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 km^2 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			

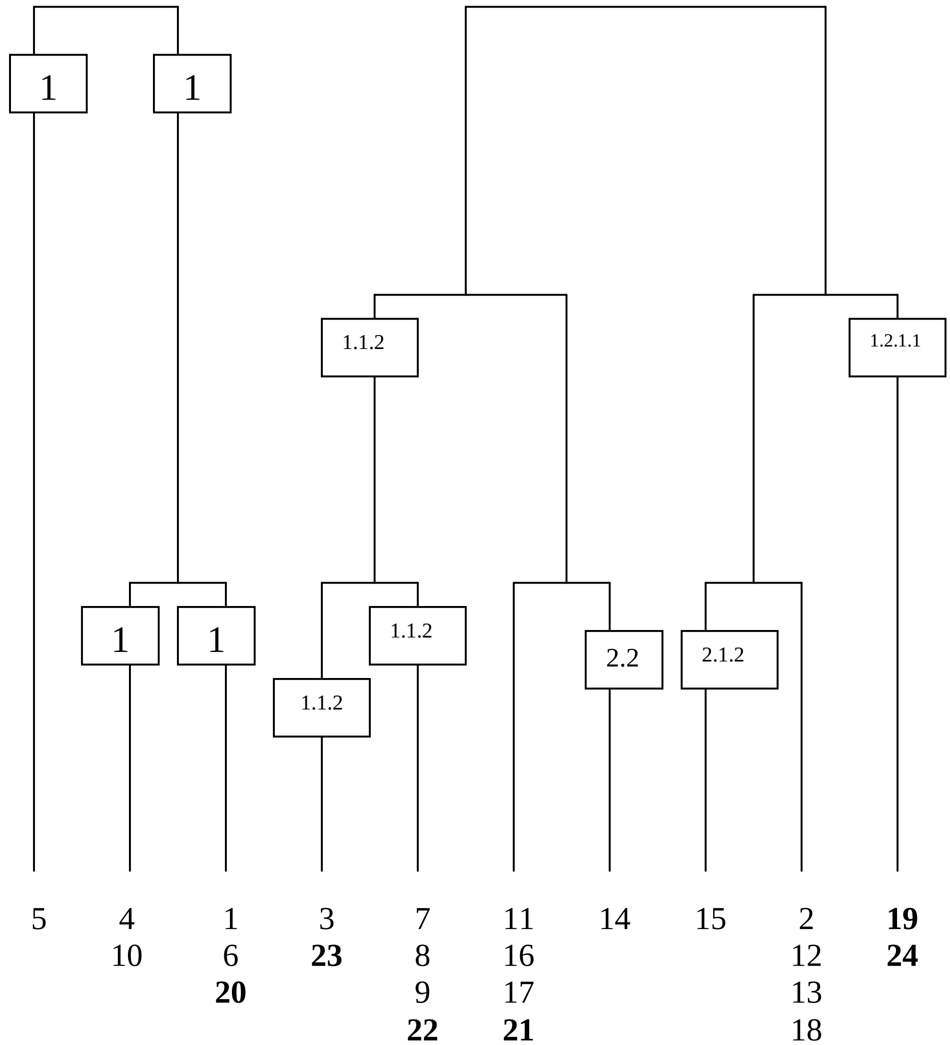

Figure 1. A TWINSPAN-based interpretation of the beetle, grasshopper and cricket assemblages in the twenty-four sample plots. Boxed numbers indicate plant communities (Kamffer, Chapter 2), and numbers at the bottom indicate sampling plot identification numbers. Control plots are numbered 19-24.

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.