Community-level effects of fragmentation of the afromontane grassland in the escarpment region of Mpumalanga, South Africa

by

DEWALD KAMFFER

Submitted in partial fulfillment of the requirements for the degree

MAGISTER SCIENTIAE

in the Faculty of Natural, Agricultural and Information Sciences

University of Pretoria

PRETORIA

Supervisor: Prof. J.W.H. Ferguson

Co-Supervisor: Prof. A.S. Van Jaarsveld

ABSTRACT

Habitat fragmentation of the afromontane grassland of the escarpment region of Mpumalanga, South Africa

by

DEWALD KAMFFER

Supervisor: Prof. J.W.H. Ferguson
Co-supervisor: Prof. A.S. Van Jaarsveld
(Department of Zoology and Entomology)
University of Pretoria

Submitted in partial fulfillment of the requirements for the degree

MAGISTER SCIENTIAE

Large scale afforestation, resulting habitat destruction and fragmentation of the afromontane grassland in the Drakensberg escarpment of Mpumalanga, South Africa, has lead to the necessity of describing the flora and fauna aspects of the remaining grassland fragments, allowing forestry companies to mitigate the effects of afforestation on the biodiversity of these fragments and for initiating a management program for the remaining grassland. This study aims, firstly, to determine if any marked human-induced disturbance to the plant communities in the grassland fragments has occurred. I do this by comparing the plant communities of eighteen fragments with those of six control plots outside of the plantations with no marked disturbance to the grassland, by determining whether the plant assemblages in the fragments can be assigned to any of the natural and intact plant communities that Matthews (1993) described from a large-scale survey of undisturbed mountain areas and by ascertaining the presence of any known intruder plant species within the fragments. I also compare the faunal biodiversity in grassland fragments within afforested areas to that of control plots in undisturbed grassland and determine to which degree the Coleoptera, Orthoptera, Lepidoptera and bird communities reflect recognized plant communities, and are restricted to specific plant communities. Secondly, the study aims to compare the habitat specificity (degree of stenotopy) of the different taxonomic groups and trophic levels of animals and to make recommendations for the conservation of the Afromontane grassland fauna in the remaining grassland fragments in afforested areas. Thirdly, I aim 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 and to test for the effects of edges on the extant insect biodiversity in the grassland fragments inside plantations. Lastly, the study aims to quantify the effects of fragment size on species richness, species diversity and assemblage structure of plants, insects and birds and to rank the grassland fragments in an order of conservation importance using factors such as biodiversity and uniqueness of the floral community.

The results indicate that afforestation and habitat fragmentation have not significantly impacted on the flora of the grassland fragments. Fragments are still identifiable as natural communities, described by previous workers during provincial-scale surveys. Also, no obvious invader – or disturbed plant communities are discernible even though some of the fragments have been isolated for as long as 40 years and the plant communities of conservation importance described by previous workers coincide with the important communities recognized in this study. Rare and endangered plant species, as well as species endemic to the region, are more frequently found on the scarce Black Reef quartzite of the region, which is more evident to the Northern part of the study area. Two plant communities are of particular conservation importance, not only as a result of their geological base, but also because of the high risk associated with the few grassland examples left of these communities. The high levels of habitat specificity of many of the taxonomic and trophic faunal groups indicate that many of the invertebrate taxa are probably endemic to the region, and that the plant endemicity encountered in the Afromontane grasslands is reflected by a similar degree of animal endemicity. The similarity in faunal assemblages and diversity between isolated fragments and large areas of grassland emphasizes the conservation importance of the fragments, even when smaller than 5 Ha in extent. Fragments therefore have a high conservation importance, since they represent natural grassland areas and are sometimes the only representative of a particular plant community remaining in the area. I detected no significant edge effects on the faunal communities 10, 20 and 50 metres from the edge of the plantation. 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, characterized by high levels of plant endemicity, have a higher conservation importance as judged by faunal biodiversity. Experimental management involving grazing, mechanical cutting, grazing and burning is needed to derive an efficient management plan, so that the grassland biodiversity can be conserved in a planned way. Such work will also allow empirical testing the efficiency of the indicator species suggested in this study.

TABLE OF CONTENTS

CHAPTER 1

"Nature, in some form, shall undoubtedly survive the next few centuries, but will we?" (Cox & Moore 1993).

INTRODUCTION

Afforestation and habitat fragmentation

Large-scale afforestation with exotic trees such as pines, is taking place in montane grasslands throughout South Africa (Armstrong & van Hensbergen 1999). The Drakensberg escarpment of Mpumalanga constitutes one of the core areas of the South African forestry industry. It is also one of the oldest afforested areas with many plantations being older than 50 years. These activities have resulted in the large-scale fragmentation of the indigenous North-Eastern mountain sourveld (Acocks 1953) of these mountains.

In addition, authors such as Matthews et al. (1993) and Deall (1985) indicated that this area constitutes a habitat very rich in endemic plant taxa – close to a tenth of the 23 000 species of seed plants indigenous to the flora of the southern Africa subregion has been recorded from the Mpumalanga Escarpment, and a total of 81 species and intraspecific taxa are endemic or near-endemic to the region. These plants, most of which are herbaceous with low reproductive rates and with large underground structures, are not able to colonise disturbed areas rapidly and are therefore potentially threatened by forestry activities. Attempting reintroduction of rare grasslands species elsewhere (Morgan 1999), has shown no promise or guarantee of success, stressing that preservation and sympathetic management of remnants must be the central strategy for the conservation of species in fragmented landscapes.

In order to promote sustainable afforestation of these grasslands, a better understanding of the dynamics and interactions of the grassland patches remaining in the area, is mandatory. The forestry industry is aware of these problems and this project is in collaboration with SafCol to provide information required for a management plan for the conservation of the remaining biodiversity in the area.

Management of grassland

Because original continuous grassland on the Mpumalanga escarpment today remain mainly as fragmented patches in a matrix of unnatural landscape characteristics, natural, sporadic disturbances that are so important to the well-being of any system, are seldom allowed to influence communities in these remnant patches. Many authors (Swengel 1998, Greatorex-Davies & Sparks 1994, Welch 1998) have indicated the need for grassland management. As a result of fundamental differences between the relatively undisturbed grasslands of the past and the grassland fragments of the present, the replication of the natural influences of the past will not satisfy the conservation and management needs of the remaining grassland patches left today (Swengel 1998).

Deciding to manage grassland is, however, the easy part. Determining the optimal management regime for a particular patch, choosing from different options, answering important questions of how, when and how often to manage, complicates the challenge of conserving grassland biodiversity greatly. Grassland patches must also be treated on individual merit, since the effects of these management options often depend on the specific environmental conditions and evolutionary history of each patch (Drechsler & Wissel 1998). To generate a successful grassland management plan for a particular fragment, the effects of each management option and the effects of the interaction between different management options should be understood and accounted for.

Comparing mechanical cutting, for instance, to grazing, highlights particular important differences. Cutting is sudden and catastrophic, rather than gradual and prolonged, it is also non-selective, and the treading and fertilising effects of grazing are absent (Morris 1981). Although some results favour cutting above grazing (Swengel 1998), and other haying above burning (Swengel 1996), there is no evidence to suggest that any one option provides optimal maintenance of biodiversity. Some evidence suggests that where management options are combined, greater conservation success transpire than is the case if any one option is implemented alone (Gross et al. 1998). It is obvious that, even when using options in combination, these options need to be controlled (Katoh et al. 1998), and often a full range of management regimes are required, if the survival of all species is to be ensured (Fensham 1998).

Grassland and fire.

Fire is widely used in the management of ecosystems worldwide, mainly because it is a relatively inexpensive option by which vegetation, and indeed all grassland ecosystem components, can be manipulated (Bond & Wilgen 1996). The greatest problem concerning fire, as a management tool is the fact that managers, researchers and students constantly treat fire as a solitary but repeatable event, seldom accepting that not two fires are the same (Whelan 1995).

When planning management regimes, it is important to remember that a fire has the immediate characteristics of intensity, season, extent and type, and the historical characteristics of pre-fire climate, time since last fire and the historical characteristics of previous fires. Present day land use conflicts ensure that land management activities, such as prescribed burning, should equally satisfy conservation needs as well as more utilitarian objectives. This would rule out activities such as hazard reduction burning, which are typically carried out at a time of year when it is easiest to control fires.

Although at first glance a sound idea, it raises serious concerns about the potentially deleterious ecological impacts of out of season burning (Whelan 1995). Furthermore, such a fixed regime will inevitably lead to the impoverishment of diversity by repeatedly selecting for the same species at the expense of others (Bond & van Wilgen 1996). To guard against the adverse effects of a fixed fire regime, frequency, season and intensity of fires used should be varied – such variability is inevitable in nature and essential in prescribed-burning plans designed to conserve biodiversity. It has been argued that historical fire-interval distributions were largely the result of large fires, during extreme weather conditions (dry in forests and wet in arid regions). Information such as long-term weather records can consequently be most beneficial, if they can be related to specific areas burned each year (Gill & McCarthy 1998).

Grassland flora is directly and severely influenced by fire intensity, season and frequency. Changes in species composition typically occur, with some species, such as *Themeda triandra*, disappearing very rapidly when fire is excluded (Whelan 1995). In the Equadorian grass páramo, the frequency of fires determined the amount of fuel that accumulated within grass tussocks, and some plants may be unable to survive repeated burning (Ramsay & Oxley 1996). One of the important factors explaining phytomass variation in tallgrass prairie vegetation was seasonal burn type (Coppedge 1998). Their results also indicate that fire intensity can be an important factor determining species distribution patterns in the Chilean mattoral, and that at areas where fires of high intensity occurred, only vigorous resprouters would dominate, while less intense fires allowed new species to get established (Segura 1998).

Although it could be argued that all such examples are isolated cases, the conclusion that fire regime has a distinct effect on community structure in grassland vegetation, is accurate. The community being the biotic unit receiving a fire, animals are likewise influenced by fire. Montane grasshoppers in Southern Africa use hilltops as thermal refugia, and burning of these hilltops not only accentuate thermal influences, but also initially deprive grasshoppers of food (Samways 1990). Fire influences prairie butterflies differently, with generalist species being over-represented in more recently burned areas, and specialists showing the most negative effects from fire (Swengel 1996). Even though this is true, fire need not be excluded as a management option, since occasional wildfires were typically more favourable for specialist abundance than regular rotational burning (Swengel 1998).

Creating the optimal fire regime, and combining it with other management options such as mechanical cutting and grazing, to devise a sensible management plan for grassland areas that will appeal to the conservationist, land owner and government official alike, is no easy task. But with an understanding of the dynamics of grassland communities gained from the recording of appropriate data and the design of appropriate experiments, there may be a future for remnant patches of grassland in a landscape of alien and disturbed habitat.

Grassland and invasive aliens

One of the greatest threats to grassland biodiversity is the change in community structure brought about by the various exotic plants that are aggressively invading grassland areas, and seriously threatening to transform patches of diverse grassland into systems of poor stability and primary succession. Areas such as the species rich and productive riparian zones are particularly susceptible to invasion, and may act as havens, corridors and sources of exotic plant invasions for upland sites (Stohlgren et al. 1998). Trees used in forestry are especially problematic, and have severely impacted large areas of grassland by causing shifts in life-form dominance, reducing structural diversity, increasing biomass, disrupting prevailing vegetation dynamics and changing nutrient cycling patterns (Richardson 1998). The aggressively invasive nature of these trees cannot be ignored. Other groups of plants such as forbs and grasses have also proven to present problems for grassland conservationists.

The seriousness of the situation has clearly been demonstrated by the extensively positive response of grasses after removal of exotic forbs. This is only possible by aggressive management of target invaders with selected herbicides (for instance) in the early stages of exotic plant invasion (Rice & Toney 1998). Invasion of natural areas by highly aggressive exotic vegetation could be, in the long term, perhaps the most spectacular and important threat to rare and endangered species (Thiollay & Probst 1999). If stability and diversity of grassland systems are to be maintained, creating grassland areas free from alien components should be a primary conservation objective.

Grassland and loss of natural habitat

Destruction of natural habitats that leads to species extinction is a conservation issue of major concern worldwide. Those natural areas still remaining are more often than not found as patches in a fragmented landscape resulting from various land use conflicts. Many ecological surveys using rapid inventory techniques assume that a diverse floral component imply high diversity for the invertebrates as well (Crisp et al. 1998). This assumption may prove to be dubious, especially for grassland.

Grassland areas that are deprived of natural disturbances such as grazing and wildfires become less diverse with time if left unmanaged for long (Swengel 1998). More often than not, managing grassland can transform the invertebrate community (Swengel 1996, Morris 1981 & Swengel 1998) without much alteration of the floral component. A model for species-specific predictions of the impact of habitat fragmentation would assist greatly in conserving biodiversity (MacNally & Bennett 1997), especially since most of the grassland in the study area is affected by habitat fragmentation.

This study attempts to identify areas of particular conservation importance by looking specifically at the native plants (Chapter 2), invertebrates and birds (Chapter 3) and using all these groups together to consider the present conservation status of the remaining grassland fragments (Chapter 4).

Fragmentation: Effects on natural populations

Edges

The effects of habitat edges on species diversity, species richness and ecosystem functioning in remnant patches of natural habitat are complex and difficult to interpret, and a clear pattern is yet to present itself. As the size of a habitat shrinks, so does the area free from edge effects (Gaston 1994), and these edge effects reduce the effective reserve area (Esseen & Renhorn 1998).

In Brazilian forest fragments species diversity and species richness for small mammals was shown to increase significantly as the distance from the edge increased (Stevens & Husband 1998). However, duck-nesting success was not significantly influenced by distance from edge (Pasitschniak-Arts et al. 1998), and in the Wog Wog Fragmentation Experiment (Margules 1992) there was no difference in species composition between inner and outer zones. Some groups such as grasshoppers have been shown to be distributed regardless of obvious landscape boundaries (Ingham & Samways 1996). To confuse matters further, so-called 'edge species' have been shown to make important contributions to the diversity patterns of remnant patches (Quinn & Robinson 1987).

Landscape boundaries (or ecotones) are described as sections of space (or time) where ecological conditions change more rapidly than in adjacent areas, leading to rapid changes in structure, function and composition of the biota (Samways 1989). Such ecotones have been proven to be, to some degree, important in satisfying life-cycle needs of many organisms, and are generally characterised by high biological diversity (Holland et al. 1991).

Island biogeography

With the intensification of land use conflicts and with the pressures of a growing human population, most of the natural areas over the world have been fragmented into remnant patches, or so-called ‘islands’. Most of the predictions of population dynamics and ecosystem functioning of these patches have centred on the theory of island biogeography of MacArthur and Wilson (1967).

The theory predicts that insularity leads to the loss of species until the biota have ‘relaxed’ to a new, lower equilibrium species number appropriate for its size and degree of isolation. Fragmentation of a population into small, isolated populations leads to inbreeding depression, loss of genetic variability, accumulation of mild deleterious mutations and genetic adaptations which can all cause higher extinction rates than in ‘mainland’ populations (Frankham 1998). Furthermore, fragmentation of source populations could lead to decline in sink populations, without further fragmentation of the sink populations (Trine 1998), and such subpopulations’ viability is the key to metapopulation stability (Drechsler & Wissel 1998). Thus, for a given structure of a natural environment, predictions can be made about the dynamics and persistence of a given metapopulation, but these predictions are complicated (Foord 1997).

Metapopulation structure

Most natural populations have come to possess some geographic structure – species whose ranges are now composed of more or less geographic isolated patches, interconnected through patterns of gene flow, extinctions and recolonizations, form metapopulations. The general effect of population subdivision is to somewhat increase the total genetic variation in the metapopulation system, but at expense of decreasing the variation within subpopulations (Lande & Barrowclough 1987). It is therefore not only the total size of the metapopulation that is important when considering population vulnerabilities, but also the geometrical character of its distribution and the dynamical aspects of the flow of its member individuals between nodes of the network of habitable patches (Gilpin 1987).

Limitations of 'accidental' fragmentation experiments

To be able to obtain robust results from any fragmentation experiment, the experiment should be designed to incorporate solutions to the problems of size-effects and random sites effects relevant to any field experiment (Margules 1992, Van Jaarsveld et al. 1998). Adequate replication in field experiments is necessary to compensate for size-effects, and sufficient variation of fragment sizes essential to insure that random sites-effects do not affect the results significantly (Margules 1992).

Environmental variation is a major source of experimental error in any field experiment, but within planned fragmentation experiments it is possible to account for this variation by including adequate replicates of fragments of different sizes as well as suitable controls. Planned fragmentation experiments are often limited by the maximum amount of land available (Margules 1992) and often by the physiography of the terrain (Van Jaarsveld et al. 1998). Furthermore, time puts an extensive limitation on any planned fragmentation experiment, since it takes many years for the fragments to become truly isolated. 'Accidental' fragmentation experiments frequently suffer from important design faults, including reduced opportunities for adequate replication and relevant controls. It is also seldom possible to incorporate and anticipate environmental variation, and therefore being able to draw firm inference from the results.

The mountain grassland of the escarpment region of Mpumalanga is all but destroyed. Many grassland specialists of the area such as the blue swallow are on the brink of local extinction. Many of the plant communities described by Matthews et al. (1993) are no longer evident in the study area, and although it would be ideal to design a proper fragmentation experiment, time and available grassland left is of the essence. All the grassland fragments and relevant controls left in the area (as far as practically possible) are included in this study to produce the best results possible considering time and spatial constraints.

Synthesis

Human-induced habitat fragmentation has changed the face of natural habitats all over the world. No longer the exception, it has influenced the population dynamics of most species on earth, and continue to threaten the continued existence of many animals and plants. Treating fragmented populations of species as interconnected metapopulations and realising the effects of edges, management of natural areas and invader species will be crucial when considering conservation options. Although the effects of edges, ecotones and subpopulation-interactions are vague and varied, it can't be denied that they are real, and influence the populations of species and community structure greatly.

Indicator taxa

The whole indicator species concept has often been criticised, and said to be problematic, at best. Often there is little consensus on what the indicator is supposed to indicate, and it is never easy to decide which is the best indicator species (Simberloff 1998, McGeogh 1998). Despite this criticism, indicators and surrogates have often been used, in a number of different ecological studies.

It is often the case that distribution data is inadequate, and, consequently, reserve selection procedures have to rely on surrogate measures for biodiversity (Wessels et al. 1999). For management of natural areas, monitoring of terrestrial arthropod indicators can provide early warnings of ecological changes, and can be used to assay the effects of further fragmentation on areas that no longer support vertebrate indicator species, and the unparalleled diversity of arthropods provides a rich data source that can improve the spatial resolution of biological inventories and hence the planning of reserve networks (Kremen et al. 1993). It is, however, important that conservation managers that use indicators realise the importance of them being region-specific (Trine 1998).

Due to a lack of complete taxonomical understanding of most arthropod groups, ecologists are often forced to use morphospecies as surrogates for species. At least some evidence suggests that this is acceptable in some environmental monitoring and conservation, in particular when estimates of richness and the assessment of turnover guide decisions. The conservative evaluation of habitat remnants may be performed, in part by defining selected invertebrate morphospecies assemblages characteristic of those remnants (Oliver & Beattie 1996).

The insect orders Orthoptera and Coleoptera are used in this study, in particular for their diversity, ease of sampling, high mobility and high biomass (Foord 1997). Grasshoppers, especially, are good indicators for general grassland communities, are relatively sensitive to landscape disturbance and a direct indication of grass species diversity (Samways & Moore 1991). Butterflies and day-flying moths (Lepidoptera) are used in this study for their habitat specificity, strong host plant preferences, and ease to monitor over any extended period of time (Pringle et al. 1994). Butterflies have also been shown to be indicative of the diversity of insect communities, and are sometimes considered to be suitable ‘process indicators’ (Oostermeijer & van Swaay 1998). Other groups showing potential as bioindicators include soil dwelling Diptera (Fourz 1999), woodlice (Paoletti & Hassall 1999), ants (Lobry de Bruyn 1999) tiger beetles (Rodriguez et al. 1998), Syrphidae (Sommaggio 1999), Staphylinidae (Bohac 1999) and pollinator guilds (Kevan 1999).

Specific taxa or species can be used as ecological indicators to show the effects of environmental change (such as habitat fragmentation) on biological systems, if chosen correctly. (McGeogh 1998, Rodriguez 1998). Although charismatic vertebrates have been used extensively in the past, invertebrates are far better suited for the purpose of ecological indication. They have high population growths, short generation times and are far more habitat specific and prone to microclimatic changes, making them ideal indicators (Rodriguez 1998). Having said that, very little is known about many insect species in terms of biology and distribution, and bioindication relies completely on species identification, supported by knowledge of the basic biological and ecological features of the organisms and landscape under study (Paoletti 1999).

Hypotheses to be tested:

1) To test whether the grassland plant communities identified by Matthews et al. (1992) over a very large spatial scale and by Deall (1985) over an extremely restricted spatial scale is also useful for characterising the plant communities in and around the pine plantations of the study area (Chapter 2)
2) To test to what degree the montane grassland fauna in the study area reflect the plant communities that have been identified (Chapter 3).
3) To test whether the assemblages of insects along edges of grassland fragments are in any way affected by the adjacent plantation (Chapter 4).
4) To test whether fragment size has any effect on the species richness, species diversity and assemblage structure of the grassland insects of the study area (Chapter 4).

METHODS AND PHYSICAL ENVIRONMENT

Area reconnoitering

Areas that could possibly represent grassland were identified on 1:10 000 aerial photographs, and this information superimposed on 1: 50 000 topographical maps. The study area is covered by six 1: 50 000 topographical maps (2430DC Ohrigstad, 2430DD Graskop, 2530BA Long Tom Pass, 2530BB Sabie, 2530BC Boshalte and 2530BD Nelspruit), stretching from the Blyde River Nature Reserve in the North, to the Sudwala caves in the South, and from God's Window in the East to the Long Tom Pass in the West (Figure 1). Using roads and other prominent landmarks, areas of forestry, grassland and other land uses (such as urban areas and newly planted plantations) were identified on the aerial photos and marked on the maps. Using these maps, and a Garmin GPS 40, the whole area was surveyed for accessible remnant and control plots of mountain grassland.

Distribution and number of sample plots

The number of sampling plots is usually influenced by various factors such as the scale of the survey, environmental heterogeneity in the study area and the scale necessary for the classification (Bredenkamp 1982, Matthews 1991). The biggest influence on the choice and distribution of plots in this study was accessibility to the sites, and of natural grassland not invaded by the various problematic exotic invaders found in the area. Many of the sites identified on the aerial photographs as possible areas of grassland are not accessible by land vehicle, and can only be reached by long excursions on foot or by air.

The twenty-four sites, of which six can be regarded as control plots, are situated between 1130 and 1980 metres above sea level, and range from 0.5 to 500 Ha (Table 1). The forestry agencies SafCol and Mondi are responsible for most of the sites with a few under private and government ownership. Only two sites benefit from any sort of official protection. Types of management range from fire and grazing to cutting and no management at all, and are inconsistent in timing and coverage.

Geology

Information concerning geology was obtained from 1: 250 000 geological survey maps (Geological Survey 1986). The whole area belongs geologically to the Transvaal sequence, and the study sites fall into two subgroups, Chuniespoort and Wolkberg, and two formations, Black Reef and Timeball Hill. As far as the Lithology is concerned, the underlying rocks consist mainly of dolomite, lime, shale and quartzite. The Black Reef Quartzite formation varies from 0 m to 500 m thick and is a succession of clean quartzite with layers of pebbles; shale is usually present near the top, on the contact zone with the overlying dolomite. The formation is resistant to weathering and is responsible, by and large, for the shape of the cliffs and gorges throughout the area. The Chuniespoort group overlies the Black Reef and is mainly made up of dolomite, with some limestone and chert. It is, on average, 400 m thick (Matthews 1991).

The general soil patterns of the area are very complex because of the complexities in topography and differences in weathering of the different rock types. Because the area has a high rainfall, many of the soils show medium to high leaching as well as high acidity (average pH of 4.7), with the soils of the dolomite being the least acidic (Matthews 1991, 1992).

Table 1. Description of the 24 study sites in the Escarpment region of Mpumalanga. Sample plot characteristics are (from left to right): geological formation, lithology, elevation (metres above sea level), slope, fragment size (ha), aspect (degrees), distance to nearest grassland (km), max. temp. (° C), min. temp. (° C), average temperature (° C), average rainfall (mm), latitude and longitude.

Sites	Geological Formation	Lithology	Elevation	Slope	Size	Aspect	Near-grass	Maxtemp	Mintemp	Avetemp	Averain	LAT	LONG
1	Timeball Hill	Shale	1980	6.5	106	180	1.25	19.2	8.9	14.1	1128	24° 50' 56"	30° 41' 07”
2	Black Reef	Quartzite	1130	11.3	1.5	225	0.875	21.8	9.5	15.6	1484	24° 53' 36"	30° 50' 05"
3	Chuniespoort	Dolomite,lime,shale	1350	6.1	1.9	225	0.1	21.9	10.3	16.1	1455	24° 57' 03"	30° 48' 54"
4	Black Reef	Quartzite	1364	4.2	3.6	135	0	22.4	11.5	16.9	1588	24° 58' 36"	30° 50' 20"
5	Chuniespoort	Dolomite,lime,shale	1260	4.9	1	225	0.5	22.9	10.2	16.6	1322	24° 57' 43"	30° 49' 18"
6	Black Reef	Quartzite	1260	5.7	210	270	0.5	22.4	11.5	16.9	1416	25° 00' 34"	30° 49' 53"
7	Timeball Hill	Shale	1270	7.2	1	135	0.1	23.1	11.5	17.3	1361	25° 04' 08"	30° 44' 54"
8	Chuniespoort	Dolomite,lime,shale	1290	17.7	0.8	135	0.1	20.9	10.7	15.8	1690	25° 03' 27"	30° 44' 16"
9	Chuniespoort	Dolomite, lime, shale	1290	19.6	0.5	135	0.1	22.8	10.6	16.7	1317	25° 02' 12"	30° 45' 39"
10	Black Reef	Quartzite	1860	8.7	34	135	1.45	20.8	10.6	15.7	1343	25° 11' 06"	30° 39' 24"
11	Timeball Hill	Shale	1860	6.5	3.8	90	1.55	21.5	9.4	15.4	1070	25° 10' 34"	30° 37' 36"
12	Timeball Hill	Shale	1800	9.1	2.1	315	1.45	20.9	10.5	15.7	1230	25° 09' 59"	30° 40' 14"
13	Timeball Hill	Shale	1530	22.2	0.9	315	2.5	21.5	10.1	15.8	1432	25° 10' 40"	30° 42' 31"
14	Timeball Hill	Shale	1200	7.9	64	45	2.1	21.6	9.8	15.7	1253	25° 12' 16"	30° 40' 26"
15	Chuniespoort	Dolomite,lime,shale	1220	9.9	15	90	4.8	23.5	10.7	17.1	1032	25° 15' 38"	30° 41' 38"
16	Chuniespoort	Dolomite,lime,shale	1380	7.4	143	315	0.325	22.3	11.6	17	1157	25° 19' 45"	30° 47' 12"
17	Black Reef	Quartzite	1260	15.4	267	360	0.325	22.7	11.7	17.2	972	25° 18' 58"	30° 47' 24"
18	Chuniespoort	Dolomite,lime,shale	1470	36	33	45	1.95	23.1	11	17	1268	25° 08' 11"	30° 45' 41"
19	Timeball Hill	Shale	1860	12.9	500	90	0	20	9.1	14.6	1268	25° 09' 49"	30° 37' 43"
20	Black Reef	Quartzite	1590	9.1	500	315	0	21	9.1	15	1700	24° 51' 17"	30° 52' 38"
21	Black Reef	Quartzite	1470	6.5	500	315	0	21.4	9.5	15.4	1627	24° 51' 31"	30° 52' 09"
22	Chuniespoort	Dolomite,lime,shale	1440	1.3	500	360	0	22.1	9.6	15.8	1293	24° 55' 33"	30° 49' 32"
23	Chuniespoort	Dolomite,lime,shale	1380	7.6	500	225	0	21.7	9.7	15.7	1320	24° 55' 27"	30° 49' 16"
24	Timeball Hill	Shale	1950	18.4	500	90	0	15.6	5.5	10.6	1497	25° 09' 23"	30° 37' 27"

Table 2. Collection dates of the eight sweep samples for Coleoptera and Orthoptera, and coinciding hand net samples for Lepidoptera and Neuroptera.

Seasons	Feb - Mrch-97		Oct - Nov-97		Feb-98		Nov-98	
Site no's	sweep 1	sweep 2	sweep 3	sweep 4	Sweep 5	Sweep 6	sweep 7	sweep 8
1	10.ii.97	26.ii.97	23.x.97	22.xi.97	6.ii.98	22.ii.98	10.xi.98	24.xi.98
2	10.ii.97	26.ii.97	23.x.97	21.xi.97	9.ii.98	20.ii.98	11.xi.98	28.xi.98
3	12.ii.97	2.iii.97	26.x.97	21.xi.97	6.ii.97	12.ii.98	11.xi.98	25.xi.98
4	12.ii.97	2.iii.97	26.x.97	14.xi.97	6.ii.97	12.ii.98	11.xi.98	25.xi.98
5	17.ii.97	2.iii.97	24.x.97	14.xi.97	6.ii.98	12.ii.98	11.xi.98	25.xi.98
6	12.ii.97	2.iii.97	26.x.97	7.xi.97	6.ii.98	15.ii.98	11.xi.98	25.xi.98
7	17.ii.97	12.iii.97	26.x.97	7.xi.97	8.ii.98	15.ii.98	11.xi.98	23.xi.98
8	17.ii.97	2.iii.97	26.x.97	7.xi.97	8.ii.98	15.ii.98	11.xi.98	23.xi.98
9	18.ii.97	2.iii.97	26.x.97	7.xi.97	8.ii.98	15.ii.98	11.xi.98	24.xi.98
10	18.ii.97	3.iii.97	1.xi.97	17.xi.97	7.ii.98	13.ii.98	6.xi.98	23.xi.98
11	18.ii.97	3.iii.97	3.xi.97	17.xi.97	7.ii.98	13.ii.98	6.xi.98	23.xi.98
12	16.ii.97	3.iii.97	1.xi.97	15.xi.97	7.ii.98	13.ii.98	12.xi.98	23.xi.98
13	16.ii.97	3.iii.97	1.xi.97	15.xi.97	7.ii.98	13.ii.98	12.xi.98	23.xi.98
14	21.ii.97	3.iii.97	30.x.97	20.xi.97	11.ii.98	25.ii.98	17.xi.98	24.xi.98
15	21.ii.97	3.iii.97	30.x.97	20.xi.97	11.ii.98	23.ii.98	17.xi.98	24.xi.98
16	21.ii.97	3.iii.97	30.x.97	20.xi.97	11.ii.98	23.ii.98	17.xi.98	24.xi.98
17	21.ii.97	3.iii.97	30.x.97	20.xi.97	11.ii.98	23.ii.98	17.xi.98	24.xi.98
18	16.ii.97	3.iii.97	1.xi.97	15.xi.97	7.ii.98	13.ii.98	12.xi.98	23.xi.98
19	16.ii.97	3.iii.97	5.xi.97	17.xi.97	7.ii.98	16.ii.98	4.xi.98	23.xi.98
20	10.ii.97	26.ii.97	23.x.97	22.xi.97	9.ii.98	20.ii.98	11.xi.98	26.xi.98
21	10.ii.97	26.ii.97	23.x.97	22.xi.97	9.ii.98	20.ii.98	10.xi.98	26.xi.98
22	12.ii.97	26.ii.97	23.x.97	21.xi.97	9.ii.98	20.ii.98	10.xi.98	26.xi.98
23	12.ii.97	26.ii.97	23.x.97	21.xi.97	9.ii.98	20.ii.98	10.xi.98	26.xi.98
24	16.ii.97	3.iii.97	5.xi.97	20.xi.97	7.ii.98	16.ii.98	4.xi.98	23.xi.98

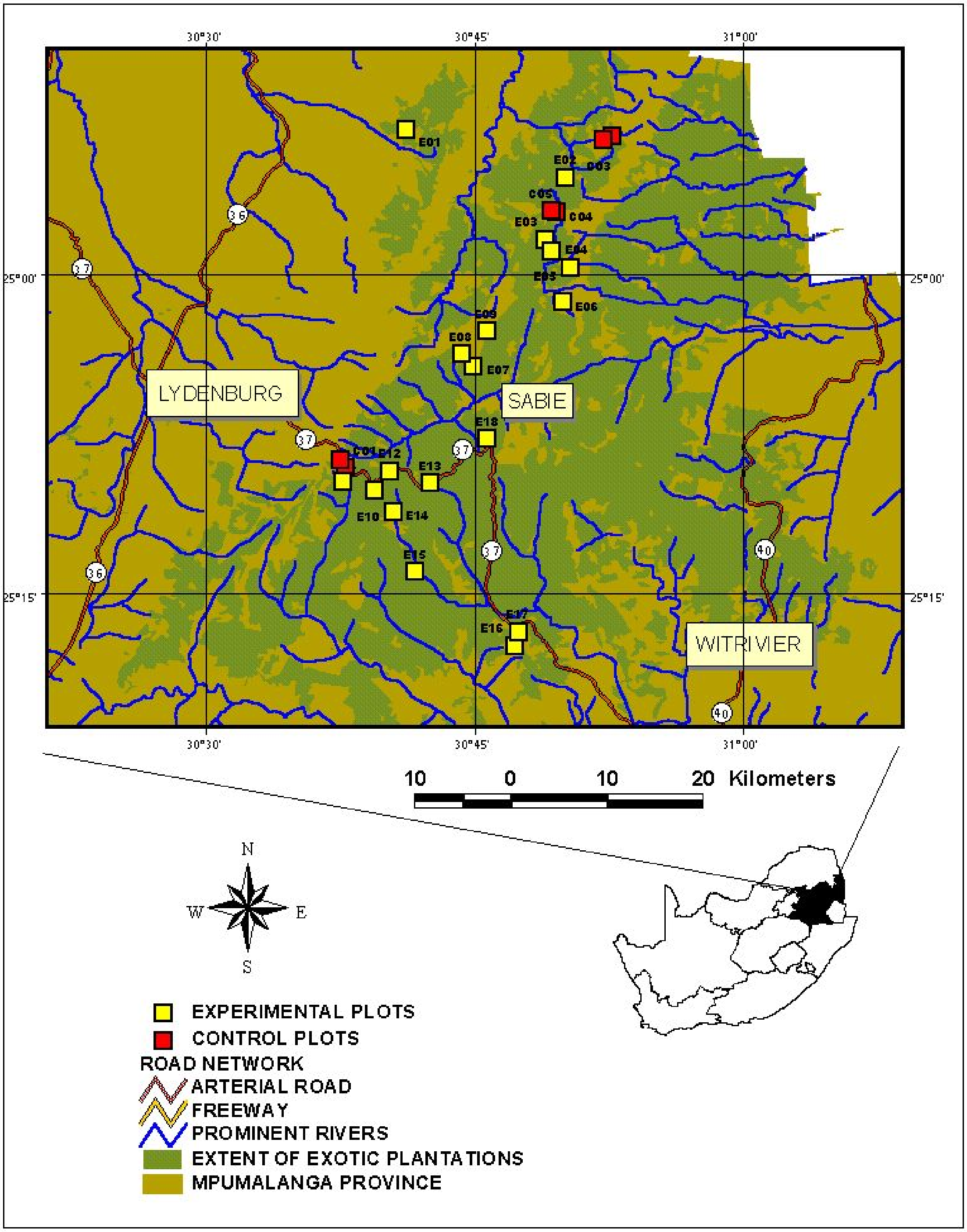


Figure 1. Map of the study area.

References

ACOCKS, J.P.H. 1953. *Veld types of South Africa*. The government printer, Pretoria.

ARMSTRONG, A.J. & VAN HENSBERGEN, H.J. 1999. Identification of priority regions for animal conservation in afforestable montane grasslands of the northern Eastern Cape Province, South Africa. *Biological Conservation* 87: 93-103.

BEHR, C.M. & BREDENKAMP, G.J. 1988. A phytosociological classification of the Witwatersrand national botanical garden. *South African Journal of Botany* 54(6): 525-533.

BOHAC, J. 1999. Staphylinid beetles as bioindicators. *Agriculture, Ecosystems and Environment* 74: 357-372.

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

BREDENKAMP, G.J. 1982. *'n Plantekologiese studie van die Manyeleti – Wildtuin.* D.Sc. dissertation, University of Pretoria, Pretoria.

COPPEDGE, B.R. 1998. Effects of seasonal fire, bison grazing and climatic variation on tallgrass prairie vegetation. *Plant Ecology* 139: 235-246.

COX, C.B. & MOORE, P.D. 1993. *Biogeography. An ecological and evolutionary approach. Fifth edition.* Blackwell Scientific Publications, Oxford.

CRISP, P.N., DICKINSON, K.J.M. & GIBBS, G.W. 1998. Does native invertebrate diversity reflect native plant diversity? A case study from New Zealand and implications for conservation. *Biological Conservation* 83(2): 209-220.

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

DRECHSLER, M. & WISSEL, C. 1998. Trade-offs between local and regional scale management of metapopulations. *Biological Conservation* 83: 31-41.

ESSEEN, P. & RENHORN, K. 1998. Edge effects on Epiphytic Lichen in fragmented forests. *Conservation Biology* 12(6): 1307-1317.

FENSHAM, R.J. 1998. The grassy vegetation of the Darling Downs, South-eastern Queensland, Australia. Floristic and grazing effects. *Biological Conservation* 84: 301-310.

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.

FROUZ, J. 1999. Use of soil dwelling Diptera (Insecta: Diptera) as bioindicators: a review of ecological requirements and response to disturbance. *Agriculture, Ecosystems and Environment* 74: 167-186.

GASTON, K.J. 1994. *Rarity*. Chapman & Hall, London.

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

GILL, A.M. & MCCARTHY, M.A. 1998. Intervals between prescribed fires in Australia: what intrinsic value should apply? *Biological Conservation* 85: 161-169.

GILPIN, M.E. IN: SOULE, M.E. (ed.). 1987. *Viable populations for conservation.* Cambridge University Press, Cambridge.

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.

HOLLAND, M.M., RISSER, P.G. & NAIMAN, R.J. (eds.) 1991. *Ecotones. The role of landscape boundaries in the management and restoration of changing environments.* Chapman & Hall, New York.

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.

KEVAN, P.G. 1999. Pollinators as bioindicators of the state of the environment: species, activity and diversity. *Agriculture, Ecosystems and Environment* 74: 373-393.

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.

KREMEN, C., COLWELL, R.K., ERWIN, T.L., MURPHY, D.D. NOSS, R.F. & SANJAYANMA, M.A. 1993. Terrestrial Arthropod Assemblages: Their use in conservation planning. *Conservation Biology* 7: 796-808.

LANDE, R. & BARROWCLOUGH, G.P. IN: SOULE, M.E. (ed.). 1987. *Viable populations for conservation.* Cambridge University Press, Cambridge.

LOBRY DE BRUYN, L.A. 1999. Ants as bioindicators of soil function in rural environments. *Agriculture, Ecosystems and Environment* 74: 425-441.

MACARTHUR, R.H. & WILSON, E.O. 1967. *The theory of island biogeography*. Princeton University Press, Princeton.

MACNALLY, R. & BENNETT, A.F. 1997. Species-specific predictions of the impact of habitat fragmentation: local extinctions of birds in the box-ironbark forests of central Victoria, Australia. *Biological Conservation* 82: 147-155.

MARGULES, C.R. 1992. The Wog Wog Fragmentation Experiment. *Environmental Conservation* 19(4): 316-325.

MATTHEWS, W.S. 1991. *Phytosociology of the North-Eastern mountain sourveld.* M Sc. Thesis, University of Pretoria, Pretoria.

MATTHEWS, W.S., BREDENKAMP, G.J. & VAN ROOYEN, N. 1992. The phytosociology of the high altitude hygrophilous vegetation of the north-eastern sourveld of the Transvaal. *Phytocoenologia* 20, 559-574.

MATTHEWS, W.S., BREDENKAMP, G.J. & VAN ROOYEN, N. 1993. Endemic flora of the North-eastern Transvaal escarpment, South Africa. *Biological Conservation* 63: 83-94.

MCGEOGH, M.A. 1998. The selection, testing and application of terrestrial insects as bioindicators. *Biological Review* 73: 181-201.

MORGAN, J.W. 1999. Have tubestock planting successfully established populations of rare grassland species into reintroduction sites in western Victoria? *Biological Conservation* 89: 235-243.

MORRIS, M.G. 1981. Responses of grassland invertebrates to management by cutting. *Journal of Applied Ecology* 18: 107-123.

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

OOSTERMEIJER, J.G.B & VAN SWAAY, C.A.M. 1998. The relationship between butterflies and environmental indicator values: a tool for conservation in a changing landscape. *Biological Conservation* 86: 271-280.

PAOLETTI, M.G. 1999. Using bioindicators based on biodiversity to assess landscape sustainability. *Agriculture, Ecosystems and Environment* 74: 1-18.

PAOLETTI, M.G. & HASSALL, M. 1999. Woodlice (Isopoda: Oniscidea): their potential for assessing sustainability and use as bioindicators. *Agriculture, Ecosystems and Environment* 74: 157-165.

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.

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.

RAMSAY, P.M. & OXLEY, E.R.B. 1996. Fire temperatures and postfire plant community dynamics in Ecuadorian grass páramo. *Vegetatio* 124: 129-144.

RICHARDSON, D.M. 1998. Forestry trees as invasive aliens. *Conservation Biology* 12(1): 18-26.

RICE, P.M. & TONEY, J.C. 1998. Exotic weed control treatments for conservation of fescue grassland in Montana. *Biological Conservation* 85: 83-95.

RODRIGUEZ, J.P., PEARSON, D.L. & ROBERTO, B.R. 1998. A test for the adequacy of bioindicator taxa: are tiger beetles (Coloeoptera: Cicindelidae) appropriate indicators for monitoring the degradation of tropical forests in Venezuela? *Biological Conservation* 83(1): 69-76.

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. 1990. Land forms and winter habitat refugia in the conservation of montane grasshoppers in Southern Africa. *Conservation Biology* 4(4): 375-382.

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.

SEGURA, A.M. 1998. The significance of fire intensity in creating local patchiness in the Chilean mattoral. *Plant Ecology* 139: 259-264.

SIMBERLOFF, D. 1998. Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? *Biological Conservation* 83: 247-257.

SOMMAGGIO, D. 1999. Syrphidae: can they be used as environmental bioindicators ? *Agriculture, Ecosystems and Environment* 74: 343-356.

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.

STOHLGREN, T.J., BULL, K.A., OTSUKI, Y., VILLA, C.A & LEE, M. 1998. Riparian zones as havens for exotic plant species in the central grasslands. *Plant Ecology* 138: 113-125.

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.

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.

TRINE, C.L. 1998. Wood Thrush population sinks and implications for the scale of regional conservation strategies. *Conservation Biology* 12(3): 576-585.

VAN JAARSVELD, A.S., FERGUSON, J.W.H. & BREDENKAMP, G.J. 1998. The Groenvaly grassland fragmentation experiment: design and initiation. *Agriculture Ecosystems & Environment* 68: 139-150.

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.

WESSELS, K.J., FREITAG, S. & VAN JAARSVELD, A.S. 1999. The use of land facets as biodiversity surrogates during reserve selection. *Biological Conservation* 89: 21-38.

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

CHAPTER 2

Floristic assessment of the remaining Afromontane grassland fragments in the escarpment region of Mpumalanga, South Africa.

ABSTRACT

The vegetation communities in 24 grassland fragments within an afforested area of the Mpumalanga escarpment is described from a phytosociological point of view. Four major plant communities were revealed using TWINSPAN based classification, and these were supported by the DECORANA analyses. The phytosociological structure of relevés within grassland fragments corresponded to those of control sites outside of the plantations. Secondly, the associations within the study sites can unambiguously be assigned to communities identified in wider-scale classifications of undisturbed grassland in the literature. Thirdly, no invader plant taxa or pioneer species were observed in large numbers within any of the grassland fragments. Taken together, these points indicate that the grassland fragments within the plantation represent largely intact plant communities that have a significant conservation importance. Conservation priorities were assigned to each of the plant communities described based on geological formation, representation of particular communities, fragment sizes as well as risk of transformation. The Wetter North and Transitional regions have higher conservation priorities than the Drier South region as a result of unique geological formations and high transformation risk.

Keywords: grassland, afforestation, conservation, endemism

Introduction

Fragmentation of habitats due to landscape transformation as a result of human activities is one of the most serious threats to the biological diversity of the planet (Thomas et al. 1997, Sotherton 1998, Turin 1988). The risk to the mountain grassland of South Africa is particularly critical as a result of extensive afforestation in the area (Foord 1997, Matthews 1991). Also, the area is exceptionally rich in endemic plant taxa (Matthews 1991, Deall 1985) and has a high plant diversity (Davis 1994). A large part of the natural vegetation in this region has been destroyed, and the remaining grassland is frequently restricted to small, isolated remnant patches.

On the central Mpumalanga escarpment, less than five percent of the area within the plantations of alien trees is still characterised by relatively undisturbed montane grassland. The native plant diversity is often also a valuable reflection of the diversity of other groups (Crisp et al. 1998) and a principal determinant of their spatial distributions (Davis 1994). Close collaboration between forestry companies and conservationists is therefore crucial to preserve and manage this valuable resource. Very little of the mountain grassland in the escarpment region between Graskop and remaining fragments, as well as sound management plans to maintain the high Ngodwana remains, (at least 80% of the study area is now covered with alien timber tree plantations) and there is a great need for the conservation prioritisation of the biodiversity in these grassland areas.

Aims

1. To determine if any marked human-induced disturbance to the plant communities in the grassland fragments has occurred. I do this in three ways:
    a) To compare the plant community composition of eighteen fragments with those of six control plots outside of the plantations where no marked disturbance to the grassland can be observed.
    b) To determine whether the plant assemblages in the fragments can be assigned to any of the natural and intact plant communities that Matthews (1993) described from a large-scale survey of undisturbed mountain areas.
    c) To determine the presence of any known intruder plant species within the fragments.
2. To assign conservation priorities to the remaining grassland fragments.

Methods

Study area

The study area is located in the escarpment region of Mpumalanga, bordered to the North by the Blyderivierspoort Nature Reserve (24° 51’ S, 30° 53’ E), and the most southern fragments (25° 20’ S, 30° 47’ E) is located near the Sudwala Caves. The eastern border of the study area is characterised by the cliffs of the great escarpment of the Drakensberg, and the most western sample plots are situated on the Long Tom Pass (25° 09’ S, 30° 387’ E). The area is represented by Northeastern mountain sourveld (Acocks 1988, Matthews 1991), and belongs geologically to the Transvaal sequence, and the relevant grassland fragments are situated in two subgroups, Chuniespoort and Wolkberg, and two formations, Black Reef and Timeball Hill.

The underlying rocks of the area consist mainly of dolomite, lime, shale and quartzite. As a result of the high rainfall in the area, many of the soil types show signs of medium to high leaching as well as high acidity (an average pH of 4.7), with the soils of dolomite being the least acidic (Matthews 1991). The study area is mountainous with many peaks, deep valleys and gorges with their associated streams.

Very little remains of the natural grassland in the study area, and eighteen sample plots were chosen in isolated grassland fragments as well as six control plots chosen in large, relatively unfragmented grassland because of their accessibility, variability in geology and physiographical distribution (Figure 1). Ten of the grassland fragments chosen were smaller than 4 ha (0.5 to 3.8 ha), four between 15 and 64 ha (15, 33, 34 and 64 ha) and four between 100 and 300 ha (106, 143, 210, 267 ha). The control plots were all located in grassland areas of at least 500 ha. The twenty-four sample plots are located between 1130 and 1980 m above sea level.

Only two of the twenty-four plots are officially protected, and most of the plots are under the control of forestry companies SafCol, Sappi and Mondi, with a few under private and government ownership. Management of the plots ranged from burning and grazing to cutting and no management at all, and management is inconsistent in timing and extent. Slopes of the sample plots were measured using the 1: 50 000 topographical maps and calculating the distances between contours within each plot.

Field survey

Since most of the grassland fragments were relatively small (mean size < 50 ha), a single relevé was used within each fragment. Relevés were chosen to be representative of the vegetation in the fragment. Relevé sizes of 50x50 metres were chosen, and a step point survey conducted for each relevé. These surveys consisted of two hundred step points, recording the individual plant closest to the indicator. This yielded adequate quantitative data to assay the frequency of dominant species (Bosch & Janse van Rensburg 1987, Hoare & Bredenkamp 1998). However, this method would be unable to detect the presence of rare, often endangered or ecologically sensitive species. Therefore an inventory of all plant species encountered along with a semi-quantitative assessment of the cover-abundance of each species according to the Braun-Blanquet cover-abundance scale was compiled for each relevé (Muller-Dombois & Ellenberg 1974, Werger 1974).

Data analysis

Classification:

The relevés were classified by using Two-way Indicator Species Analysis (TWINSPAN) (Hill 1979), a multivariate polithetic, divisive clustering algorithm (Kent & Coker 1995). Refinement was done by Braun-Blanquet procedures, and the results presented in the form of a phytosociological table.

A Detrended Correspondence Analysis (DECORANA) (Hill 1979a) was performed as a quantitative way of classifying the twenty-four relevés.

Deall (1985) and Matthews (1991) did extensive work on the vegetation of the escarpment region of Mpumalanga (Matthews et al. 1992, Matthews et al. 1993, Deall et al. 1989a, Deall et al. 1989b).

Deall's work included vegetation from a restricted part in the centre of the study area, from the Mac Mac Nature Reserve to the Vertroosting Nature Reserve and included the thicket vegetation of the lowveld as far west as Hazyview.

Matthews' study area was wide ranging, covering the escarpment region of the Drakensberg from the Wolkberg (Limpopo province) in the north to Barberton in the south (Mpumalanga province).

In order to place the relevés of this study within the regional floristic description above, they were compared to the communities described by Matthews and by Deall. However, because each of the three studies mentioned (Deall, Matthews and the present study), made use of different plot sizes (10x10, 10x20 and 50x50m), quantitative statistical comparisons of these studies were not possible. As a result, the sample plots and communities were compared in a qualitative way, using geology, altitude, dominant species and characteristic species defined by Matthews and by Deall.

Results

Classification of study sites

The TWINSPAN analysis revealed four associations and six alliances, grouped hierarchically into four orders and two major classes of montane grassland (Figure 1). This community-level structuring is evident from the Braun-Blanquet ordination table

(Table 1), where the total number of plant species is divided into seventeen groups, Species Groups A to Q. The DECORANA supported these results, indicating clear differences between four communities 1.1, 1.2, 2.1 and 2.2 (Figure 2), described below:

Plant communities:

1. Helichrysum acutatum – Themeda triandra grassland of the wetter North and Transitional regions. This is a grassland community found throughout the region, and includes eighteen relevés, distributed throughout the northern part of the study area. It is found on most of the geological formations of the region, between 1130 and 1980 metres above sea level and is represented by relevés of varying sizes, slopes, elevations, aspects and geological characteristics. This community is dominated by the grasses Themeda triandra, Monocymbium ceresiiforme, Panicum natalense, Eulalia vllosa and Loudetia simplex (species group P). Species from group K such as Monopsis decipiens, Selago atherstoni and Helichrysum acutatum are characteristic of this community and differentiate it from community 2.

1.1 Eriosema salignum – Loudetia simplex grassland of the wetter North region. This is a community of grassland found throughout the region, and includes ten relevés. It is found on most of the geological formations of the region, between 1130 and 1980 metres above sea level. The grass species of Themeda triandra, Loudetia simplex, Monocymbium ceresiiforme, Eragrostis racemosa and Eulalia villosa dominate this community, and it is characterised by Eriosema salignum (Species Group D).

1.1.1 Helichrysum wilmsii – Loudetia simplex grassland. Represented by only one relevè (4), this marsh-like community is found on Black Reef quartzite at 1364 metres above sea level, and is dominated by the grasses Loudetia flavida, Loudetia simplex and Diheteropogon amplectens. It is characterised by Species Group A, including Felicia muricata, Satyrium cristatum and Helichrysum wilmsii.

1.1.2 Acalypha angustata – Loudetia simplex grassland of relatively high altitudes. This alliance is represented by nine relevés, mostly occurring on dolomite, lime and shale. Mostly found on plots with south-westerly to south-easterly facing slopes, it is dominated by the grasses Themeda triandra, Monocymbium ceresiiforme and Eragrostis racemosa. Characteristic species include Acalypha angustata, Pseudarthria hookeri and Crabbea hirsuta (Species Group D).

1.1.2.1 Rhynchosia villosa - Monocymbium ceresiiforme grassland. The four relevés representing this association have gentle slopes (less than 12°), mostly facing in a southerly direction. The main geological component is shale, and it is found over varying elevations. This community is dominated by Themeda triandra and Monocymbium ceresiiforme and characteristic species include Rhynchosia villosa and Watsonia wilmsii (Species Group B).

1.1.2.2 Pteridium aquilinum – Eulalia villosa grassland. Found on dolomite, lime and shale, this community is represented by five relevés smaller than two ha, and all with south-westerly and south-easterly facing slopes and elevations between 1170 and 1350 metres above sea level. It is dominated by Themeda triandra, Loudetia flavida, Loudetia simplex and Eulalia villosa and characterised by Species Group C, including Pteridium aquilinum, Peucedanum capense and Rhoicissus tridentata.

1.2 Lobelia erinus – Panicum natalense grassland of the Transitional region. Relevés of this community are all bigger than two ha, and found on shale and quartzite, but never on dolomite. Elevation is varied, and slopes range from gentle to steep and from south-easterly to north-westerly facing. The community is dominated by the grasses Panicum natalense, Eragrostis racemosa and Moncymbium ceresiiforme. The characteristic species are Lobelia erinus and Stiburus alopecuroides (Species Group J).

1.2.1 Helichrysum chionosphaerum – Panicum natalense grassland. Five relevés represent this alliance, and all are found on Long Tom Pass, between 1800 and 1950 metres above sea level. It is mainly found on shale, and never on dolomite. Panicum natalense, Monocymbium ceresiiforme, Eragrostis racemosa and Themeda triandra dominate this relatively wet grassland of high altitudes, and it is characterised by Helichrysum chionosphaerum and Sutera neglecta (Species Group G).

1.2.1.1 Berkheya echinacea – Rendlia altera grassland. This grassland association is represented by two control plots larger than 500 ha, with elevations between 1860 and 1950 metres above sea level. Both have steep, easterly facing slopes (> 12 degrees), and occur on shale. The grass species Rendlia altera, Panicum natalense and Monocymbium ceresiiforme dominate this community, and the characteristic species are Berkheya echinacea, Trachyandra asperata and Dierama medium (Species Group E).

1.2.1.2 Hemizygia pretoriae – Sporobolus pyramidalis grassland. Three relevés constitute this community, all between 1800 and 1860 metres above sea level, with moderately steep slopes with varying aspects. Plot sizes range from 2.1 to 34 ha, and is found on shale and quartzite, but never on dolomite. It is dominated by Sporobolus pyramidalis, Loudetia simplex, Eragrostis racemosa and Themeda triandra. Characteristic species are those of Species Group F in Table 1, and include Hemizygia pretoriae and Conostomium natalense.

1.2.2 Eragrostis sclerantha – Panicum natalense grassland. This grassland community of large plots (> 200 ha) is only found on quartzite, and between 1260 and 1590 metres above sea level. It is gentle sloping grassland (< 10°), with westerly and north-westerly aspects. Dominant species include Panicum natalense, Loudetia flavida and Trachypogon spicatus. Species Group H contains the characteristic species for this alliance, and includes Eragrostis sclerantha, Crassula compacta and Oldenlandia herbacea.

2. Barleria ovata – Eragrostis racemosa grassland of the Drier South region. This grassland is found to the south of Long Tom Pass, in an area of relatively low altitude (1200 – 1530 metres above sea level) and with a slightly drier climate. The relevés representing this community have moderately steep to very steep slopes with varying aspects, and are seldom found on quartzite. The grassland of this area is visibly

different from the typical mountain grassland of the area (Matthews 1991) and as a result classified as a different class in Figure 1. Grasses such as Eragrostis racemosa, Andropogon schirensis and Bulbostylis burchelli dominate the vegetation of this area.

2.1 Parinari capensis – Eragrostis racemosa grassland. This grassland of relatively low altitude (< 1530 metres above sea level) occurs on various geological formations, mostly on dolomite, lime and shale. The fragments represented by this community have varying sizes and slopes, but never with a southerly aspect. Dominating this grassland is Eragrostis racemosa and Bulbostylis burchelli and characteristic species are Barleria ovata, Tephrosia glomeruliflora, Eragrostis curvula and Parinari capensis (Species Group N).

2.1.1 Senecio glaberrimus – Andropogon schirensis grassland. The three relevés representing this alliance have contrasting sizes and are found on various geological formations. All have moderately steep to steep slopes, facing north-westerly to north-easterly. It is dominated by the grasses Eragrostis racemosa, Andropogon schirensis and Loudetia simplex, and characterised by Species Group L, including Elionurus muticus, Senecio glaberrimus and Melinus repens.

2.1.2 Linum thunbergii – Loudetia flavida grassland. This alliance is found between 1220 and 1380 metres above sea level and on dolomite, lime and shale, but never on quartzite. Slopes of the representing fragments are relatively gentle (7.4 – 9.9°), and sizes differ greatly (0.9 – 267 ha). Grass species Eragrostis racemosa, Loudetia flavida and Themeda triandra dominate the vegetation, and the characteristic species of this community (Species Group M) include Acalypha villicaulis, Hypochaeris radicata, Panicum dregeanum and Linum thunbergii.

2.2 Helichrysum rugulosum – Eragrostis racemosa grassland. One relevè (14) represents this grassland community, and is found at 1200 metres above sea level, on shale, and has a gentle north-easterly facing slope. The grasses Eragrostis racemosa and Loudetia flavida dominate this grassland fragment and it is characterised by two species, Callilepis leptophylla and Helichrysum rugulosum (Species Group O).

Although the fragments and control plots were selected to be similar physiographic traits and climatic conditions and in vegetation (homogenic floristic units), differences in floristic composition of relevés is inescapable in such a large study area. Communities occurring closely together have similar geological characteristics and experience similar weather conditions, and as a result have similar plant communities (Table 2). The four major communities (1.1, 1.2, 2.1 and 2.2) were distinct in both the TWINSPAN-based classification, (Fig.1) as well as the DECORANA ordination (Fig. 2).

Comparability of grassland fragments with the control plots

Relevés from isolated grassland fragments and those of large unfragmented areas compare well with each other. The species richness of experimental and control plots do not differ significantly (Table 3). Furthermore, the species composition of plots from the

Wetter North, Transitional and Drier South region show more variation than is evident between experimental and control plots (Figure 1).

Qualitative comparisons with existing communities, in terms of dominant and characteristic species as well as geomorphology

The relevés compared well to the communities described by Deall and Matthews, and each of the twenty-four sample plots was comparable to one of Matthews' communities, and some to Deall's communities (Table 2).

Matthews (1991) described the vegetation of a large area in Mpumalanga, including a large part of the study area of this study. Three of his important community groups were found to be comparable to relevés of this study – The Grasslands of Drier Dolomitic Regions, Hygrophilous Grasslands of High Altitude and Grasslands of Relatively Low Altitude. Seven, nine and eight relevés were respectively comparable to these community groups, however, these relevés did not correspond with the three regions described in this study, and there is no clear link between the Wetter North, Transitional and Drier South Regions with those described by Matthews.

Invasive plant species within the grassland fragments.

The most obvious of invader species in the twenty-four plots studied, was *Pteridium aquilinum*. It was, however, very localised in its distribution, and restricted to community 1.1.2.2 (Table 1). No other obviously invasive or pioneer species in the context of the natural grassland communities of Matthews or in the abundances of such species within the twenty-four relevés of this study were found.

Discussion

The twenty-four sample plots are situated along a fifty kilometre North-South gradient, and the floristic differences between the Wetter North and Drier South regions are therefore hardly surprising. The average rainfall of plots in the Drier South region is about 210 mm less (on average) than that of their Wetter North counterparts, and the Drier South plots are located, on average, 179 metres closer to sea level than the plots of the Wetter North and Transitional regions. Furthermore, the geology between the three regions differs significantly, with most of the Black Reef quartzite plots located within the Wetter North and Transitional regions. These factors clearly contribute towards the plant community differences between the three regions.

Three lines of evidence suggests that the extensive afforestation in the study area has not had a clearly measurable effect on the floral species composition of the isolated grassland fragments within plantations, and their isolation and restriction did not result in significant differences from their unfragmented equivalents (Fig 1, Table 3).

Firstly, both the control sites and grassland fragments were classified into both the wetter northern associations as well as the transitional associations of community no. 1 (Table1, Fig. 1). Unfortunately, suitable control sites could not be identified in the drier southern community (no. 2; Table 1, Fig. 1), because no suitable, unfragmented grassland areas remain in the southern part of the study area.

In addition, the species richness values of relevés within the fragments did not differ from those at the control sites (Table 3), indicating that fragmentation has not visibly influenced the number of plant species found in small, isolated grassland fragments.

Secondly, all the relevés analysed here could be classified into plant communities identified in the large-scale study of Matthews (1993) (Table 2 of this thesis). Since Matthews' study largely concentrated on intact and natural montane plant communities, the inference is that the communities identified here have not been subject to systematic changes in community structure. I conclude that fragmentation of the montane grassland of the study area has not influenced the plant communities of the remaining fragments within plantations significantly, and the presence of invader and pioneer species have not yet changed the nature of these communities.

The lack of representation of several of Matthews' and Deall's grassland communities by the sample plots of this study may reflect the extent and extent of habitat destruction in the afforested areas of the region.

Thirdly, no major invasive plant species were observed within the grassland fragments. The only recognised invader plant species found within the grassland fragments of the study area, *Pteridium aquilinum*, were restricted to community 1.1.2.2 and had very little impact on the study area as a whole. No other plant species found is obviously invasive in the context of the study area, the natural grassland communities described by Matthews and their relative abundances in the twenty-four relevés of this study.

The fact that fragmentation has had no obviously significant effects on the plant communities of the isolated grassland fragments of the study has important conservation implications. Although the possibility exists that Matthews' communities may represent stages in a successional gradient (therefore influencing the conservation status of some of the isolated fragments of this study), the fact that Matthews' study focused on relatively undisturbed communities renders that possibility remote.

Conservation of the grassland fragments identified during this study.

Within the study area, and indeed throughout the region, the quartzite of the Black Reef Formation (Geological Survey 1986) is restricted to a few isolated areas, and is associated with unique and rare plant communities, both as far as grassland and forests are concerned (Matthews 1993).

Very few of the current sample plots of afromontane grassland are found on Black Reef Quartzite, and are restricted to two communities – communities 1.1 and 1.2.2 are therefore of great conservation importance, not only in regards to the study area, but on a much larger scale– it includes many endemic and rare species (Matthews 1991) and reflects the rarity of Black Reef Quartzite as an underlying geological basis for montane grassland in general.

Community 1.2.2 is represented by three relevés, two of which are under official protection (experimental plot 6 – Mac Mac Pools, and control plot 21 – in the Blyderivierspoort Nature Reserve), but the two plots in community 1.1 found on Black Reef Quartzite are small isolated patches (relevés 2 and 4), and at great risk of being transformed to the surrounding afforested landscape. It is critical that the importance of these unique plots are realised, and that the appropriate steps are taken to ensure the continued survival of this unique plant community.

In order to arrive at an objective but useful recommendation about the relative conservation priorities of the remaining grassland fragments, a conservation importance index is proposed that depends on four factors: a) Geological formation, b) degree of representation within the study area, c) fragment size and d) degree of risk of habitat transformation. Risk of transformation was estimated in three categories: high risk assigned to fragments totally surrounded by plantations and without any form of protection, moderate risk to fragments with some form of protection and not completely isolated and low risk to fragments within protected areas and with a very low level of isolation.

The following scoring system was used, with the resulting total score used to assign conservation rank (Table 5):

1. <u>Geology</u>

All relevés on Black Reef Quartzite – 10 points

All but one on Black Reef Quartzite – 8

All but two on Black Reef Quartzite – 6

Various Geology with one relevè on Black Reef Quartzite – 4

All relevés on Shale – 2

Various Geology – 0

2. Level of representation

One relevè – 3 points

Two relevés – 2

More than two relevés – 1

3. Fragment sizes

All relevés smaller than 10 ha – 5 points

All but one smaller than 10 ha – 4

All but one larger than 10 ha – 3

All between 10 and 100 ha – 2

All but one larger than 100 ha – 1

All larger than 100 ha – 0

4. Risk of transformation

All relevés high risk – 5 points

All but one high risk – 4

All relevés moderate risk – 3

All but one moderate risk – 2

All relevés low risk – 1

Communities 1.1 and 1.2.2 are of particular conservation importance (Table 4), because of their rare geological (Black Reef Quartzite) and floristic characteristics, and their uniqueness within the area and region. As a general geographical trend, the communities have less conservation importance the further south it is found, with the northern communities 1.1 and 1.2.2 the most important, and the southern communities 2.1 and 2.2 the least important for conservation (Table 4).

The diversity, high levels of endemism and variation within the mountain grassland of the study area emphasise the importance of the escarpment region of the Drakensberg in Mpumalanga as a conservation area. The fact that no clear changes were detectable in the plant community structure and the plant diversity within the existing fragments (including even the fragments smaller than 5 ha in extent) emphasises the conservation importance of these fragments. They need to be included in any conservation plan for these fragments.

Management of the grassland fragments

The grassland fragments of the study area were subjected to chemical weed control, and burning on a two-year cycle. Grazing and cutting occurred sporadically, and never with any regularity. Unfortunately, no specific and accurate historical information on the management of any individual grassland fragment is available, because of a large number of owners.

In order too quantify the effects of management of the remaining grassland patches, precise experimental planning involving grazing, mechanical cutting, grazing and burning is needed to decide on the optimal management regime for each fragment if biodiversity is to be conserved properly. Furthermore, grassland patches within plantations may change in structure and characteristics when the surrounding plantations are sawn, especially since management of these patches often is neglected, as is the case with relevè 5 where large amounts of moribund grass have accumulated.

Conclusion

Many of the grassland fragments surrounded by plantations are still easily identifiable as natural communities, described by Matthews and Deall in broader-scale surveys in the past. They are not discernible as obvious invader – or disturbed plant communities, even though some of them have been isolated for as long as 40 years. If it is assumed that other influences such as management (natural or human-induced) did not differ significantly between fragments since the onset of afforestation in the area, it stands to reason that afforestation and habitat fragmentation have not significantly impacted on the floristics of the montane grassland of the study area.

The plant communities of conservation importance described by Matthews coincide with the important communities recognized in this study. Rare and endangered plant species, as well as species endemic to the region, are more often than not found on the scarce Black Reef quartzite of the region, which is more evident to the Northern part of the study area. Communities 1.1 and 1.2.2 are therefore of particular conservation importance, not only as a result of their scare geological base, but also because of the high risk associated with the few grassland examples left of these communities.

The importance of the small, isolated fragments is evident from the results of this study. They do not differ significantly in species composition from the large, unfragmented grassland areas, and are often the only representation left of specific grassland variants. The management of these grassland areas are critical, and serious consideration should be given to the different management options (burning, grazing, etc.) by plantation managers and relevant officials, to ensure the continued survival of all grassland communities in the area.

The latitudinal and moisture gradient within the study area, best explains the plant communities described for the twenty-four sample plots. This indication will be used fundamentally in the next two chapters where, amongst other, the faunal component of the sample plots of the study will be investigated.

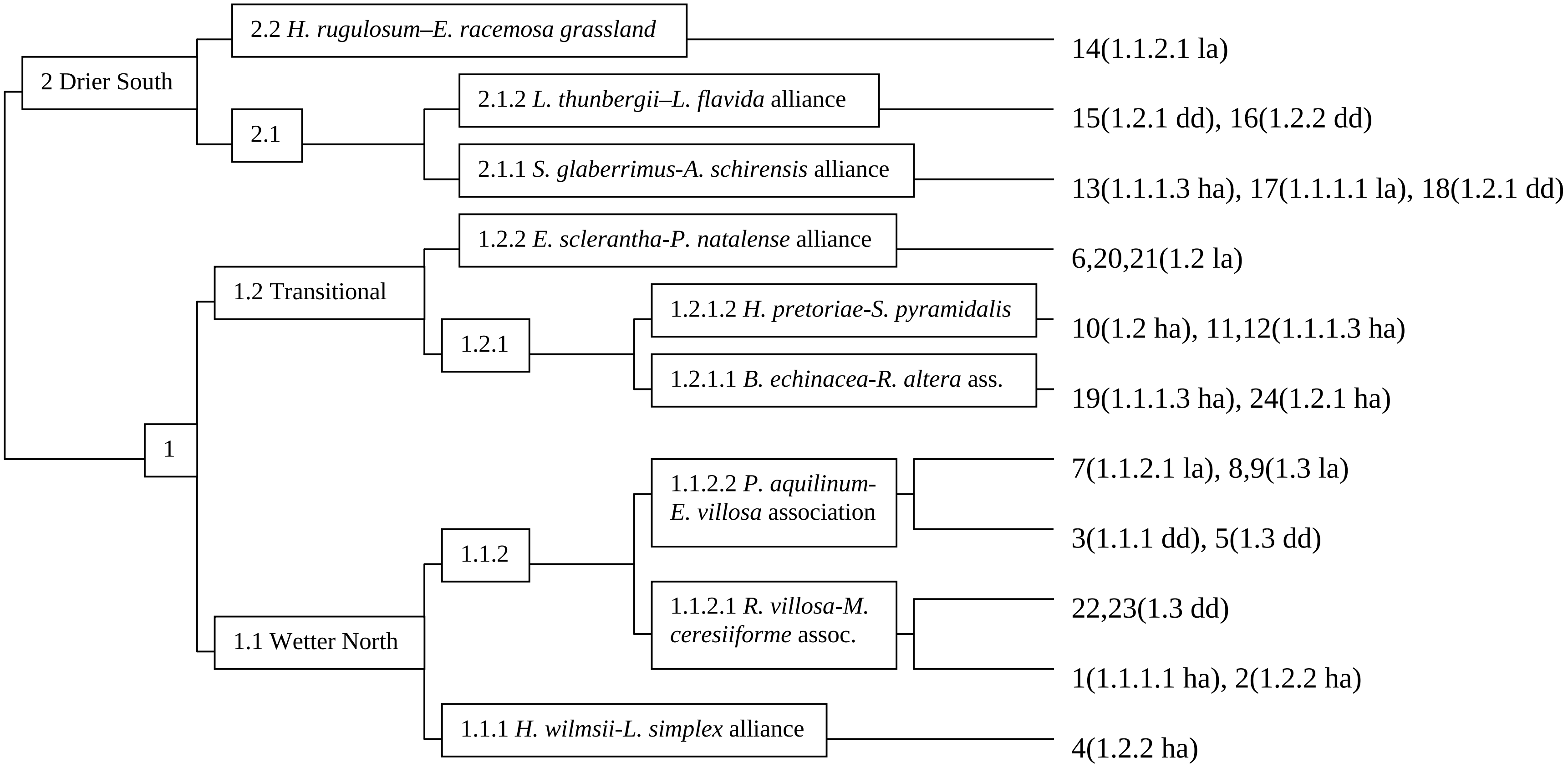


Figure 1. A TWINSPAN-based classification of the vegetation of the twenty-four relevés. The column on the right gives the identification of plot within an association, the identification of the association within then text, and the broad region within which an association was located. Control plots are numbered 19-24, and Matthews' relevant communities are given for each relevè (dd – drier dolomitic, ha – high altitude, la – relatively low altitude – Table 2).

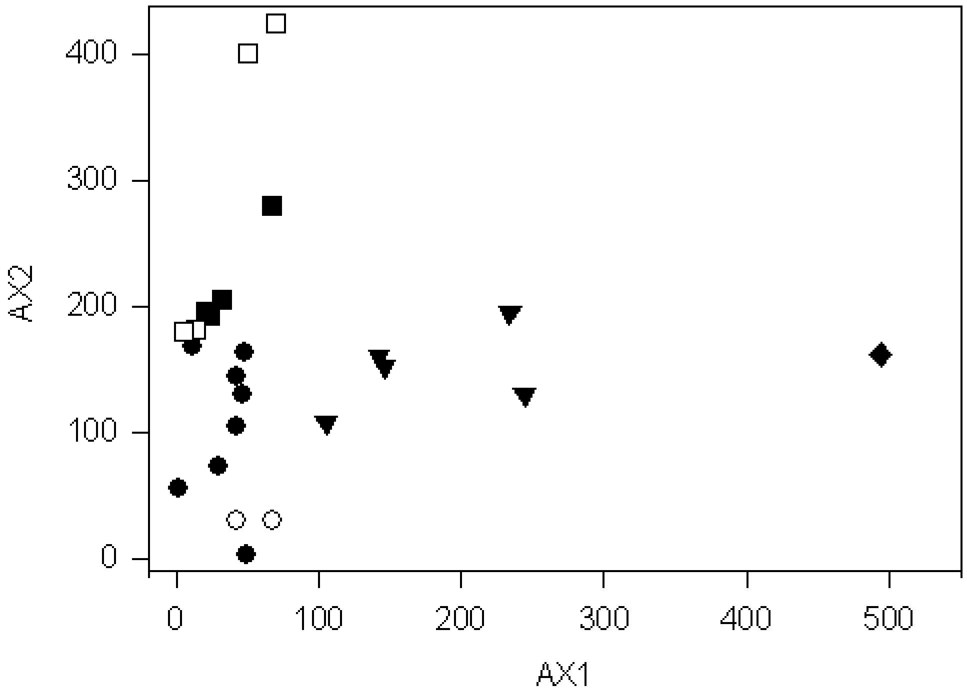


Figure 2. Decorana of the twenty-four relevés. Circles represent community 1.1 (Wetter North), squares community 1.2 (Transitional), triangles community 2.1 (Drier South) and diamonds community 2.2 (Drier South). The six open symbols represent the six control relevés, and the eighteen closed symbols the experimental relevés. The four communities are distinct within the ordination, but the experimental and control relevés show no obvious separation.

Table 1. A Braun-Blanquet phytosociological interpretation of the plant species identified in the twenty-four relevés in the Drakensberg Escarpment region of Mpumalanga. Decimal numbers at the top of the table indicate TWINSPAN-based communities corresponding to those indicated in Fig. 1.

Community number	1																		2					
	1.1										1.2								2.1					2.2
	1.1.1	1.1.2									1.2.1					1.2.2			2.1.1			2.1.2		
		1.1.2.1				1.1.2.2					1.2.1.1		1.2.1.2											
Sample plot number	4	1	2	22	23	3	5	7	8	9	19	24	10	11	12	6	20	21	13	17	18	15	16	14
Floristic data																								
Species Group A	+																							
Felicia muricata	+																							
Satyrium cristatum	+																							
Helichrysum wilmsii	+																							
Schizochilus cecilii	+																							
Sopubia mannii																								
Species Group B		B	3										+				1							
Heteropogon contortus		+	+					1																
Cyphia assimilis			2	A	1																			
Rhynchosia villosa		+		+	+																			
Watsonia wilmsii																								
Species Group C																						+		
Diospyros lycioides						+	+																	
Agapanthus nutans						+	+																	
Gomphocarpus fruticosus						+	+																	
Rhus discolor				1		+	+	+																
Rhoicissus tridentata							+	1																
Pteridium aquilinum						1	+	1	A	A														
Peucedanum capense						+		+	+	+														
Species Group D																								
Acalypha angustata	+	1	+	1			+	+																
Eriosema salignum		+			+		+			+														
Hypericum lalandii		+							+															
Pseudarthria hookeri		+				+																		
Crabbea hirsuta			+					+																
Species Group E																								
Trachyandra asperata							1				1	+												
Berkheya echinacea											1	+												
Dierama medium											+	+												
Species Group F																								
Conostomium natalense													+	+										
Hemizygia pretoriae													+	+										
Gazania krebsiana											+			+	+									
Species Group G																								
Helichrysum chionosphaerum												+			+									
Sutera neglecta												+	+											

Table 1 -cont-

Species Group H																								
Eragrostis sclerantha								+								+	A	+						
Chlorophytum fasciculatum		+															+	+						
Buchnera longespicata			+														+	+						
Crassula compacta																	+	+						
Oldenlandia herbacea																	+	+						
Species Group I																								
Digitaria monodactyla															1	+								
Gladiolus longicollis															+	+								
Wahlenbergia undulata														+		+								
Species Group J																								
Lobelia erinus		+										+	+			+								
Stiburus alopecuroides												+					+							
Species Group K																								
Erica drakensbergensis		+	+		+				+		+													
Commelina africana		+	+				+					+												
Scilla natalensis		+					+				+		+											
Helichrysum spiralepis		+									+	+												
Helichrysum platypterum				+	+	+				+		+												
Alepidea longifolia	1							1		+	+													
Crassula vaginata	+					+				+		1												
Satyrium longicauda						+		+			+	+		+	+									
Silene burchellii			+			+		+							+									
Craterocapsa tarsodes		+	+											+	+									
Tristachya leucothrix	+	A	+		+	+					+		1											
Chlorophytum cooperi	+	+				+	+							+	+									
Koeleria capensis	1	+									1			+	1									
Helichrysum umbraculigerum				+				1		+					+									
Rabdosiella calycina						+	+			+			+											
Sporobolus pectinatus	1	1											+											
Ledebouria revoluta			1								+			+										
Drosera madagascariensis	+											+			+									
Helichrysum acutatum	+	+	+			+	+	1						+		+								
Senecio oxyriifolius	+	+				+		+		+		+				1								
Monopsis decipiens	+	A										+	+			+	+							
Selago atherstonei	+								+		+	+				1	+	+						
Sebaea grandis	+	+						+							+	1		+						
Thesium utile	1	+									1			+				+						
Species Group L																								
Elionurus muticus		A																		A	+			
Senecio glaberrimus																			+		+			
Melinis repens																				+	+			
Species Group M																								
Acalypha villicaulis						1																1	1	
Hypochaeris radicata																						+	+	+
Panicum dregeanum																+						+	+	
Helichrysum glomeratum		+																				+	+	
Berkheya densifolia																						+	+	
Linum thunbergii																						+	+	

Table 1 -cont-

Species Group N																								
Barleria ovata																				1	1		1	
Tephrosia glomeruliflora																				+		+		
Eragrostis curvula																				+			+	
Parinari capensis																					1		+	
Species Group O																								
Callilepis leptophylla																								+
Helichrysum rugulosum																								+
Species Group P																								
Themeda triandra		B	B	B	A	B	3	B	1	A	3	1	3	4	A	+	+			A	A	1	A	A
Eragrostis racemosa		A	1	A		1		1	1	1	B	1	1	B	B		1	1	B	B	1	3	A	3
Monocymbium ceresiiforme	1	B	+	A	1	+		1	+	+	A	1		1	A	A	1	+	+	+				1
Panicum natalense	+		+				+	1	3	A	A	1	+	A	A	A	1	1	A	A	A	1		+
Eulalia villosa	1		A	1	1	1	1	1	A	A		+				1	+	+		1	1	1	+	1
Bulbostylis burchellii		B	1	1	+	+		1		+	1	1		A			+	1	A	1	1	B		+
Loudetia flavida	A			1		1	A	A	+	A				1	A	3	3	1	1	1		A	A	B
Aristea galpinii	+		+			+	+	+	+	+	+	+	+		+				+	+		+		1
Scabiosa columbaria	1	+	+		+	+	+	+	1	+	+	+							+			+	+	+
Inulanthera calva			+				+			+				1		+	1	1				+	1	+
Gladiolus exiguus	+		+			+	+				+	+							+		+	+	+	+
Cymbopogon excavatus				1		1	1		+	+	1			1	A					+		1		1
Ctenium concinnum																			A	A				
Pentanisia angustifolia		+	+	1		1		+						1	+						+			
Dicoma anomala		+	+									+							+					
Gnidia capitata		+	+			1													+	+				
Clutia species				+	+								+					+	+					
Loudetia simplex	B	A	A	B		A	3	A	3	B	1	+	B	1	A	3		B	A	A	A			
Helichrysum cephaloideum		1	A			1			+	1	1	+		+						+				
Andropogon chinensis			+	1						+					+	+					+			
Pearsonia obovata												1			A				+	1	1		A	
Rhynchosia caribaea								1								1		B	A		1	1	B	
Hemizygia subvelutina								1			+				1				1				+	
Buchnera reducta						+			+						+							1	1	
Chamaecrista comosa				A		B		1	+							+	+	B				+		
Helichrysum pallidum				+	1						+	+			+			+	+	+	+		+	
Gnidia kraussiana				1				+			1			+	+			+					+	
Helichrysum pilosellum		1	+	+	1	+		+	1		+	1		+	+	+			+	+	+	+	+	
Trachypogon spicatus		B		1	1		1						+	+		A	3	+		1	1	+		
Cyperus obtusiflorus		+	+	+							1	+	+	1	+			+	1			+		
Alloteropsis semialata		1	1						+		+		+	+	1				1				+	
Clerodendrum triphyllum			+	1		1		1	+											+	+	+	+	
Zornia linearis		+		+	+	+		+													+	+	+	
Pearsonia sessilifolia		+	+									+				1			+				+	
Zaluzianskya katharinae		+			+			+				+			+								1	
Polygala hottentotta		+									+			+				+		+			+	
Lotononis foliosa		+		1								+		+									+	
Lippia javanica			+			+										+					+		+	
Sebaea leiostyla		+				+											+	+				+		
Senecio venosus		+													1					+		+		

Table 1 -cont-

Diheteropogon amplectens	A	A	A	1		A		+	+	+		A	1		+	1	+		+	1	A	1	1	
Helichrysum aureonitens	A	A	1	+		1	1		1	1		1	1	+	1	1	+	+		+			A	
Haplocarpha scaposa		+	1	1	1	+		+	+	+	1	1		+		+			+	+	+		1	
Rendlia altera	1			A	A	3	B	3			1	A			A			+	A		1	A	1	
Andropogon schirensis	1		A		A	+	1				1	1			A	+		+	B	A	A		A	
Sopubia cana		+	1	+		1	+	+	1	+	+	+		+	+			+					+	
Cyanotis speciosa	+		+		+	+			1	+	+	1			+	+		+					+	
Inezia integrifolia					+				+	1	+	+	+	+					+	+		+		
Crassula alba	+		+	+	+		+		+		+								+				+	
Schizachyrium sanguineum										+						+				+		+	1	
Clutia pulchella		+		+			1	1		1									+	1	A		+	
Cliffortia linearifolia								+	+	+		+								+		+	+	
Senecio gerrardii													+	+						1		+	+	+
Helichrysum nudifolium											+						+					+	+	+
Eriosema cordatum		+	+	1		+			+		+				+	+	1	+					A	+
Indigofera rostrata		+		+	+	+			+							+		+	+	A		A	+	1
Sporobolus pyramidalis		A	+	1	1	+						+	A	1	1			+	+	+	+		1	1
Euryops pedunculatus		1	+	1		+							A		+	1							A	+
Vernonia natalensis		+	1			A	1	1	1		+		1	+					1	1				1
Hermannia coccocarpa		+		+		+	+	+					+						+			+	+	1
Pentanisia prunelloides		+			+	+	+	+					+			+		+	+	1			1	+
Kyllinga alba		+	+						+				+	+		+	+	+		+			+	+
Raphionacme hirsuta		+	+	+				+			+	+		+										+
Aristida junciformis		+	1		1							+	3	1			+				+			+
Eucommis montana				+	+			+	1				1											+
Oxalis depressa		+	+															+						+
Anthospermum rigidum		+	+																					A
Vernonia galpinii	+		+		+			+						+										+
Hyparrhenia hirta										+												1		B
Eragrostis capensis	1															1				+	1		A	+
Trichoneura grandiglum							+	+		1										+			+	
Desmodium setigerum									+	+												+		1
Melinis nerviglumis															+									+
Berheya setifera								+		+									+					
Xyris capensis	1						1									+				+				
Schistostephium crataegifolium								+		1														
Tetradenia riparia													+	+						+				
Setaria nigrirostris							+	+													+			
Dipcadi viride		+		+																	+			+
Helichrysum mimetes										+												+		
Stachys natalensis											1			+							+			+
Hypoxis rigidula									+															
Ammocharis coranica	1												1											
Eriosema transvaalense				+												+								
Hypoxis iridifolia						A									+									
Aster peglerae			+											+										
Harpochloa falx		+										1												
Disa patula			+								+													
Helichrysum miconiifolium		+																						
Monsonia attenuata															+					+				
Myrica brevifolia										+											+			
Striga asiatica				+															+			+		
Chaetacanthus costatus				+																				+

Table 1 -cont-

Species Group Q																			
Crepis hypochoeridea		+																	
Festuca scabra		+																	
Senecio erubescens		+																	
Solanum retroflexum		+																	
Sonchus wilmsii		+																	
Vigna unguiculata		+																	
Gomphocarpus tomentosus			+																
Indigofera hedyantha			+																
Indigofera hilaris			+																
Disa patula				+															
Habenaria lithophila				+															
Eucomis autumnalis					+														
Helichrysum uninervium					1														
Kalanchoe thyrsiflora					+														
Maytenus heterophylla					+														
Talinum caffrum					+														
Dimorphotheca spectabilis						+													
Cyathea dregei						+													
Cyphostemma lanigerum						+													
Hypericum revolutum						+													
Senecio inaequidens						+													
Digitaria diagonalis							1												
Helichrysum mixtum							1												
Costularia natalensis								+											
Calpurnia aurea								+											
Gladiolus dalenii								+											
Paspalum scrobiculatum								+											
Vernonia oligocephala								1											
Conyza podocephala									+										
Wahlenbergia huttonii									+										
Alepidea setifera										+									
Aristea angolensis										+									
Hypoxis galpinii										+									
Cyphia assimilis										+									
Clutia monticola											+								
Helichrysum splendidum											+								
Cyphia elata											+								
Paspalum urvillei												+							
Cheilanthes viridis													+						
Psammotropha myriantha													+						
Cotula hispida														1					
Craterostigma wilmsii														1					
Kohautia amatymbica														1					
Ledebouria cooperi														+					
Cyperus rupestris															+				
Alectra sessiliflora																+			
Otholobium polystictum																	+		
Senecio affinis																	+		
Aloe simii																		+	
Elephantorrhiza elephantina																		+	
Faurea speciosa																		1	
Geigeria burkei																		+	
Hypericum aethiopicum																		+	
Tephrosia longipes																		+	

Table 1 -cont-

Vernonia schlechteri								+	
Convolvulus sagittatus								+	

Table 2. Qualitative comparison of the twenty-four study sample plots to the grassland communities of the escarpment region of Mpumalanga described by the wide-scale studies of the wide-scale studies of Matthews (1991) and Deall (1985).

Matthews' Grassland Communities	Geology	Altitude	Shared Dominant Species	Shared Characteristic Species	Shared communities	
					Deall	Kamffer
Grasslands of the Drier Dolomitic Regions					Comm.	Relevés
1.1.1 The Eragrosto curvulae – Hyparrhenietum filipendulae - hyparrhenietosum tambae grassland	Dolomite	1100 – 1400 m.a.s.	*Themeda triandra*	*Pseudarthria hookeri*	51a&b 52a&b	3
1.2.1 The Hemizygio transvaalensis – Loudetietum simplex – barlerietosum ovatae grassland	Dolomite	1100 – 1500 m.a.s.	*Panicum natalense* *Trachypogon spicatus*	*Barleria ovata*		15, 18
1.2.2The Hemizygio tranvaalensis – Loudetietum simplex – indigoferetosum oxalidea grassland	Dolomite	1100 – 1400 m.a.s.	*Eragrostis racemosa* *Diheteropogon amplectens*	*Polygala hottentotta* *Scabiosa columbaria*	49a 49b	16
1.3 The Rhoicisso tridentatae – Rhynchosietum nitentis grassland	Dolomite	1100-1400 m.a.s.	*Themeda triandra*	*Aristida junciformis Rhus discolor Scilla natalensis Rhoicissus tridentata*		5, 22, 23
Hygrophilous Grasslands of High Altitude Regions						
1.1.1.1 The Festuco costatae – Proteetum gaguedi grassland	Shale	Above 1600 m.a.s.	*Monocymbium ceresiiforme*	*Helichrysum acutatum* *Sporobolus pectinatus*		1
1.1.1.3 The Gnidio kraussianae – Festucetum costatae grassland	Shale	1600 – 2000 m.a.s.	*Monocymbium ceresiiforme* *Helichrysum pilosellum*	*Polygala hottentotta Gnidia kraussiana Schizachyrium sanguineum Helichrysum nudifolium*		11,12, 13, 19
1.2 The Helichryso aureonitentis – Monopsion decipientis grassland	Quartzite	1600 – 2000 m.a.s.	*Loudetia simplex*	*Monopsis decipiens* *Aristida junciformis*		10
1.2.1 The Helichryso aureonitentis – Sopubietum canae grassland	Quartzite Dolomite	1100 – 1600 m.a.s.	*Monocymbium ceresiiforme* *Loudetia simplex*	*Microchloa caffra* *Sopubia cana*	47 48	24
1.2.2 The Helichryso aurreonitentis – Stiburetum alopecuroidis grassland	Quartzite	1100 – 1450 m.a.s.	*Eragrostis racemosa* *Helichrysum aureonitens*	*Drosera madagascariensis* *Koeleria capensis*		4, 2
Grasslands of Relatively Low Altitude						
1.1.1.1 The Diheteropogono amplectentis – Proteetum gaguedi – Hemizygietosum transvaalensis grassland	Quartzite	Around 1250 m.a.s.	*Loudetia simplex* *Diheteropogon amplectens*	*Melinus repens*		17
1.1.2.1 The Panico natalensis – Andropogonetum schirensis – Bulbostyletosum oritrephes grassland	Shale	1200 – 1600 m.a.s.	*Eragrostis racemosa* *Diheteropogon amplectens*	*Kyllinga alba* *Pentanisia prunelloides*		14, 7
1.2 The Eragrostido scleranthae – Monocymbietum ceresiiformis grassland	Quartzite	1450 – 1850 m.a.s.	*Loudetia simplex* *Rendlia altera*	*Eragrostis sclerantha*		20, 21, 6
1.3 The Diheteropogono filifolii – Scilletum nervosae grassland	Dolomite	1300 – 1800 m.a.s.	*Eragrostis racemosa* *Monocymbium ceresiiforme*	*Pteridium aquilinum Cyanotis speciosa Helichrysum cephaloideum*		8, 9

Table 3. Statistical comparisons (t-tests) of species richness of control plots with that of experimental plots also showed no significant differences for the Wetter North (community 1.1), the Transitional (community1.2), or overall (including the Drier South region which unfortunately has no control plots).

COMPARISON Exp vs. control	*t*	df	*P*
Overall: (Exp = 1-18) (Control = 19-24)	1.308	22	0.2041
Community 1 (WN & T) (Exp. = 1-12) (Control = 19-24)	1.3914	16	0.1831
Community 1.1(WN) (Exp. = 1-5,7-9) (Control = 22-23)	1.143	8	0.286
Community 1.2 (T) (Exp. = 6,10-12) (Control = 19-21,24)	0.294	6	0.778

Table 4. Conservation rank priorities of the twenty-four sample plots within their nine respective plant communities. Scores are assigned for geology, level of representation, fragment sizes and risk of transformation, which contribute towards a total score used to assign conservation priorities. The Wetter North (WN) and Transitional (T) regions receive conservation priority above the Drier South (DS) region.

Community	Geology: score	# relevés: score	Size: score	Risk: score	Total score	**Rank**
1.1.1(WN)	10	3	5	5	23	**1**
1.2.2(T)	10	1	0	2	13	**2**
1.1.2.1(WN)	4	1	3	4	12	**3**
1.1.2.2(WN)	0	1	5	5	11	**4**
1.2.1.2(T)	4	1	4	2	11	**5**
2.2(DS)	2	3	2	3	10	**6**
2.1.1(DS)	4	1	2	3	10	**7**
1.2.1.1(T)	2	2	0	3	7	**8**
2.1.2(DS)	0	2	1	3	6	**9**

References

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

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.

CRISP, P.N., DICKINSON, K.J.M. & GIBBS, G.W. 1998. Does native invertebrate diversity reflect native plant diversity? A case study from New Zealand and implications for conservation. *Biological Conservation* 83(2): 209-220.

DAVIS, A.L.V. 1994. Habitat fragmentation in southern Africa and its distributional response patterns in five specialist or generalist dung beetle families (Coleoptera). *African Journal of Ecology* 33: 192-207.

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

DEALL, G.B. 1989a. The vegetation ecology of the Eastern Transvaal Escarpment in the Sabie area. 1. Physical environment. *Bothalia* 19: 53-67.

DEALL, G.B. 1989b. . The vegetation ecology of the Eastern Transvaal Escarpment in the Sabie area. 2. Floristic classification. *Bothalia* 19: 69-89.

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.

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

HILL, M.O. 1979a. *DECORANA. A FORTRAN programme for detrended correspondence analysis and reciprocal averaging.* Department of Ecology and Systematics, Cornell University, Ithaca, New York.

HILL, M.O. 1979b. *TWINSPAN. A FORTRAN programme for arranging Multivariate data in an ordered two-way table by classification of the Individuals and attributes.* Cornell University, Ithaca, New York.

HOARE, D.B. & BREDENKAMP, G.J. 1999. Grassland communities of the Amatola/Winterberg mountain region of the Eastern Cape, South Africa. *South African Journal of Botany* 65(1): 75-82.

KENT, M. & COKER, P. 1995. *Vegetation description and analysis – A practical approach.* Wiley, Chichester.

MATTHEWS, W.S. 1991. *Phytosociology of the North-Eastern mountain sourveld.* M Sc. Thesis, University of Pretoria, Pretoria.

MATTHEWS, W.S., BREDENKAMP, G.J. & VAN ROOYEN, N. 1992. The phytosociology of the high altitude hygrophilous vegetation of the north-eastern sourveld of the Transvaal. *Phytocoenologia* 20, 559-574.

MATTHEWS, W.S., BREDENKAMP, G.J. & VAN ROOYEN, N. 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.

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.

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.

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

Chapter 3

Strong habitat preference and habitat-specific differentiation of faunal assemblages in the threatened Afromontane grassland.

ABSTRACT

An analysis of the Coleoptera, Orthoptera, Lepidoptera, Neuroptera and birds of twenty-four afromontane grassland fragments in the pine-afforested escarpment region of Mpumalanga, South Africa, is presented. The ordination of the faunal assemblages indicated significant similarities between animal and plant communities of corresponding sample plots within the study area. The faunal community structures were compared using ANOSIM (analysis of similarity) that indicated, firstly, that the three main plant communities (Community (Wetter North, Transitional and Dryer South) differed significantly in faunal community structure and, secondly, that experimental and control plots within a plant community did not differ. The plant community-based differences were emphasized by the large number of grassland specialist taxa found in the Wetter North, compared to relatively few in the remaining plant communities. Plants and butterflies were found to be more habitat specific than beetles, grasshoppers and birds. Twenty species were chosen as potential ecological indicators to enable monitoring of the remnant grassland patches within the study area. The indicator list of the Wetter North was dominated by beetles, birds and butterflies with no grasshoppers, whereas the indicators of the other faunal assemblages were dominated by grasshoppers. Since the fragments contained largely undisturbed faunal assemblages, including many habitat-specific species, the grassland fragments among the pine plantations should have a high conservation priority.

Keywords: habitat fragmentation, bioindicators, afromontane, habitat specificity

Introduction

One of the most critical pressures on the global biological diversity of the twenty-first century is habitat fragmentation (Thomas et al. 1997, Turin 1988, Foord 1997, Sotherton 1998). The montane grassland of the Mpumalanga escarpment is a unique and threatened habitat with a very high level of plant endemicity (Matthews et al. 1993, Matthews 1991, Deall 1985). As a result of extensive afforestation, most of the remaining grassland in the area has been fragmented into small, isolated patches surrounded by exotic timber tree plantations.

Since insect communities, especially assemblages of phytophagous insects, are often dependent on specific plant communities (Brown & Hyman 1986, Crisp et al. 1998), they may be at risk in this area. Habitat fragmentation is a real threat for many insect and plant populations that are less mobile, and might possibly be considered as island populations, since genetic and demographic causes of vulnerabilities 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 (Haig et al. 1998, Vickery & Gill 1999, Pasitschniak-Arts, et al. 1998). Associated dangers (Richardson 1998), such as invasion of natural vegetation by exotic species could have strong effects on small insular bird populations (Thiollay & Probst 1999).

Although relatively much is known about the taxonomic and conservation status of the botanical part of the Afromontane grasslands, knowledge about its fauna lags far behind. Among the vertebrates, several bird species are restricted to these grasslands and are strongly affected by afforestation (Allan et al.1997). In contrast, information on the taxonomy and ecology of the African Coleoptera is rudimentary, most species being undescribed and with little knowledge of the geographic distributions of known taxa.

For implementing conservation measures for these grasslands it is crucial to know whether the Afromontane fauna shares the endemicity that plants have. Given that the beetles of these grasslands are taxonomically unknown to a large degree, we have to turn to alternative approaches in order to make statements about beetle endemicity.

A large proportion of the Coleoptera is dependent on specific host plants (Anderson 1993, Jolivet and Hawkeswood 1995). If the Afromontane beetle fauna included a large proportion of endemics, we would predict that beetle assemblages would largely reflect the plant associations described by Kamffer (Chapter 2). Testing this hypothesis would be a first step towards understanding the significance of the Afromontane arthropod biodiversity.

This study has four aims:

1. To compare the faunal biodiversity in grassland fragments within afforested areas to that of control plots in large, relatively undisturbed grassland areas.
2. To determine to which degree the Coleoptera, Orthoptera, Lepidoptera and bird communities reflect recognised plant communities, and are restricted to specific plant communities.
3. To compare the habitat specificity (degree of stenotopy) of the different taxonomic groups and trophic levels of animals.
4. To make recommendations for the conservation of the Afromontane grassland fauna in the remaining grassland fragments in afforested areas.

Study Area

In the study area, represented by north-eastern mountain sourveld (Acocks 1988, Matthews 1991), twenty-four sample plots were chosen due to their accessibility, variability in geology and physiographical distribution. The study area covers about 535 km² from the Blyderivierspoort Nature Reserve in the north to the Sudwala Caves in the South, and from the Long Tom Pass in the west to the escarpment of the Mpumalanga Drakensberg in the east. The plots range from 0.5 ha to continuous grassland between 1130 and 1980 metres above sea level. Six control sites were chosen in continuous, undisturbed grassland.

Only two of the twenty-four sites are officially protected, and most of the sites are under forestry control, with a few under private and government ownership. Management of the grassland fragments range from fire and grazing to cutting and no management at all, and is inconsistent in timing and coverage. The underlying rocks of the area consist mainly of dolomite, lime, shale and quartzite (Geological Survey 1986). The study area is mountainous with many peaks, deep valleys and gorges with their associated streams.

Materials & Methods

Field Survey

Sweepnetting was used to calculate the species composition and relative abundances of the Coleoptera and Orthoptera of the twenty-four fragments. Although sweepnetting has some constraints, it remains the only realistic means of sampling a large grassland area with many sampling points in a reasonably short period of time. Although it could provide biased estimates of absolute abundances, sound approximations of the relative abundances of insects can be obtained (Evans 1988).

Each of the twenty-four sampling points was sampled eight times, twice in each of the four seasons (early & late summer 1997, early & late summer 1998). A sweep consisted of two hundred sweep movements through the grassland vegetation, using a canvas bag (30 cm in diameter). Insects were collected using an aspirator, and placed in killing jars with ethyl acetate. Sweeping was performed between ten in the morning and three in the afternoon and with at least fifty percent clear skies.

Identification of the Coleoptera and Orthoptera was done up to family and subfamily level using the keys of Scholtz and Holm (1986), and classified to morphospecies, which is sufficient for ecological surveys of this magnitude (Oliver & Beattie 1996). Identification of the most important taxa, and easily identifiable species was done with the key in Holm & Marais (1992) for the Cetoniinae, and using the voucher collection of Foord (1997), including many of the Curculionidae and Chrysomelidae encountered during this study. Identification of beetle taxa comprising 95% of all Coleoptera individuals was done at the National Collection of Insects, Pretoria. A voucher collection is kept at the National Collection of Insects.

During each survey, presence/absence data was collected for Lepidoptera and Neuroptera. The butterflies, day-flying moths and ant lions seen flying during a fifteen minute collecting period was collected using a butterfly net with a 50 cm diameter. Specimens were preserved by freezing them in plastic bags. The Lepidoptera was identified using Pennington's Butterflies of Southern Africa (Pringle et al. 1994) and Moths of Southern Africa (Pinhey 1975). The National Collection of Insects, Pretoria, Pretoria, identified the two species of ant lion.

During each of the four sampling periods, one hour of bird identification of four fifteen minute periods each were conducted while walking a series of transects that systematically covered each grassland fragment. Although many bird species could be identified by sight (using 8x40 binoculars), sound was used to identify cryptic species (a reference CD collection was used to compare sounds).

Only bird species that could be considered as grassland specialists to some degree were noted. For instance, bird species such as Columba arquatrix (rameron pigeon), Oriolus larvatus (blackheaded oriole), Pycnonotus barbatus (blackeyed bulbul) and Psalidoprocne holomelas (black sawwing swallow) were considered generalists, or specialist species of habitats other than grassland, and were therefore ignored.

Data Analyses

The ordination of assemblages based on Coleoptera and Orthoptera was very similar to that of the plants (Fig. 1). Therefore, to enable faunal community descriptions directly comparable to the botanical data, ordering of animal taxa was performed based on the classification and hierarchical notation for plant communities described by Kamffer (Chapter 2), and the results presented in the form of a habitat-based ordination table (Table 1). Briefly, the main plant communities are the Wetter North (community 1.1), the Transitional Region (community 1.2) and the Drier South (community 2).

Habitat specificity of species were classified as follows: Species were considered 'habitat specific' if they occurred in only one of the two major plant communities (1 or 2), or specifically at a lower level (for instance only within 1.1 or 1.1.2.1). 'Habitat constrained' species were those taxa excluded from at least one of the nine communities (1.1.1, 1.1.2.1, 1.1.2.2, 1.2.1.1, 1.2.1.2, 1.2.2, 2.1.1, 2.1.2 and 2.2). Species were labelled 'everywhere' if they were included in all of the nine communities, and 'single occurrence' if they occurred in only one of the twenty-four relevés.

From all the species occurring in more than one of the sample plots (i.e. excluding 'single occurrences'), the proportion of species restricted to one of the two major communities (1 and 2) was used as an indication of habitat specificity among taxonomical groups (Table 4) and among trophic levels (Table 5).

Analyses of similarity (ANOSIM) were performed to compare the faunal community structure of the three major floral community groups (Wetter North, Transitional and Dryer South). A similar analysis was also performed to compare the assemblage structures of the isolated fragments within the afforested areas to the large control plots in the adjacent, relatively undisturbed areas of grassland (Table 6). The statistical analysis was performed on the Bray-Curtis similarity indices (Bray & Curtis 1957), calculated from square-root transformed abundance values.

Potential ecological indicator taxa for each plant community were qualitatively chosen using the following criteria:

1. Habitat specificity: species found in several sites within a particular plant community.
2. Ease of sampling: abundant species while during sweepnetting, thus excluding elusive species such as fast-flying Lepidoptera.
3. Ease of identification: distinct species that could possibly be identified without entomological expertise.
4. Ease of recognition: obvious insects and birds that are easily picked up during sampling, excluding cryptic and shy species.

These criteria were used in conjunction, and representative species of each plant community were chosen to provide the first step in the continued monitoring of these grassland areas (Table 5).

Results

During the four sample periods, 15602 beetles, grasshoppers and crickets were collected, with an average of 3900 per sampling period. Although the plant communities are very similar, and mostly identical to the naked eye, the fragments contained unique combinations of animal species (Table 1, Table 4, Figure 1). The characteristic taxa of animal assemblages of the plant communities recognised by Kamffer (Chapter 2) can be summarised as follows:

Plant Community 1

Animals of the Helichrysum acutatum – Themeda triandra grassland of the wetter North and Transitional regions:

Coleoptera: Eleven of the 180 beetle species are restricted to this plant community, a group with a strong weevil contingent (five species). Six families are represented in this group (Species Group I, Table 1), all phytophagous. It is also weevil-dominated, with two of the three most dominant species from the Curculionidae (Eudraces sp 1 and Oosomini sp 1).

Orthoptera: There is no characteristic grasshopper or cricket species for this community. It is dominated by the katydid, Xiphidium conocephalus.

Lepidoptera: Eight butterfly species from five families are characteristic for this community. Five of these species occur almost exclusively on grassland, and three have restricted ranges.

Birds: Community 1 is characterised by three bird species, the common Grassveld Pipit, the locally common Yellowrumped Widow and the endangered Blue Swallow.

Plant Community 1.1

Animals of the Eriosema salignum – Loudetia simplex grassland of the wetter North region:

Coleoptera: Six beetles are restricted to the grasslands of the Wetter North from three families and as many trophic levels.

Lepidoptera: Five species of Lepidoptera are habitat specific and only found in this plant community, and this group includes the only habitat specific day-flying moth, Brephos decora (Red Tiger).

Birds: The grassbird, Sphenoeacus afer, was the only bird species not found outside the Wetter North region.

Plant Community 1.2

Animals of the Lobelia erinus – Panicum natalense grassland of the Transitional region:

Coleoptera: Two beetle species were only found in the Transitional region – the leaf beetle Mecistes cf. seriatus and the fruit chafer Atrichelaphinis tigrina.

Plant Community 2

Animals of the Barleria ovata – Eragrostis racemosa grassland of the Drier South region:

Coleoptera: Community two had five characteristic beetle species, from four families and one trophic level. In contrast to community 1.1's weevil-domination, community two was characterised (two species) and dominated (two of the three most dominant species) by leaf beetles (Chrysomelidae).

Orthoptera: The acridid grasshopper Cantantops fasciatus is characteristic of the Drier South region, and it is, again, dominated by X. conocephalus.

Lepidoptera: In sharp contrast to community one's list of characteristic species; community two has no characteristic butterfly species.

Birds: The Drier South region also had no bird species to distinguish it from the wetter North and Transitional regions.

Plant Community 2.1

Animals of the Parinari capensis – Eragrostis racemosa grassland:

Orthoptera: Only two animals were restricted to community 2.1, the grasshoppers Heteropternis guttifera and Lentulidae sp. 3.

Plant Community 2.2

Animals of the Helichrysum rugulosum – Eragrostis racemosa grassland:

Coleoptera: The single animals species not found anywhere but in community 2.2, is the monkey beetle Eriesthis sp. (Rutelinae: Scarabaeidae).

Analyses of similarity (ANOSIM) were used to compare the faunal community structure of the twenty-four sample plots. One-way analyses of similarity were used to compare the faunal community structures of sample plots of the Wetter North, Transitional and Dryer South regions. Significant differences were evident from the results for both the comparisons between all three groups (Table 2) and between the Wetter North and Transitional regions. However, the faunal community structures of the experimental and control plots of the Wetter North and Transitional regions (unfortunately no appropriate control plots could be found in the Dryer South region) did not differ significantly (Table 2).

The indexes of habitat specificity (fractions of species constricted to certain plant communities) indicated that the plants and butterflies were more habitat-specific than the Coleoptera, Orthoptera and Birds (Table 3). Indeed, log-likelihood ratio tests indicate that the division of the fauna of table 3 into these two groups contributes by far the greatest component of difference ($G = 11.275$; $df = 3.840$, $p = 0.05$) towards the overall likelihood ratio for all the taxa in that table ($G = 12.8696$; $df = 9.488$; $p = 0.05$).

The carnivorous insects showed a surprisingly high level of habitat specificity (0.43) compared to the relatively low 0.26 of the phytophagous insects (Table 4). This surprising trend was also evident in various insect families – Acrididae (0.43), Scarabaeidae (0.45) and Nymphalidae (0.46) compared to the Curculionidae (0.30) and the 0.29 of the Chrysomelidae (Table 5).

Discussion

Invertebrate grassland specialists and habitat specificity

Throughout the taxa studied here, species were found that can be considered grassland specialists, in other words, insects that are seldom found outside grassland or grassland associated habitats, and these species occurred in all of the above-mentioned grassland variants of the afromontane grassland of the escarpment of Mpumalanga.

Plant community 1 had a large number of Lepidoptera grassland specialists, with seven species restricted to grassland habitats, from three families, the Lycaenidae, Hesperiidae and Nymphalidae (Satyrinae). In contrast, community 2 had no species of habitat-restricted butterflies or day-flying moths, and therefore no Lepidopteran grassland specialists (see Pringle et al. 1994).

Unfortunately little is known about the biology of the mountain grassland Coleoptera in general, but one taxon at least has been well-studied - Gnathocera (Gnathocerida) hirta Burmeister is a fruit chafer (Scarabaeidae: Cetoniinae) whose biology is clearly linked to wet grasslands (Holm & Marais 1992). Adults are found on the flower heads of various grasses (Imperata cylindrica, Andropogon eucomis and Setaria sphacelata), always near streams or seepages, and mostly at high altitudes. Although none of these plants were observed during sampling, the closely related species, Setaria nigrigrostis, Andropogon chinensis and A. schirensis were recorded.

Beetles of the families Chrysomelidae and Curculionidae include many grassland specialists, but little information is available on the biology of the great majority of these beetles, especially for the weevils (Scholtz & Holm 1986). Despite our lack of knowledge on these inverterbrates, many known grassveld-specific invertebrates were found in the fragments, particularly among the Lepidoptera and birds, whose biology are better understood than is the case for the other taxa. For the less known insect taxa, the community composition each fragment closely corresponds to the equivalent plant communities.

The grassland biome is one of the most threatened in South Africa, with 60-80% irreversibly transformed, while only 2% is formally conserved. Its high degrees of plant diversity and endemism are well known, and, although grassland insects are poorly known, this study showed that many insect taxa are habitat specific within the grassland. It therefore appears that the remarkable plant diversity of this region is mirrored by its insect diversity. The remaining areas of relatively undisturbed grassland should therefore receive a high conservation priority, especially areas such as the Wetter North region of this study which has been shown to host many grassland endemics.

Although very little is known about the geographical distributions of beetles, habitat specificity estimates indicate that many of the beetles, especially phytophagous groups such as the weevils (Curculionidae) and leaf beetles (Chrysomelidae) are grassland specialists, restricted to specific plant assemblages. All of the taxonomical groups had very few species (on average three percent – Table 3) occurring throughout all the grassland variants. On average, 69 percent of the species observed occurred either in a specific grassland community or were constrained to some of the grassland variants.

Few of the animal species preferred any single plant community, and the degree of habitat specificity was in general not very high - on average 28% of the beetles, grasshoppers, crickets and birds were restricted to specific plant communities (Table 4). Within the Coleoptera, the coprophagous and carnivorous beetles revealed higher levels of habitat specificity (67 and 43% respectively), but this is probably a sampling artefact of the small number of species (3 and 16 respectively).

Of the habitat specific bird species, one is of particular conservation importance. Hirundo atrocaerulea (Blue Swallow) is an uncommon to rare breeding intra-African migrant endangered by continuous destruction of its habitat (Maclean 1993). Very few pairs still breed in South Africa and, within the study area; it is restricted to plant community 1 (occurring in only two of the sample plots). Almost half of the butterflies and day-flying moths occurred habitat specifically (47%, Table 4), reflecting the habitat specificity of the plants (46%) and some of the grassland butterflies of the Subregion are known to be vulnerable to further habitat destruction.

At least one of the butterflies found in the study area, Dingana bowkeri clarki Van Son, is significantly restricted (restricted to only two of the twenty-four sampling plots), and is probably under severe strain. It is known from nine locations in the subregion, including two in the study area, the Verloren Vallei Nature Reserve and the Long Tom Pass, and its larvae presumably feeds on Merxmuellera (= Danthonia) sp. (Poaceae), but this is not confirmed (Pringle et al. 1994) since the plant species was not found in the any of the sampling plots.

Even though many of the insect species are poorly known, and little can be said about their geographical distributions, let alone their habits and conservation status, the well known species such as the Blue Swallow and Bowker's Widow seem to suggest that a high level of faunal endemicity exists, and many of these taxa are probably restricted to the study area and surrounding regions of similar habitat. This underlines the importance of the conservation of these animals as well as their habitat.

Implications for conservation

There appears to be no large scale difference in community structure between isolated grassland fragments and large areas of relatively undisturbed grassland (Table 2). This is a possible indication that the extensive fragmentation of the grassland in the area has not yet affected the bird and insect assemblages greatly. The few animal species (mostly birds and butterflies) that currently provide enough information to assist with conservation planning, indicate the conservation priority of the Wetter North and Transitional regions, since all of the habitat-specific birds and Lepidoptera known to be of conservation importance occurred in plant community 1. Included in this community, were all the sample plots on the scarce Black Reef Quartzite geological formation (Kamffer, Chapter 2).

These results support the conclusions of Matthews et al. (1993), based on the botanical structure of these grasslands. The Dryer South region had no animals known to have restricted ranges or numbers, and could probably be considered to be of less conservation importance, at least until more is known about grassland beetles in particular.

Interactions between grassland and other vegetation types.

The recently described Violescent Blue Orachrysops violescens G.A. and S.F. Henning that we encountered occurs in Mpumalanga from Hendriksdal to Mariepskop and is often found near montane forest, in the vicinity of their food plants, a species of small Indigofera (Fabaceae) (Pringle et al. 1994). It is possible that its larval host is one of the three species of Indigofera found in the study area (Kamffer, Chapter 2), and its relationship with the montane forest remains unclear.

In addition, the Blue Swallow Hirundo atrocaerulea is found in moist, montane grassland usually with sinkholes, dongas and potholes, often close to evergreen mistbelt forest (Maclean 1993). The particular landscape characteristics needed for nesting (such as dongas) coincide with close-by forests. These examples emphasise that the mountain grassland of Mpumalanga can not be treated and conserved as an entity on its own, and the importance of the surrounding habitats and landscape characteristics should be considered when planning a conservation strategy.

Indicator taxa.

If chosen correctly, specific taxa or species can be used as ecological indicators to show the effects of environmental change (such as habitat fragmentation) on biological systems. Continuous monitoring of such taxa can potentially indicate that a particular stressor (such as invasive aliens, poor management) does (or does not) have an impact on the natural biota, and they can provide critical information for conservation of the ecological system and all of its components (McGeogh 1998, Rodriguez et al. 1998). It can also be valuable for decision-making in agriculture - in monitoring environmental contamination (Paoletti 1999).

Although charismatic vertebrates have been used extensively in the past, invertebrates are far better suited for the purpose of ecological indication. They have high rates of population growth, short generation times and are far more habitat specific (cf. Table 4 – Lepidoptera – 47% habitat specific taxa, compared to birds – 33%) and are sensitive to microclimatic changes, making them ideal indicators (Rodriguez et al. 1998). Although invertebrates fulfil most of the criteria proposed for indicator species (McGeogh 1998), they are often taxonomically and biologically unknown, restricting their use in bioindication.

With this in mind, a list of potential ecological indicators is proposed for continued monitoring of the grassland fragments in the study area (Table 5). The indicators are chosen specifically for each of the two major plant communities, with specific indicators for communities 1.1, 1.2, 2.1 and 2.2:

Table 7 lists twenty species of potential ecological indicators for the study area. These include nine beetles, five butterflies, three grasshoppers and three birds. All of these potential indicators are habitat-specific, easy to identify and should be easy to recognise and sample in the field. A contrast exists between the proposed ecological indicators of Community 1 (including 1.1 and 1.2) and Community 2 (including 2.1 and 2.2). The list of potential indicator species of Community 2 includes all of the grasshopper species, three of the nine beetles and none of the birds or butterflies listed. Community 1 has no grasshopper species listed as potential indicators, but six of the nine beetles and all of the birds and butterflies. This trend accentuates the notable differences between Communities 1 and 2.

Conclusion:

The high levels of habitat specificity of many of the taxonomic and trophic faunal groups indicate that many of the invertebrate taxa are probably endemic to the region, and that the plant endemicity encountered in the Afromontane grasslands by Matthews et al. (1993) is reflected by a similar degree of animal endemicity. In addition, the similarity in faunal assemblages and diversity between isolated fragments and large areas of grassland emphasises the conservation importance of the fragments, even when smaller than 5 Ha in extent.

Appropriate management of the grassland fragments within the plantations is therefore important for the conservation of the plant and animal taxa encountered there. The existing management of the study area is non-coordinated and includes chemical weed control, and burning on a two-year cycle. Grazing (sample plots 1, 14) and cutting (7, 8, 9) occurred sporadically, and never with any regularity; while plot 5 was left unmanaged for a long period of time. Experimental management involving grazing, mechanical cutting, grazing and burning is needed to decide on an efficient management regime, so that the grassland biodiversity can be conserved in a planned way. Such work will also allow empirical testing the efficiency of the indicator species suggested above.

Table 1. A tabular ordination of the Coleoptera, Orthoptera, Lepidoptera, Neuroptera and bird species identified in the twenty-four sample plots in the Drakensberg escarpment region of Mpumalanga. Decimal numbers at the top of the table indicate the TWINSPAN-based plant communities (Kamffer, Chapter 2) and the taxonomic group of each species is indicated in the second column (C: = Coleoptera, O = Orthoptera, L = Lepidoptera, N = Neuroptera and B = Birds).

Community number		1																		2					
		1.1										1.2								2.1					2.2
		1.1.1	1.1.2									1.2.1					1.2.2			2.1.1			2.1.2		
			1.1.2.1				1.1.2.2					1.2.1.1		1.2.1.2											
Sample plot number	Code	4	1	2	22	23	3	5	7	8	9	19	24	10	11	12	6	20	21	13	17	18	15	16	14
Species Group A																									
Lycidae sp 3	CLY	+																							
Rhiphiphoridae sp 2	CRH	+																							
Elateridae sp 4	CEL	1																							
Eicochrysops messapus	LLY	+																							
Species Group B																									
Melitonoma sp 1	CCH		+				+																		
Nephus sp	CCH		1		+	+				+	+														
Sisyphus alveatus	CSC				+				+																
Scymnus levaillanti	CCH					+			+																
Cantharidae sp 1	CCA							+	+																
Afrophthalma sp	CCH								+	+	+														
Lentulidae sp 1	OLE								+		+														
Azanus moriqua	LLY		+						+																
Acraea horta	LNY				+						+														
Anthene definita	LLY					+	+																		
Byblia ilithyia	LNY						+		+																
Brephos decora	LAG		+			+																			
Sphenoeacus afer	BSY				+						+														
Species Group C																									
Galerucinae sp 9	CCH											1		1											
prob. *Gymnetron* sp	CCU												+	+											
Dingana bowkeri	LNY											+	+												
Species Group D																									
Lagriinae sp 5	CTE																	+	+						
Monticola rupestris	BTU																	+	+						
Species Group E																									
Mecistes cf. *seriatus*	CCU														+			A							
Atrichelaphinis tigrina	CSC														1			+							
Species Group F																									
Astylus atromaculatus	CME		+	+			+						+												
Apion sensu latu sp	CAP		+							+					+			+							
Lema sp 1	CCH		+									+	+						1						
Ocladius sp 1	CCU				+	A	+							1											
Mordellidae sp 1	CMO				+	+						+						+							
Eremnus lineatus	CCU						+		+	+	+			+	+		1								
Anthicus sp	CAN						1									+	+								
Pissodes nemarensis	CCU							+								+									
Galerucinae sp 4	CCH								+			B		1											

Table 1 -cont-

Lalagetes sp 1	CCU								+						+										
Stenophida pygialis	CCU								+					+				+							
Calliptamicus antennatus	OAC		+												+	+									
Machaeridia conspersa	OAC				+											+									
Pontia helice	LPI	+													+										
Dingana dingana	LNY	+				+						+	+	+		+									
Kedestes mohuzutsa	LHE		+												+										
Colias electo	LPI		+	+		+									+		+								
Pseudonympha swanepoeli	LNY		+				+			+				+				+							
Kedestes barbarae	LHE			+											+										
Precis archesia	LNY					+					+					+		+							
Lepidochrysops irvingi	LLY					+									+				+						
Euplectes capensis	BPL	+				+												+	+						
Anthus cinnamomeus	BMO		+							+	+							+							
Hirundo atrocaerulea	BHI						+							+											
Species Group G																									
Aphodius sp 1	CSC																			+		1	1		
Lycidae sp 2	CLY																				+	+			
Asbecesta near *capensis*	CCH																				A		+		
Alticinae sp 4	CCH																						+	+	
Heteropternis guttifera	OAC																			+			+		
Lentulidae sp 3	OLE																			+			+	+	
Species Group H																									
Eriesthis sp	CCR																								+
Zizula hylax	LLY																								+
Syntomis cerbera	LCT																								+
Species Group I																									
Melolonthinae sp 2	CSC																			+	+		1		+
Cleridae sp 1	CCL																			+	+		+		+
Colaspoma cf. *pusillum*	CCH																				+		+	+	+
Ellimenistes sp	CCU																					+		+	+
Catantops fasciatus	OAC																				+			+	+
Galerucinae sp 1	CCH																					+	+		
Species Group J																									
prob. *Miarus* sp 1	CST	1	+			+			+	+		+	+			+	+	1		+					
Chrysomelidae sp 28	CCH	+																				+			
Exochomus concavus	CCO	+	+		+	+								+		+	+					+			
Isora circularis	CCO	+											+	+		+				+			+		
Sciobius sp 1	CCU	+				+	+		+					+		+					A		1		
Afrocrepis sp	CCH	+													+									+	
cf. *Exosoma gerstaeckeri* sp 1	CCH	1		+			1	B	1	+		1	B				+		+		+		+	+	
cf. *Exosoma gerstaeckeri* sp 2	CCH	+		+	+	+	+	A		1	+	+	A					+	+		A	+		1	
Chaetocnema sp 2	CCH	+	A	A	+	1	1	B		+		+	1	1		+	+	1	1	1	1		+	+	
Elateridae sp 1	CEL	A							+		+	+	1		1		1	+	1		+		1		+
Lagria sp 2	CTE		+		+				+												+				
Elateridae sp 2	CEL		+	+			+									+	+	+	+		1	+			
Colaspoma cf. *acaciae*	CCH		+				+			+	+												A		
Toxaria indica	CCH		+		1		+		+		+						+				+	+	A		
Protostrophus sp 2	CCU		+		+												+	+	+				+	+	
Curculionidae sp 14	CCU		+			+																		+	
Alleculinae sp 4	CTE		+	+		1			+		+	B	A	1	1	A			A	+		A	A	1	

Table 1 -cont-

Alleculinae sp 1	CTE		1	B	+	+			B	1	1	A	B		1	A		1	B	1	A	1	A	+	
Malachiinae sp 8	CCH		+					+	+	+			+												+
Colaspoma cf. *amplicolle*	CCH		+		+	+	1	+	+	1	+			+			+	B	1	1	1	1	A	B	B
Heterochelus vulpinus	CSC			1								+	+			1				+					
Eumolpinae sp 5	CCH			+	+		+	+			+	+	+	1				+	+		+				
Gastrida sp	CCH			+	+						+	1				+		+	+			+			
Dorcatispa sp 1	CCH			+		1		1								+			+	+		+			
Melolonthinae sp 1	CSC			1																+			1		
Eremnus sp 2	CCU			+	+		+		+	+					+	+								+	
Gnathocera hirta	CSC			+	+		+		+							+	+	+	1		+			+	
Hoplinae sp 3	CSC			+		+		+				1		+	1	A				+				+	
Lagria sensu latu sp	CTE			+	+	+	+	1	1	+	+	+	+		1	+	+		A		+	1	+	A	
Macrocoma aureovillosa	CCH			1	A	1			B	1	+	+			1	1			B	1	1	1	1	+	B
Cryptocephalus clypeatus	CCH			+					+	+	+	+						+					+		+
Clavicornia sp 2	CUN			+	+		+			+			1			1		+	A	A		+	1	+	+
Decapotoma sp 1	CML			+																					+
Clavicornia sp 1	CUN			+	+		+		1				1			+			A	A			+		1
Lagria prob. *villosa*	CTE			+	1		+	1	+	+		+			+	+	+		1		A	+	+	1	1
Scarabaeidae sp 2	CSC			+					+	+			+		1			+		+	1	+	+	A	1
Curculionidae sp 38	CCU				+								+			+				+					
Menemachus sp 1	CCU				+				+		+		+							+	+		+		
Monolepta sp	CCH				+	+	+	+	+		+								+				+		
Coccinellidae sp 6	CCO				+											+					+			+	
Eumolpinae sp 6	CCH				+										+			+						+	
Curculionidae sp 3	CCU				+				+	+						+					1			1	
Lalagetes sp 2	CCU				+			+				+	+	B		+						1		+	
Chrysomelidae sp 8	CCH				+				+	+		A		+							+	+	A	1	
Oosomini sp 3	CCU				+					+		+			+						1				+
Ntidulidae sp 1	CNT				+		+		+		+		+	+		+	+	+	+		+			1	+
Malachiinae sp 1	CCH				+	+	+															+		+	+
Pseudivongius near *apicicornis*	CCH				+	+	1		+	+			+	+		+	+	1	+	+	1	+		+	+
Cyrtothyrea marginalis	CSC					+		+	+						+						+				
Eremnus sp 4	CCU					+									+					+	+				
Anubis scalaris	CCE					+														+			+		
Hylastes sp 1	CCU						+																+		
Latridiidae sp 1	CLA						+					+											+		
Rhythirrinini sp 1	CCU						+	+	+							+	+	+					+		
Monochelus sp	CSC						+																	+	
Platycopes tuberculates	CCU						1	1	+																+
Lagria sp 1	CTE						+	+	+	+										+		+	1		+
Hipporrhinus sp	CCU						+								+	+						+			+
Protostrophus sp 1	CCU						1			+		1			+								+		+
Platyxantha distanti	CCH							+					+	+									+		
Galerucinae sp 5	CCH							+	+	+		B	+						+				1	+	A
Blepharida cf. *ornata*	CCH								+													+			
Lagria aeneipennis	CTE								+											+					+
Smaragdina sp	CCH								+		+														+
Eudraces sp 2	CCU								+	+	+	+	+	+		+			+			+		+	+
Alleculinae sp 6	CTE									+									+		+				
Nitidulidae sp 5	CNT									+		+						1		+	1				
Oosomini sp 2	CCU									+	+								+	+		+			

Table 1 -cont-

Cheilomenes sp 1	CCO									+				+	+								+		
Eremnus sp 1	CCU									+			+											+	
Lema sp 2	CCH									1									+						+
Curculionidae sp 39	CCU										+	1			+			+			1			+	
Eremnus near *humeralis*	CCU											+	+	+									+		
Malachiinae sp 2	CCH											1				+			+	+		1	+		1
Cleridae sp 3	CCL											+		+		+			1			+			+
Estcourtiana cf. *litura*	CCH													+							+	+	+	+	
Hoplinae sp 4	CSC															+					+				
Chosnia arcuata	CCH															+		+				+			
Elateridae sp 5	CEL																	+			+				
Elateridae sp 3	CEL																		+		+			+	
Nomadacris septemfasciata	OAC	+																		+	+				
Acrida propinqua	OAC	+	+		+	+										+	+					+			
Comacris semicarinatus	OAC		+			+									+					+					+
Orthochtha dasycnemis	OAC		+	+	+	+	+		+			+			1					1	+	+	+		+
Tetrigidae sp 3	OTE			+	+						+	+			+	+	+			+	+	+			
Gryllidae sp 1	OG R			1	+	1	+	+	+	+							+		+	1		1			
Cannulta sp	OAC			+																+	+		+		
Duronia chloronata	OAC			+				+	+						+						+	+	+		
Gryllidae sp 2	OGR			1	+	1				+					+	+			+	1		A	+		
Ruspolia sp	OTT			+								+	+	+			+		+					1	
Phloenotus sp 1	OTE			+	+	+		+	+	+	+				1				+		1	+		1	+
Phloenotus sp 2	OTE			+		+	+		+		+										+	+		+	1
Acridinae sp	OAC				+			+	+									+	+	+		+	+		
Tettigoniidae sp 2	OTT				+							+	+		+	+	+	+	+		+	+	+		
Tettigoniidae sp 3	OTT						+		+						+					+					
Aneuryphymus sp	OAC														1									+	
Belenois creona	LPI	+				+	+		+	+		+	+	+	+	+		+		+	+				
Belenois aurota	LPI	+	+			+		+			+	+	+	+	+	+		+	+		+	+	+	+	
Gegenes niso	LHE	+	+	+	+	+		+				+		+	+					+	+	+		+	
Danaus chrysippus	LNY	+	+	+	+	+			+		+			+	+	+		+	+				+	+	+
Leptotes jeanelli	LLY	+	+		+												+			+	+	+	+		+
Actizera lucida	LLY	+	+			+		+		+					+		+		+	+					+
Precis octavia	LNY		+		+								+								+			+	
Cupidochrysops cissus	LLY			+																	+		+		
Catacroptera cloanthe	LNY			+																			+	+	
Eurema brigitta	LPI			+	+		+		+	+	+		+	+		+	+	+	+		+	+	+	+	+
Acraea nohara	LNY			+				+			+	+						+			+			+	+
Vanessa cardui	LNY					+						+			+	+		+	+	+	+				
Catopsilla florella	LPI								+					+	+			+	+	+			+		
Precis hierta	LNY								+					+						+	+				
Henotesia perspicua	LNY									+												+			
Myrmeleon doralice	NMY				+	+			+	+	+	+			+	+		+	+			+		+	
Palpares caffer	NMY								+						+			+			+	+	+	+	+
Vidua macroura	BVI	+			+	+											+						+		
Ortygospiza atricollis	BES	+	+		+	+						+		+			+	+	+				+		+
Mirafra apiata	BAL	+	+			+				+			+		+			+	+						+
Euplectes ardens	BPL		+		+		+							+			+						+	+	+
Macronyx capensis	BMO		+		+	+						+	+	+			+	+	+		+		+		+
Coturnix coturnix	BPH				+		+										+				+				

Table 1 -cont-

Euplectes progne	BPL						+							+			+						+		+
Oenanthe bifasciata	BTU																+	+	+			+			
Species Group K																									
Elateridae sp 9	CEL	1		+	+				+			+	+	1	1	+	+		+	+	1	+	1		+
Alticinae sp 5	CCH	3		+		+	+		+				+	A		+	1	3			+		1	1	1
Meligethes sp	CNT	1	1		+	1		+	+	+		+	A	+		+		1	+	+	1	+	+	1	+
Chaetocnema sp 1	CCH	B	A	1	A	B	+	B	1	1	+	1	+	4		+	3	+	+	1	1	+	1	A	+
Eremnus sp 3	CCU	+	1	1	1	1	+	+	1	A	+	+	+	+	1	+	1	+	+		1		+		+
Oosomini sp 1	CCU	1	B	+	A	+		1	1	1	+	+	+	+	1	+	A	B	1		1	+	+	+	+
Eudraces sp 1	CCU	A	3	1	3	3	3	B	3	4	5	1	B	A	A	4	+		B	B	1	3		B	3
Eyprepocnemis calceata	OAC	+	+		+	+		+			+	+			+		+		+	+			+		+
Xiphidium conocephalus	OTT	A	1	3	1	A	B	1	1	1	1	+	1	+	3	A	1	B	1	3	1	B	A	B	A
Saxicola torquata	BTU	+	+	+	+	+	+		+	+	+	+	+	+		+	+	+	+		+	+	+	+	+
Cisticola lais	BSY	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
Species Group L																									
Hoplinae sp 2	CSC		+																						
prob. *Cybocephalus* sp	CCH		+																						
Rutelinae sp 1	CSC			+																					
Aphodius sp 2	CSC			+																					
Staphylinidae sp 1	CST				+																				
Curculionidae sp 45	CCU				+																				
Curculionidae sp 27	CCU				+																				
Buprestidae sp 4	CBU				+																				
Elateridae sp 8	CEL				+																				
Staphylinidae sp 3	CST					A																			
Tenebrionidae sp 1	CTE					+																			
Carabidae sp 5	CCR					+																			
Carabidae sp 1	CCR					+																			
Palpoxena sp	CCU						+																		
Colaspoma fulgidum	CCH						+																		
Hippodamia variegata	CCH						+																		
Lampyridae sp 1	CLM							+																	
Buprestidae sp 2	CBU							+																	
Curculionidae sp 29	CCU								+																
Buprestidae sp 3	CBU								+																
Cryptocephalus bistripustulatus	CCH									+															
Elateridae sp 10	CEL										+														
Curculionidae sp 23	CCU										+														
Chrysomelidae sp 22	CCH												+												
Malachiinae sp 7	CCH												+												
Curculionidae sp 49	CCU													+											
Melyridae sp 1	CME													+											
Curculionidae sp 31	CCU													+											
Dactylatispa sp 1	CCH													+											
Cardiophorus near *histrio*	CEL														1										
cf. *Palaeophylia* sp	CCH															+									
Chrysomelidae sp 24	CCH															+									
Ceroctis groendali	CML																		+						
Monolepta cruciata	CCH																		+						
Curculionidae sp 24	CCU																			+					
Afromaculepta sp	CBU																					+			

Table 1 -cont-

Porphyronota hebreae	CSC																+			
Coccinellidae sp 5	CCO																+			
Decapotoma sp 2	CML																+			
Curculionidae sp 37	CCU																+			
Curculionidae sp 46	CCU																+			
Elateridae sp 7	CEL																+			
Onthophagus deterrens	CSC																	+		
Chrysomelidae sp 7	CCH																	+		
Hispinae sp 5	CCH																	+		
Lycus ampliatus	CLY																	+		
Diclatispa near *caffra*	CCH																	+		
Cleridae sp 2	CCL																	+		
Coccinellidae sp 10	CCO																	+		
Curculionidae sp 12	CCU																	+		
Coccinellidae sp 4	CCO																		+	
Buprestidae sp 1	CBU																		+	
Curculonidae sp 42	CCU																		+	
Mimobolbus maculicollis	CGE																		+	
Cleridae sp 4	CCL																			1
Anthicidae sp 1	CAN																			+
Curculionidae sp 47	CCU																			+
Curculionidae sp 33	CCU																			+
Gymnobothrus carinatus	OAC		+																	
Lentulidae sp 2	OLE			+																
Oxya hyla	OAC				+															
Heteracris acuticercus	OAC						+													
Gastrimargus crassipes	OAC							+												
Mesops abbreviatus	OAC								+											
Taphronota cincta	OAC									+										
Graphium angolanus	LPA		+																	
Aeropetes tulbagia	LNY			+																
Metisella malchacha	LHE			+																
Hyalites anacreon	LNY				+															
Aegoceropsis fervida	LAG					+														
Phalanta phalantha	LNY						+													
Hypolycaena philippus	LLY						+													
Acraea natalica	LNY						+													
Azanus mirza	LLY						+													
Orachrysops violescens	LLY						+													
Hyalites esebria	LNY									+										
Colotis evenina	LPI										+									
Aloeides nubilus	LLY											+								
Coeliades pisistratus	LHE												+							
Colotis subfasciatus	LPI												+							
Spialia spio	LHE													+						
Poecilmitis aethon	LLY														+					
Hypolimnas misippus	LNY															+				
Syntomis kuhlweinii	LCT																+			
Stygionympha wichcrafi	LNY																	+		
Freyeria trochylus	LLY																	+		
Aloeides dryas	LLY																			+

Table 1 -cont-

Hemimacronyx chloris	BMO				+					
Vanellus senegallus	BCH						+			
Vanellus melanopterus	BCH						+			

The following codes were used to abbreviate the families of the species in the table above:

CODE	FAMILY	CODE	FAMILY	CODE	FAMILY	CODE	FAMILY
LEPIDOPTERA		**ORTHOPTERA**		**BIRDS**			
LAG	Agaristidae	OAC	Acrididae	BAL	Alaudidae	BPH	Phasianidae
LCT	Ctenuchidae	OGR	Gryllidae	BCH	Charadriidae	BPL	Ploceidae
LHE	Hesperiidae	OLE	Lentulidae	BES	Estrildidae	BSY	Sylviidae
LLY	Lycaenidae	OTE	Tetrigidae	BHI	Hirundinidae	BTU	Turdidae
LNY	Nymphalidae	OTT	Tettigoniidae	BMO	Motacillidae	BVI	Viduidae
LPA	Papilionidae	**NEUROPTERA**					
LPI	Pieridae	NMY	Myrmeleontidae				
COLEOPTERA							
CAN	Anthicidae	CCL	Cleridae	CLA	Latridiidae	CNT	Ntidulidae
CAP	Apionidae	CCO	Coccinellidae	CLM	Lampyridae	CRH	Rhiphiphoridae
CBU	Buprestidae	CCR	Carabidae	CLY	Lycidae	CSC	Scarabaeidae
CCA	Cantharidae	CCU	Curculionidae	CME	Melyridae	CST	Staphylinidae
CCE	Cerambycidae	CEL	Elateridae	CML	Meloidae	CTE	Tenebrionidae
CCH	Chrysomelidae	CGE	Geotrupidae	CMO	Mordellidae	CUN	Undetermined

Table 2. Analyses of similarity (ANOSIM) comparing the insect assemblages of three habitats, as well as grassland fragment sites with control sites. (WN=wetter north, T=transitional community; DS=dryer south).

Anosim	Comparison	Similarity Measure	Transformation	Global R	Sign. level
One-way Analysis	Community Groups (WN, T, DS)	Bray Curtis	Square Root	0.199	0.008**
One-Way Analysis	Community Groups (WN & T)	Bray Curtis	Square Root	0.174	0.032*
Two-way nested Analysis	Experimental vs Control plots	Bray Curtis	Square Root	-0.37	0.958

Table 3. Habitat specificity of the different plant and animal taxa, in relation to the plant communities (cf. Table 1). Categories of habitat specificity (first four columns) are given as percentages of the total number of species.

Group	Habitat Specific (%)	Habitat Constrained (%)	Every-where (%)	Single Occurrence (%)	Total number of species	Index of Habitat Specificity
Plants	35	41	0	24	227	0.46
Coleoptera	19	45	4	32	180	0.27
Orthoptera	19	52	6	23	31	0.24
Lepidoptera	27	30	0	43	56	0.47
Birds	28	44	11	17	18	0.33
Mean	26	43	4	28	102	0.35

Table 4. Habitat specificity of Coleoptera in the different trophic levels, in relation to the plant communities (cf. Table 1). Categories of habitat specificity (first four columns) are given as percentages of the total number of species.

TROPHIC LEVEL	Habitat Specific (%)	Habitat Constrained (%)	Every-Where (%)	Single Occurrence (%)	Total Number of Species	Index of Habitat Specificity
Phytophagous	18	47	5	30	149	0.26
Carnivorous	19	25	0	56	16	0.43
Detritivorous	0	33	0	67	3	0
Coprophagous	67	33	0	0	3	0.67

Table 5. Habitat specificity of Coleoptera, Orthoptera, Lepidoptera, Neuroptera and birds within families in relation to the plant communities (cf. Table 1). Categories of habitat specificity (first four columns) are given as percentages of the total number of species.

FAMILY	Habitat Specific (%)	Habitat Constrained (%)	Every-Where (%)	Single Occurrence (%)	Total number of species	Habitat specificity
			COLEOPTERA			
Curculionidae	21	44	6	29	48	0.30
Chrysomelidae	20	43	5	32	40	0.29
Scarabaeidae	31	38	0	31	16	0.45
Tenebrionidae	11	78	0	11	9	0.12
Elateridae	10	30	20	40	10	0.17
Melyridae	50	50	0	0	4	0.50
Lycidae	67	0	0	33	3	1.00
Rhiphiphoridae	100	0	0	0	1	1.00
Carabidae	0	33	0	67	3	0
Anthicidae	50	0	0	50	2	1.00
Cleridae	50	0	0	50	4	1.00
Coccinellidae	22	45	0	33	9	0.33
Cerambycidae	0	100	0	0	1	0
Ntidulidae	0	50	25	25	4	0
Meloidae	0	33	0	67	3	0
Staphylinidae	0	0	0	100	2	0
Buprestidae	0	0	0	100	4	0
Bolboceratidae	0	0	0	100	1	0
Brentidae	100	0	0	0	1	1.00
Lampyridae	0	0	0	100	1	0
Lathridiidae	0	100	0	0	1	0
Cantharidae	100	0	0	0	1	1.00

ORTHOPTERA						
Acrididae	30	35	5	30	20	0.43
Tettigoniidae	0	75	25	0	4	0
Tetrigidae	0	100	0	0	3	0
Lentulidae	67	0	0	33	3	1.00
Gryllidae	0	100	0	0	2	0
LEPIDOPTERA AND NEUROPTERA						
Nymphalidae	30	35	0	35	20	0.46
Lycaenidae	27	20	0	53	15	0.57
Pieridae	25	50	0	25	8	0.33
Hesperiidae	33	17	0	50	6	0.66
Agaristidae	50	0	0	50	2	1.00
Ctenuchidae	0	0	0	100	2	0
Myrmeleontidae	0	100	0	0	2	0
Papilionidae	0	0	0	100	1	0
BIRDS						
Sylviidae	50	50	0	0	2	0.50
Turdidae	33	67	0	0	3	0.33
Hirundinidae	100	0	0	0	1	1.00
Ploceidae	33	67	0	0	3	0.33
Motacillidae	33	33	0	33	3	0.50
Phasianidae	0	100	0	0	1	0
Viduidae	0	100	0	0	1	0
Estrilidae	0	100	0	0	1	0
Alaudidae	0	100	0	0	1	0
Charadriidae	0	0	0	100	2	0

Table 6. Number of habitat-specific animal taxa found in the different vegetation communities.

Vegetation community	Plants	Coleoptera	Lepidoptera + Neuroptera	Orthoptera	Birds	No of habitat specific species	No of species encountered	Overall habitat specificity
Community 1	24	11	8	0	3	46	447	0.10
Community 1.1 (Wetter North)	21	9	6	1	1	38	287	0.13
Community 1.2 (Transitional)	18	5	1	0	1	25	298	0.08
Community 2 (Dryer South)	0	5	0	1	0	6	203	0.03
Community 2.1	13	4	0	2	0	19	269	0.07
Community 2.2	2	1	0	0	0	3	97	0.03

Table 7. Proposed list of ecological indicator taxa for the continued monitoring of the effects of afforestation on the grassland communities of the study area.

Community	1.1	1.2	1	2.1	2.2	2
Coleoptera	Nephus sp Afrophthalma sp	Mecistes cf. seriatus, Atricelaphinis tigrina	Ocladius sp 1, Eremnus lineatus		Eriesthis sp	Ellimenistes sp, Colaspoma cf. pusillum
Orthoptera				Lentulidae sp 3, Heteropternis guttifera		Cantantops fasciatus
Lepidoptera	Azanus moriqua, Anthene definita		Dingana dingana, Pseudonympha swanepoeli, Lepidochrysops irvingi			
Birds	Sphenoeacus afer		Hirundo atrocaerulea, Euplectes capensis			

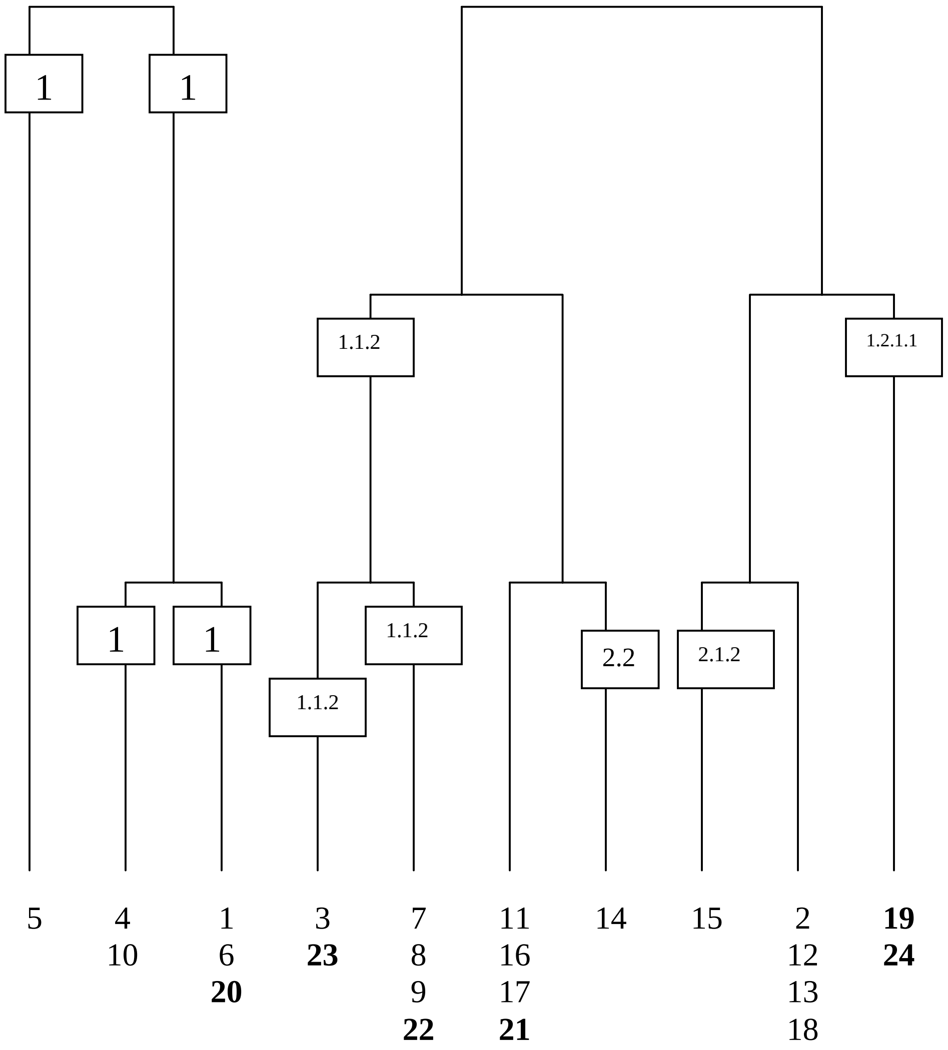


Figure 1. A TWINSPAN-based interpretation of the beetle, grasshopper and cricket assemblages in the twenty-four sample plots. Boxed numbers indicate plant communities (Kamffer, Chapter 2), and numbers at the bottom indicate sampling plot identification numbers. Control plots are numbered 19-24.

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.

BRAY, J.R. & CURTIS, J.T. 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.*. 27: 325-349.

BROWN, V.K. & HYMAN, P.S. 1986. Successional communities of plants and phytophagous Coleoptera. *Journal of Ecology* 74: 963-975.

CRISP, P.N., DICKINSON, K.J.M. & GIBBS, G.W. 1998. Does native invertebrate diversity reflect native plant diversity? A case study from New Zealand and implications for conservation. *Biological Conservation* 83(2): 209-220.

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.

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

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.

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.

MCGEOGH, M.A. 1998. The selection, testing and application of terrestrial insects as bioindicators. *Biological Review* 73: 181-201.

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

PAOLETTI, M.G. 1999. Using bioindicators based on biodiversity to assess landscape sustainability. *Agriculture, Ecosystems and Environment* 74: 1-18.

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.

RICHARDSON, D.M. 1998. Forestry trees as invasive aliens. *Conservation Biology* 12(1): 18-26.

RODRIGUEZ, J.P., PEARSON, D.L. & ROBERTO, B.R. 1998. A test for the adequacy of bioindicator taxa: are tiger beetles (Coleoptera: Cicindelidae) appropriate indicators for monitoring the degradation of tropical forests in Venezuela? *Biological Conservation* 83(1): 69-76.

SAMWAYS, M.J. 1990. Land forms and winter habitat refugia in the conservation of montane grasshoppers in Southern Africa. *Conservation Biology* 4(4): 375-382.

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

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.

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.

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 α = 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.

- <u>Effects of distance to nearest grassland:</u>

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).

- <u>Edge effects:</u>

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.

- <u>Effects of fragment size:</u>

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.

- <u>Effects of fragment size:</u>

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.

- <u>Conservation evaluation:</u>

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.

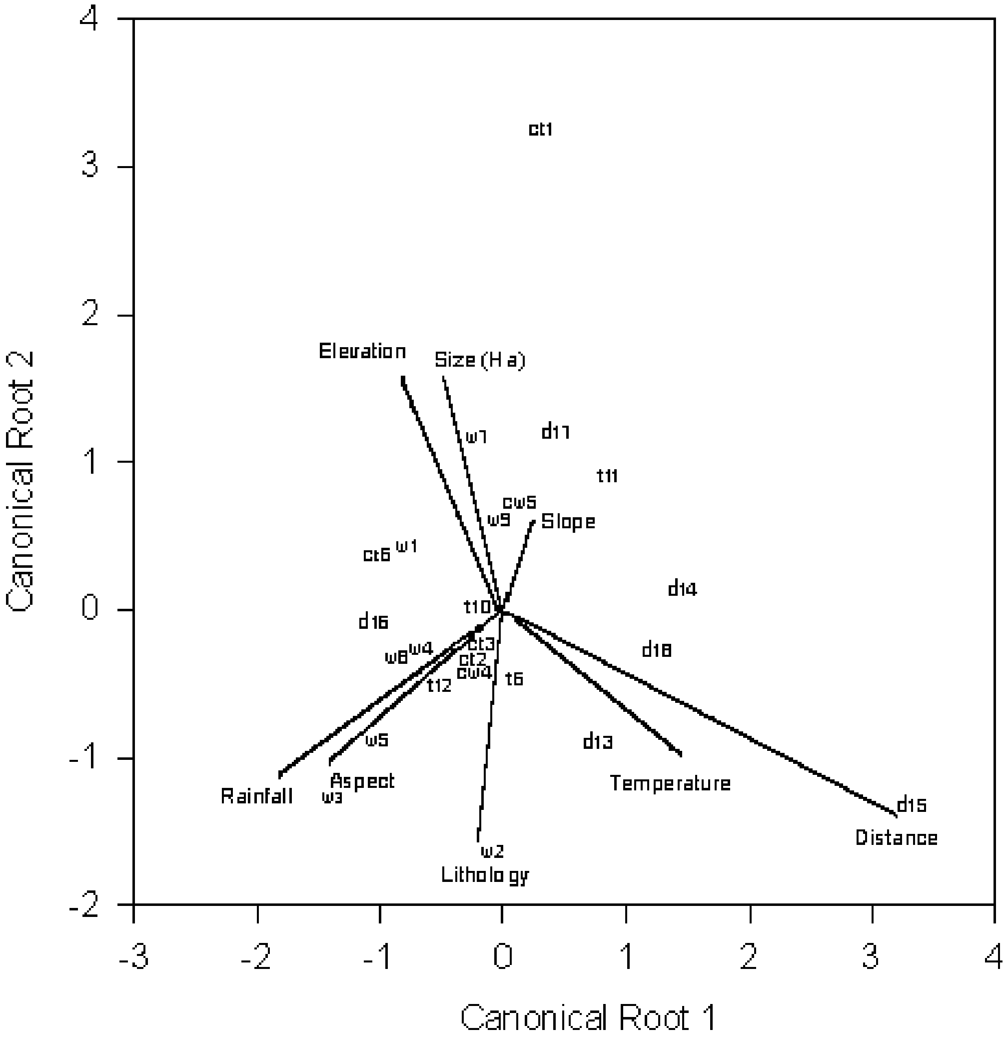


Figure 1. Results of the Redundancy Analysis (RDA) on the faunal community structure of the twenty-four grassland fragments. The plot of canonical root 1 vs. canonical root 2 shows the relative influences of fragment characteristics (distance to nearest grassland neighbour, elevation, fragment size, 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).

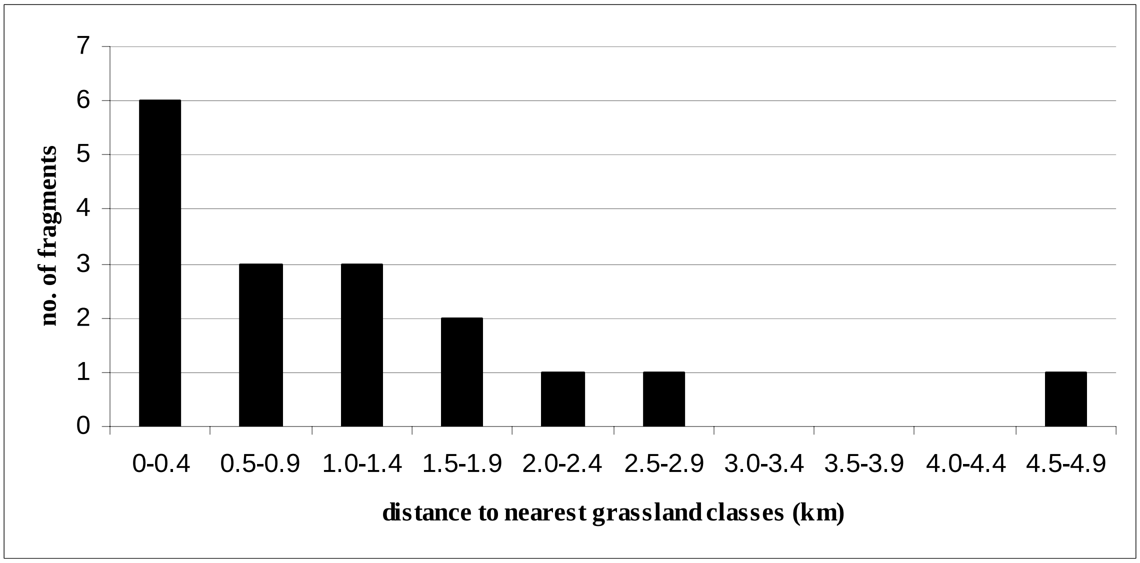


Figure 2. Histogram to show distance to nearest grassland classes. Fragments were divided divide into two groups, those closer than one kilometre (nine fragments) to the nearest grassland, and those further than one kilometre (eight fragments) for data analysis.

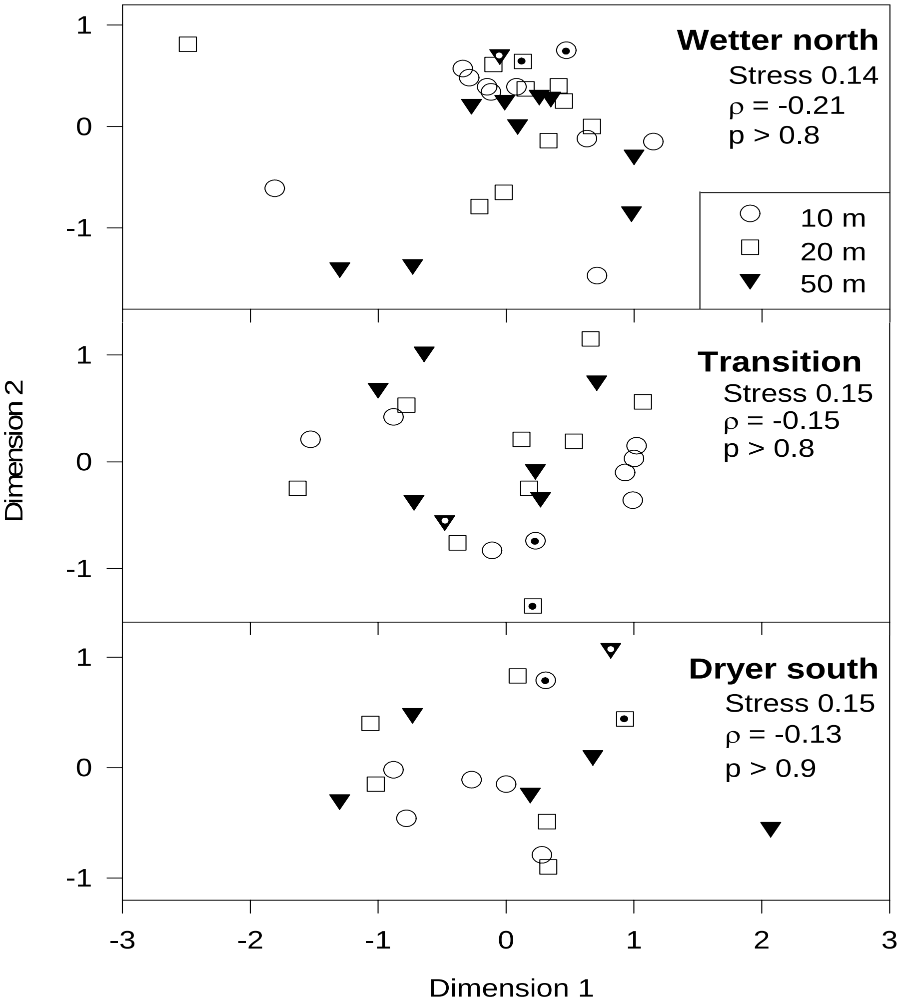
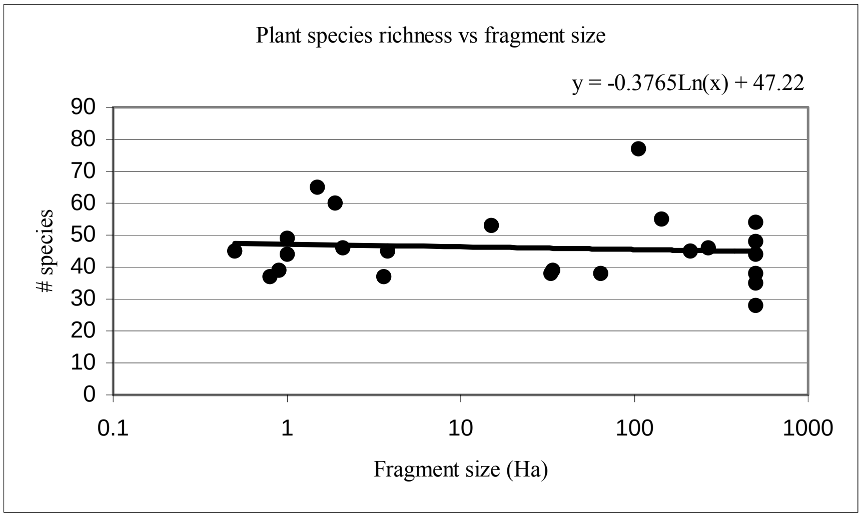
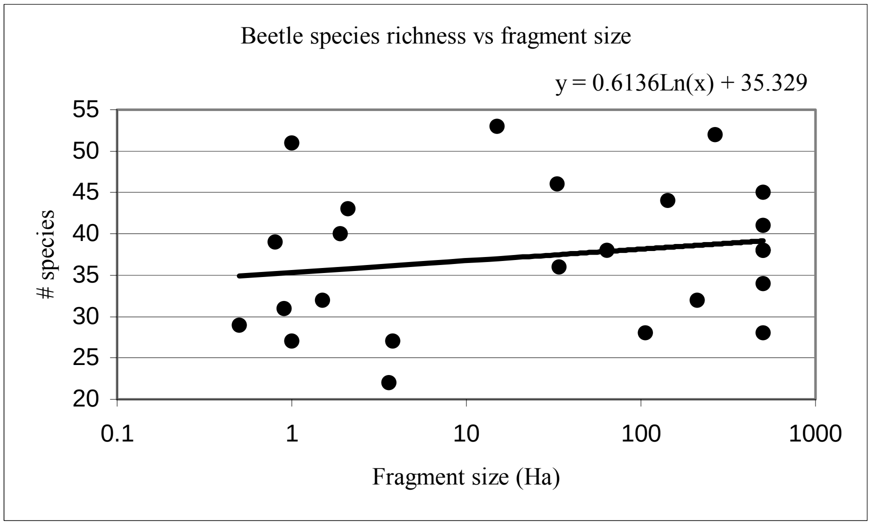
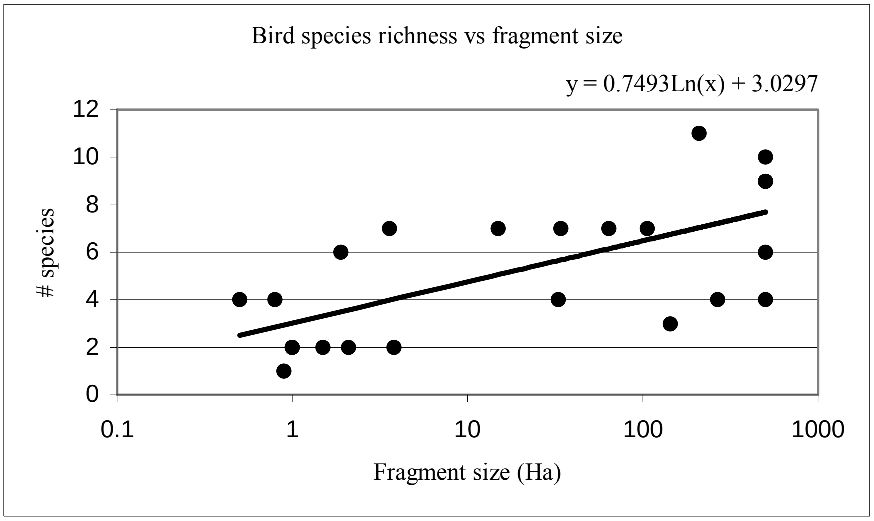
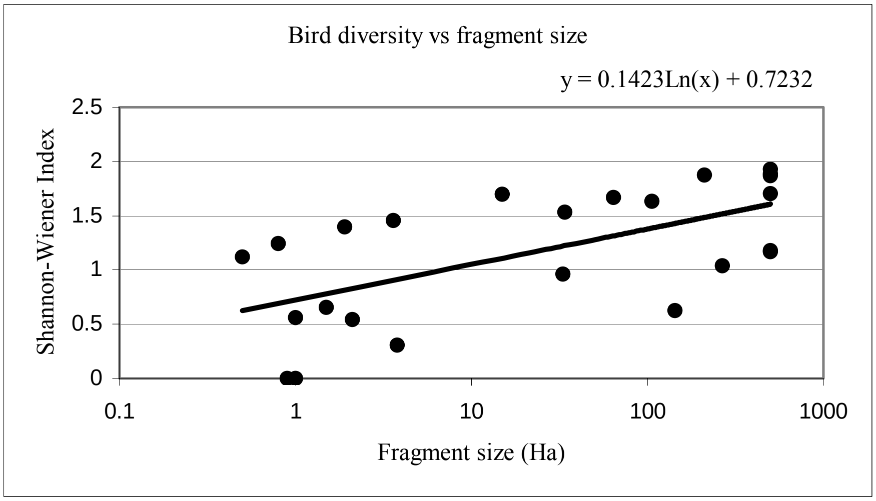


Figure 3. Multi dimensional scaling (MDS) of the fragments with distinct habitat edges in the three major plant communities (Wetter North – 1,4,7-9; Transitional – 6, 10-12 and Drier South – 15, 17,18). The insect assemblages found at 10, 20 and 50 metres from the habitat edge do not differ significantly,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



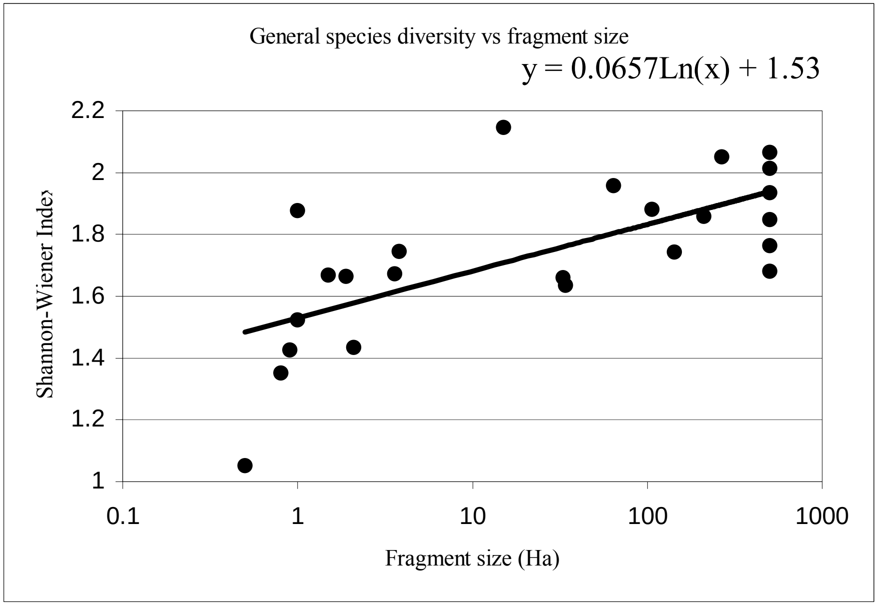


Figure 4. Scatter plots of plant species richness (# of species), beetle species richness, bird species richness, bird diversity and diversity of al the faunal groups in relation to fragment size. The Shannon-Wiener Index for diversity was used, and only bird species richness, bird diversity and general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

SUMMARY

Habitat fragmentation of the afromontane grassland of the escarpment region of Mpumalanga, South Africa

by

DEWALD KAMFFER

Supervisor: Prof. J.W.H. Ferguson
Co-supervisor: Prof. A.S. Van Jaarsveld
(Department of Zoology and Entomology)
University of Pretoria

Submitted in partial fulfillment of the requirements for the degree

MAGISTER SCIENTIAE

The biological diversity of the planet is at great risk as a direct result of an ever-expanding human population and its associated activities. Landscape transformation to accommodate such activities leads to habitat loss and habitat fragmentation, often creating patches of relatively undisturbed habitat within a matrix of transformed areas that are often too small too support most species previously occupying the area and as a result loses its ecological integrity. A century ago the escarpment region of Mpumalanga consisted of large open plains covered with montane grassland dissected by montane forests and riparian vegetation alongside mountain streams. Today the grasslands and forests have almost disappeared from the area, the remaining patches mostly small fragments within a matrix of exotic tree plantations which have also dried up many of the rivers and streams in the area. The natural grassland areas persisting in the region are unique in habitat characteristics and floral species composition. It is also high in plant species richness, diversity and endemicity. The high degree of isolation experienced by

these floral communities poses serious threats to both the floral and faunal species that currently exits within these isolated ‘islands’, many of which are endemic to the area and at great risk of extinction. These risks call for serious collaboration between the land owners (mostly forestry companies) and conservationists to assure the practical and necessary preservation and management of this unique and crucially valuable natural resource.

This study aims to provide the first step into understanding the ecological principles associated with habitat fragmentation related specifically to the mountain grassland fragments within the afforestation matrix of the escarpment region of Mpumalanga, and to create a platform for the process of collaboration between land owners and conservation agencies to assess and manage these grassland patches.

The aims of Chapter 2 included:

1 To determine if any marked human-induced disturbance to the plant communities in the grassland fragments has occurred. I do this in three ways:
    a) To compare the plant community composition of eighteen fragments with those of six control plots outside of the plantations where no marked disturbance to the grassland can be observed.
    b) To determine whether the plant assemblages in the fragments can be assigned to any of the natural and intact plant communities that Matthews (1993) described from a large-scale survey of undisturbed mountain areas.

   c) To determine the presence of any known intruder plant species within the fragments.

2 To assign conservation priorities to the remaining grassland fragments.

The results obtained from the TWINSPAN analysis revealed six alliances of plant communities grouped hierarchically into four orders and two major classes of montane grassland. The DECORANA supported these results, indicating clear differences between communities 1.1 (Eriosema salignum – Loudetia simplex grassland of the wetter North region), 1.2 (Lobelia erinus – Panicum natalense grassland of the Transitional region), 2.1 (Parinari capensis – Eragrostis racemosa grassland) and 2.2 (Helichrysum rugulosum – Eragrostis racemosa grassland). Different plant communities revealed different combinations of geological characteristics, slope, aspect and elevation. The sample plots of isolated grassland fragments and those of large unfragmented areas compare well with each other - the species richness of experimental and control plots do not differ significantly. Also, the species composition of plots from the Wetter North, Transitional and Drier South regions show more variation than is evident between experimental and control plots. There was also good qualitative comparisons (quantitative comparisons were not possible as a results of sampling and analytic discrepancies) between the sample plots used in this study and the plant communities described by Graham Deall and Wayne Matthews. Some evidence of exotic invader plants was found within the sample plots, notably *Pteridium aquilinum*. Fortunately such species were localized in their distribution and restricted to community 1.1.2.2.

The aims of Chapter 3 included the following:

1. To compare the faunal biodiversity in grassland fragments within afforested areas to that of control plots in large, relatively undisturbed grassland areas.
2. To determine to which degree the Coleoptera, Orthoptera, Lepidoptera and bird communities reflect recognized plant communities, and are restricted to specific plant communities.
3. To compare the habitat specificity (degree of stenotopy) of the different taxonomic groups and trophic levels of animals.
4. To make recommendations for the conservation of the Afromontane grassland fauna in the remaining grassland fragments in afforested areas.

The sampling of 15602 beetles, grasshoppers and crickets were collected, with an average of 3900 per sampling period, revealed unique combinations of animal species linked to the different plant communities mentioned above. Significant differences were evident from the one-way analyses of similarity (ANOSIM) used to compare the faunal community structures of sample plots of the Wetter North, Transitional and Dryer South regions. The faunal community structures of the experimental and control plots of the Wetter North and Transitional regions did not differ significantly. The indexes of habitat specificity (fractions of species constricted to certain plant communities) indicated that the plants and butterflies were more habitat-specific than the Coleoptera, Orthoptera and Birds. The carnivorous insects showed a surprisingly high level of habitat specificity compared to the relatively low level of the phytophagous insects. This surprising trend was also evident in various insect families – Acrididae, Scarabaeidae and Nymphalidae had relatively high levels of habitat specificity compared to that of the Curculionidae and the Chrysomelidae.

Chapter 4 has the following aims:

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

No clear relationship between fragment size and area sampled and species richness and/or – diversity was evident from the results. Indeed, the smallest area sampled had the fourth highest species richness and the largest area sampled had the fourth lowest species richness and species diversity. Regressions results 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.

The Detrended correspondence analysis (DCA - using square root transformed abundance data) used, indicated the need to perform a gradient analysis using a redundancy analysis (RDA). The permutation test resulting from this analysis revealed a non-significant value for the first canonical axis, but a significant value for the first four canonical axes together. 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. Slope was the environmental characteristic with the smallest effect. 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. This trend was the most evident for fragments of the Transitional region and the least obvious for the fragments of the study area as a whole. The SIMPER analysis 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).

The insect communities found at 10, 20 and 50 metres from the edge of the grassland fragments did not differ significantly, nor did an ANOSIM performed separately for each of the three major plant communities reveal any significant edge-related differences. 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. Of all the groups, only bird diversity, bird richness and general faunal diversity showed significant relationships with fragment size. There was a non-significant trend for insects to biodiversity to be reduced in very small fragments. Most of the botanical data exhibited no significant relationship with fragment size. The species composition of control sites were not found to be significantly different from that of experimental fragments for all the faunal groups pooled together or for the fragments of the Transitional Region and the Wetter North Region. 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. Fragments of the Wetter North had an average score of 65.3, fragments of The Transitional Region 66.6 and fragments of the Drier South 52.3.

The results relating to this study has lead to the following conclusions:

- It is concluded that afforestation and habitat fragmentation have not significantly impacted on the flora of the montane grassland of the study area since many of the grassland fragments surrounded by plantations are still easily identifiable as natural communities, described by Matthews and Deall in broader-scale surveys in the past. Also, no obvious invader – or disturbed plant communities are discernible even though some of them have been isolated for as long as 40 years.
- The plant communities of conservation importance described by Matthews coincide with the important communities recognized in this study. Rare and endangered plant species, as well as species endemic to the region, are more often than not found on the scarce Black Reef quartzite of the region, which is more evident to the Northern part of the study area. Communities 1.1 and 1.2.2 are therefore of particular conservation importance, not only as a result of their scare geological base, but also because of the high risk associated with the few grassland examples left of these communities.
- The high levels of habitat specificity of many of the taxonomic and trophic faunal groups indicate that many of the invertebrate taxa are probably endemic to the region, and that the plant endemicity encountered in the Afromontane grasslands is reflected by a similar degree of animal endemicity.
- The similarity in faunal assemblages and diversity between isolated fragments and large areas of grassland emphasizes the conservation importance of the fragments, even when smaller than 5 Ha in extent.

- Appropriate management of the grassland fragments within the plantations is therefore important for the conservation of the plant and animal taxa encountered there. Experimental management involving grazing, mechanical cutting, grazing and burning is needed to decide on an efficient management regime, so that the grassland biodiversity can be conserved in a planned way. Such work will also allow empirical testing the efficiency of the indicator species suggested above.
- 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, characterized by high levels of plant endemicity, have a higher conservation importance as judged by faunal biodiversity.

ACKNOWLEDGEMENTS

I am sincerely grateful to SafCol and the University of Pretoria who made this study possible, and for financial support. Special thanks to Prof. J.W.H. Ferguson and Prof. A.S. Van Jaarsveld for limitless patience and much appreciated guidance. The University is also thanked for the use of their facilities, and a special word of thank you to all the people at Botany, for putting up with my constant pestering. Lastly big thanks to my parents, and lastly (definitely not least!) to Krisjan Deschodt for infinite help during the fieldwork, his help making grassland bird identification a lot easier.