera species to shade and aspect in rides of coniferised lowland woods in southern England. *Biological Conservation* 67: 255-273.

GROSS, K., LOCKWOOD III, J.R., FROST, C.C. & MORRIS, W.F. 1998. Modelling controlled burning and trampling for conservation of Hudsonia montana. *Conservation Biology* 12(6): 1291-1301.

HAIG, S.M., MEHLMAN, D.W. & ORING, L.W. 1998. Avian movements and wetland connectivity in landscape conservation. *Conservation Biology* 12(4): 749-758.

HOLM, E. & MARAIS, E. 1992. *Fruit Chafers of Southern Africa.* Ekogilde, Hartbeespoort.

INGHAM, D.S. & SAMWAYS, M.J. 1996. Applications of fragmentation and variegation models to epigaeic invertebrates in South Africa. *Conservation Biology* 10(5): 1353-1358.

KATOH, K., TAKEUCHI, K., JIANG, D., NAN, Y. & KOU, Z. 1998. Vegetation restoration by seasonal exclosure in the Kerqin sandy land, inner Mongolia. *Plant Ecology* 139: 133-144

MACARTHUR, R.H. & MACARTHUR, J.W. 1961. On bird species diversity. *Ecology* 42: 594-598.

MACLEAN, G.L. 1993. *Roberts' Birds of Southern Africa.* The Trustees of the John Voelcker Bird Book Fund, Cape Town.

MATTHEWS, W.S. 1991. *Phytosociology of the North-Eastern mountain sourveld.*

M Sc. Thesis, University of Pretoria, Pretoria.

MATTHEWS, W.S. *et al*. 1993. Endemic flora of the North-eastern Transvaal escarpment, South Africa. *Biological Conservation* 63: 83-94.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974. *Aims and methods of vegetation Ecology.* John Wiley & Sons, New York.

OLIVER, I & BEATTIE, A.J. 1996. Invertebrate morphospecies as surrogates for Species. A case study. *Conservation Biology* 10: 99-109

PASITSCHNIAK-ARTS, M., CLARK, R.G. & MESSIER, F. 1998. Duck nesting success in a fragmented prairie landscape: is edge effect important? *Biological Conservation* 85: 55-62.

PINHEY, E.C.G. 1975. *Moths of southern Africa*. Tafelberg Publishers Ltd., Cape Town.

PRINGLE, E.L.L., HENNING, G.A. & BALL, J.B. (eds.). 1994. *Pennington's Butterflies of Southern Africa.* Struik Winchester, Cape Town.

QUINN, J.F. & ROBINSON, G.R. 1987. The effects of experimental subdivision on flowering plant diversity in a California annual grassland. *Journal of Ecology* 75: 837-856.

SAMWAYS, M.J. 1989. Insect conservation and landscape ecology: a case history of Bush crickets (Tettigoniidae) in Southern France. *Environmental Conservation* 16(3): 217.226.

SAMWAYS, M.J. & MOORE, S.D. 1991. Influence of exotic conifer patches on grasshopper (Orthoptera) assemblages in a grassland matrix at a recreational resort, Natal, South Africa. *Biological Conservation* 57: 117-137.

SCHOLTZ, C.H. & HOLM, E. 1985. *Insects of Southern Africa*. Butterworths, Durban.

SHERROD, P. 2003. *NLREG, Nonlinear Regression Software*. www.nlreg.com.

SIMPSON, G.G., ROE, A. & LEWONTIN, R.C. 1960. *Quantitative Zoology*. Harcourt, Brace, Jovanovich, New York.

SOTHERTON, N.W. 1998. Land use changes and the decline of farmland wildlife: an appraisal of the set-aside approach. *Biological Conservation* 83: 259-268.

STEVENS, S.M. & HUSBAND, T.P. 1998. The influence of edge on small mammals: evidence from Brazilian Atlantic forest fragments. *Biological Conservation* 85: 1-8.

SUTCLIFFE, O.L. & THOMAS, C.D. 1996. Open corridors appear to facilitate dispersal by ringlet butterflies (Aphantopus hyperantus) between woodland clearings. *Conservation Biology* 10(5): 1359-1365.

SWENGEL, A.B. 1996. Effects of fire and hay management on abundance of prairie butterflies. *Biological Conservation* 76: 73-85.

SWENGEL, A.B. 1998. Effects of management on butterfly abundance in tallgrass prairie and pine barrens. *Biological Conservation* 83(1): 77-89.

JONGMAN, R.H.G., TER BRAAK, C.J.F. & VAN TONGEREN O.F.R. 1995. *Data analysis in community and landscape ecology*. Cambridge University Press, UK.

THIOLLAY, J.-M. & PROBST, J.-M. 1999. Ecology and conservation of a small insular bird population, the Reunion cuckoo-shrike Coranica newtoni. *Biological Conservation* 87: 191-200.

THOMAS, R.C., KIRBY, K.J. & REID, C.M. 1997. The conservation of a fragmented ecosystem within a cultural landscape – the case of ancient woodland in England. *Biological Conservation* 82: 243-252.

TURIN, H. 1988. Changes in of Carabid beetles in the Netherlands since 1880. Isolation of habitats and long-term trends in the occurrence of Carabid species with different powers of dispersal (Coleoptera: Carabidae). *Biological Conservation* 47: 179-200.

VICKERY, J.A. & GILL, J.A. 1999. Managing grassland for wild geese in Britain: a review. *Biological Conservation* 89: 93-106.

WELCH, D. 1998. Response of bilberry Vacinnium myrtillus L. in the Derbyshire district

to sheep grazing, and implications for moorland conservation. *Biological Conservation* 83: 155-164.

WERGER, M.J.A. 1974. On concepts and techniques applied in the Zurich-Montpellier method of vegetation survey. *Bothalia* 11: 309-323.

WHELAN, R.J. 1995. *The Ecology of Fire*. Cambridge University Press, Great Britain.