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Response of ground-dwelling spider assemblages (Arachnida, Araneae) to Montane Grassland management practices in South Africa

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Abstract. 1. Frequent and extensive burning practices coupled with intensive grazing management are known to impact negatively on the vegetation diversity of grassland ecosystems. Few studies have investigated the impacts on spider diversity and community structure as a result of these management practices, and no studies have been conducted in high mountain grasslands on how these spider assemblages are influenced by this form of management.

2. Here, we present the results of a study conducted in the Mpumalanga grasslands on the eastern escarpment of South Africa. Ground-dwelling spiders were sampled in the summer season from 180 pit-fall traps in five study sites that varied from either being burnt annually and grazed heavily, burnt biennially and conservatively grazed, to communal land with no set management practice. Variations between sites were assessed and based on spider species composition and assemblage structure.

3. A total of 1145 individuals were collected representing 86 species from 60 genera and 43 families. Our results show that a majority of genera in these grasslands were represented by very few individuals, where a total of 37 species were represented by singletons and 17 species that were doubletons. The most abundant families were the Lycosidae (64.3%), Gnaphosidae (9.0%), Zodariidae (5.3%), Linyphiidae (4.7%) and Salticidae (3.1%).

4. Grazing intensity and fire frequency had no measurable effect on ground-dwelling spider abundance diversity or assemblage structure. Only when rare or single species occurrence was included, was there some form of association with sites. This study has provided for the first preliminary inventory of ground-dwelling spiders for this habitat.

Key words. Burning, grassland management, grazing, spider assemblage.

Introduction

The Highveld grasslands of the Mpumalanga Province are endemic to the province and are highly threatened by human transformation primarily from agriculture, mining, afforestation and urbanisation, which have resulted in the extensive fragmentation of these grasslands (Armstrong & Van Hensbergen, 1999; Morris, 2001; Wessels *et al.*,

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2003). The North-eastern Mountain Grassland Biome, which encompasses a total area of 42 458 km^2 (Bredenkamp *et al.*, 1996), for instance, has been transformed mainly for agricultural and forestry purposes (Bredenkamp *et al.*, 1996; Morris, 2001). Mucina *et al.* (2006) mention that only 2.4% of Lydenberg Montane Grassland in Mpumalanga Province (North-eastern Sandy Highveld Grassland: Acocks, 1988 or North-eastern Mountain Grassland: Bredenkamp *et al.*,1996) is formally conserved in protected areas. This 2.4% falls short of the IUCN's nominal recommendation of 10% protected area coverage for a biome (Rouget *et al.*, 2006). In addition, this habitat is considered vulnerable in terms of its conservation status and has been identified as a priority habitat for conservation (SANBI, 2008). Within this habitat, there is also a high level of transformation, which is estimated at 45% by Bredenkamp *et al.* (1996), 55% by Morris (2001) and 23% by Mucina *et al.* (2006), with forestry alone contributing 20% of the transformation (Mucina *et al.*, 2006).Yet, the extent of this degradation may be underestimated, as more subtle impacts that are often not as obvious, such as extensive and intensive grazing, in addition to frequent burning practices, may be overlooked. No studies to date have been undertaken on the changes in spider communities within these grasslands and how varying forms of grassland management may impact upon their assemblage structure.

Although the Araneae constitute an abundant and highly successful group of invertebrates, little is still known of their diversity within most ecosystems in South Africa (Dippenaar-Schoeman & Wassenaar, 2002). As many invertebrate taxa are undescribed, our knowledge of the geographical ranges of these animals is virtually nonexistent (Foord *et al.*, 2002). Indeed, research on spider communities within South African grasslands is lacking where the status of these communities and the presence of individual species are not known and a large number of species are consistently still being described, for example Haddad and Wesolowska (2011) recently described a number of new jumping spiders from the grasslands of central South Africa.

Although spiders can be considered a ubiquitous component of invertebrate assemblages and important generalist predators in ecosystems (Wise, 1993), they are also known to be sensitive to fine-scale changes in environmental factors (Foord *et al.*, 2008). Even though spider populations may be high, even within disturbed habitats, spider communities are strongly influenced by most aspects of land management such as grazing and the frequency of burning within grassland ecosystems. As such, the structure of spider communities or the component of species that make up assemblages of spiders may be a useful tool for monitoring the effects of land use change within particular ecosystems, as spiders respond directly to prey abundance and the structure of vegetation (see Bell *et al.*, 2001 for a review). As such, they may prove to be a valuable group of organisms to indicate ecosystem health; particularly ecosystems such as South Africa's moist highland grasslands that are currently under severe threat.

Studies have indicated that the presence or absence of spider species may be related to the subtle changes in the vegetation structure as a result of grazing. Churchill and Ludwig (2004) mention that livestock grazing changes habitat structure and inhibits ecological succession in the Australian savannah. Dennis (2003) indicated that arthropod diversity can be altered by livestock grazing through changes in plant community composition and soil physical properties in Scotland. The effect of grazing management on spider communities is well documented in European pastures where grazing has been recognised as a form of disturbance, which at low to moderate intensities results in high structural heterogeneity in the habitat (Hodgson, 1986; Dupre & DIekmann, 2001; Ausden *et al.*, 2005). Therefore, a light to moderate grazing intensity should effectively promote spider community conservation. Dennis *et al.* (2001) suggested that there was higher species richness and abundance of spiders in pastures grazed only by sheep than by both sheep and cattle. Yet, Gibson *et al.* (1992b) study mentions that increased grazing in general reduces overall spider species richness. While studying the influence of grazing on the spider fauna in the American grasslands, Deltschev and Kajak (1974) found that intensive grazing had a highly detrimental effect on the spider assemblage of the former vegetation. In Africa, intensive grazing by domestic livestock has also been shown to alter savannah vegetation cover and significantly reduce the diversity of spider fauna (Warui *et al.*, 2005). Furthermore, Abensperg-Traun *et al.* (1996) also recorded spider diversity as being strongly influenced by sheep grazing in Australia, stating that intense grazing had an adverse effect on the primitive arachnid sub-order Mygalomorphae, although moderate grazing favoured wolf spiders (Family: Lycosidae) and those species belonging to the Idiopidae, known as brown trap-door spiders. Churchill (1998) further recorded the Family Zodariidae as being strongly affected by grazing in the Mitchell Grasslands of the Northern Territory of Australia. Yet, no changes in ground-dwelling spider assemblage structure or species composition were reported in different grazing regimes within Hungarian pastures (Batary *et al.*, 2008; Samu *et al.*, 2010; Szinetár & Samu, 2012) or in Dutch grasslands (Kleijn *et al.*, 2006). Some spider species may require specific features of the microclimate or structure, which only exist in grazed grasslands (e.g. Thomas,1983), or even in grasslands with a mosaic structure, to provide conditions for different phases of their life cycles (Cherrill & Brown, 1990a,b; Weidemann *et al.*, 1990). It is clear that grazing with cattle or other large mammalian herbivores reduces relative vegetation cover and may thus influence spider diversity, abundance and community structure. Yet, this has not been investigated in the moist highland grassland of South Africa.

This study is the first attempt to document the spider community composition within South Africa's moist highland grasslands in Mpumalanga Province. Furthermore, this study will investigate whether or not spider assemblage structure differs between fine-scale grassland management practices and if particular assemblages can act as indicators of grassland ecosystem health, as spiders are known to be sensitive to fine-scale changes in environmental conditions (Foord *et al*., 2008). In addition, spiders were selected because they are diverse, relatively easily collected, are functionally significant in ecosystems as predators and as food for higher predators, and interact with their abiotic and biotic environments in a manner that reflects ecological change (Churchill, 1997; Haddad *et al*., 2010). In addition, the results of this study will contribute to the South African National Survey on Arachnida (SANSA) database by inventorying spiders and by measuring species richness and abundance within these grasslands.

Materials and methods

This study was conducted in the moist highland grasslands in the Dullstroom district (25° 42′ 846″S and 30° 09′ 818″E), located between the towns of Belfast and Lydenburg (now called Mashishing) in Mpumalanga Province, Republic of South Africa (Fig. 1). The vegetation of the study area is classified as North-eastern Mountain Grassland by Bredenkamp *et al*. (1996) or Lydenburg Montane Grassland by Mucina *et al*. (2006) or North-eastern Mountain Sourveld by Acocks (1988). The region is characterised by a high rainfall in summer (Bredenkamp *et al*., 1996) and mist through most months of the year, with a mean annual rainfall ranging between 660 and 1180 mm per annum (Mucina *et al*., 2006). Temperature variation in the region is from below 0 °C in winter to 39 °C in summer, with an average of 15 °C per annum (Bredenkamp *et al*., 1996). The soils in this region are derived from shale and quartzite (Mucina *et al*., 2006) and are usually shallow (Bredenkamp *et al*., 1996). The Dullstroom district is situated within an altitudinal range of 1260–2160 m above sea level with undulating plains, mountain peaks and slopes, hills and valleys with the low lying slopes usually supporting grass growth (Mucina *et al*., 2006). The study was completed in areas over 1900 m above sea level.

Study sites

The most dominant land use in the study area is livestock farming, primarily with cattle in the commercial farms and mixed herds of cattle, sheep and goats within the communal farms. In examining the impacts of burning and grazing on these highland grasslands, different grassland management practices were chosen that took into account landscape heterogeneity and farm management practices that included burning frequency, the proportional mix of herds and stocking rates. Five study sites were selected based on the farmer's willingness to allow the study to be undertaken on their property and that it reflected the common farming practices in the study area. Relative grazing intensity was defined as the amount of hectares of grazing land available per large animal unit (ha/LAU). One large animal unit was estimated to be equivalent to one cow or five sheep or goats and represents the metabolic equivalent of a 454 kg cow (Owen-Smith & Danckwerts, 1997). Heavy, moderate and low grazing intensity were assumed to be a stocking rate of 1 LAU on 3 ha or less, 1 LAU on 4–10 ha and 1 LAU on 11–25 ha respectively. The sites consisted of commercial farms that were stocked mainly with cattle at a heavy grazing intensity and burned annually (Site 1: Annual farm/AF), and biennially or every second year (Site 2: Biennial farm/BF), and a communal land (Sakhelwe Township) with no planned burning regime and holding a mixed proportion of cattle, goats and sheep at a high grazing intensity (Site 3: Communal Land/Com). Two

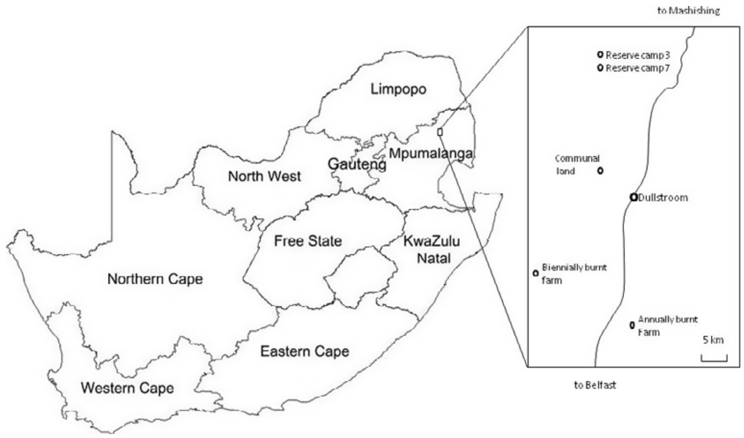

Fig. 1. Map of study area. The inset shows the locations of the study sites and their associated management regimes.

other study sites were selected within an 8000 ha conservation area managed by the provincial government conservation body (Mpumalanga Parks and Tourism Authority); Verloren Valei Nature Reserve. This area is grazed by indigenous herbivores stocked at a very low grazing intensity (Site 4: reserve Camp 3/V3) and another with free roaming mix proportion of indigenous ungulates at a moderate grazing intensity (Site 5: reserve Camp 7/V7). Verloren Valei Nature Reserve is an international RAMSAR site recognising its importance for intact wetland conservation. Four of the five study sites were last burnt during the spring of 2008, except the communal land, which was partially burnt (unplanned burning) in that year. The management practices of all the sites chosen for this study have been the same since 1983, with the exception of the communal lands that had no proper management records, but is assumed to have varied little in the past 30 years. The study sites and their grazing intensity and ungulates species are presented in Appendix A.

Spider sampling

Spiders were sampled over the summer months from the onset of November to the end of February. Within each site, four 25 ha replicates were marked out with at least 500 m between replicates. Sampling sites were selected with sufficient distance between sites to avoid pseudo-replication (Hurlbert, 1984), but were sufficiently close together to standardise as far as possible for extrinsic factors including soil type, rainfall, aspect, slope and temperature. In each of the replicates nine pit traps were laid in a 20 m diameter nested cross array with one central trap and with the two outside traps being only 5 m apart respectively (Fig. 2). Each trap was made up of a 10 cm diameter and 11 cm deep cup. This cup was fitted into a permanent sleeve that was sunk into the soil, with the sleeve lip flush with the soil surface. Trap covers were made up of zinc lids which were just 4 cm above the lip of the trap. These covers help in keeping out rain water and any falling debris (Mallis & Hurd, 2005). Sampling was done in 3-day intervals and in each sampling period 2 cm of a 70% ethylene glycol preservative was poured into each trap and the samples collected after 3 days. The timing of setting traps was weather dependent, based on rain avoidance.

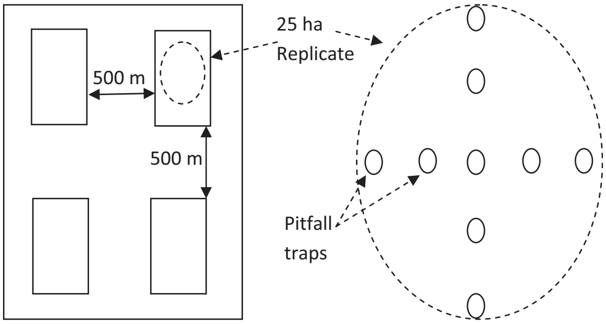

Fig. 2. Study site sample design indicating the four 25 ha replicates within each study site. Within each of these replicates is the nested cross array of nine pitfall traps.

Spiders are broadly grouped into web-builders and active hunters. The active hunters can further be divided into plant wanderers and ground wanderers (Haddad *et al*., 2010). As pitfall sampling was used, only ground wandering spiders were sampled and identified in this study. Due to the large number of immature specimens collected and the unresolved taxonomy of many families (such as the Linyphiidae), some specimens could only be identified to genus level and are referred to as morphospecies where necessary (Haddad *et al*., 2010). All arachnids sampled were sorted and identified into morphospecies using the taxonomic keys in Dippenaar-Schoeman and Jocqué (1997). Data collected form part of the South African National Survey of Arachnida (SANSA) and voucher specimens are housed in the National Collection of Arachnida (NCA) at the Plant Protection Research Institute of the Agricultural Research Council Pretoria.

Vegetation analysis

Vegetation density. Vegetation density measurements were conducted on each site within each replicate at the beginning of each month. A disc pasture meter, described by Bransby and Tainton (1977), was used. The disc pasture meter consists of three main parts: a central aluminium rod, an aluminium sleeve that slides freely in the central rod and an aluminium disc that is attached to the base of the aluminium sleeve. The central rod is marked at 0.5 cm interval starting from 0 to 60. A 500 m transect was set thrice on each replicate. To reduce the influence of edge effect, transects were laid 250 m from the edge of the replicate. The second transect was 150 m away from the first transect and the third was 200 m from the second transect. At 5 m intervals along each of the three 500 m long transects, the central rod of the disc pasture meter was held perpendicular to the ground surface and the sleeve with the attached disc released onto the sward from the upper end, thus the 60 cm mark. The settling height of the disc was then recorded yielding 100 readings per transect and a total of 300 readings per replicate. The numbers of rocky samples recorded at each 5 m along the 500 m transect were noted, but eliminated from the analysis because it was considered not to be an indication of grazing pressure.

Vegetation percentage cover. A Modified Whittaker design was established in all four replicates of each site to measure plant species cover (Stohlgren *et al*., 1995). The Modified Whittaker sampling design involves a 1000 m^2 plot with nested subplots consisting of one 100 m^2, two 10 m^2, and ten 1 m^2 subplots. The 1 m^2 plots were surveyed with 1 m^2 frames that were nested at 0.5 m^2 to increase the accuracy of visual cover measurement. Plant species cover in each subplot was visually estimated using a cover class to represent the different percentage range for cover. The cover class and percentage range of coverage are presented in Table 1.

Data analysis

The number of spiders from each replicate within each site was pooled for that site to compare spider numbers and diversity between sites. ANOVA assumes that the data are sampled from populations with identical standard deviations. We tested this assumption using the method of Bartlett (Snedecor & Cochran, 1989). Bartlett statistic (corrected) = 85.012, the *P* value is <0.0001. As such, Bartlett's test suggests that the differences among the standard deviations between sites are significant. We then Log_{10} transformed the spider abundance data and performed a Kruskal–Wallis one-way analyses of variance (non-parametric ANOVA) to test if there were any change in spider abundance between sites. The Statistica statistical software package was used to perform these analyses (version 6, Statsoft Inc, 2009). Shannon–Wiener Index of diversity was calculated for each site and compared between habitats using ANOVA. Simple linear (Pearson) correlation analysis was undertaken to investigate the relationship between the spider presence and abundance, vegetation density and vegetation cover.

Multivariate data analysis was conducted between all study sites using the statistical program PC-ORD (PC-ORD 5.10; McCune & Mefford, 2006) to note any significant difference between sites in terms of spider assemblage structure. First, a presence/absence matrix of all species across all sites at all habitats was created. A Bray–Curtis similarity matrix (Bray & Curtis, 1957) was generated using the presence/absence transformation. Thereafter, three analyses were performed from the resulting matrix.

First, a cluster analysis of the Bray–Curtis matrix using group average cluster option was performed. The percentage difference between sites calculated by the cluster program allows a two dimensional representation of how closely linked sites are to one another based on the presence of spider species at each study site.

Table 1. Cover classes used when calculating plant vegetation cover.

Cover class	Range of coverage (%)	Midpoint range (%)
1	<5	2.5
2	5–10	7.5
3	10–20	15
4	20–30	25
5	30–40	35
6	40–50	45
7	50–60	55
8	60–70	65
9	70–80	75
10	80–100	90

Secondly, a non-metric multidimensional scaling (MDS) ordination (using Sørensen coefficient also known as the Czekanowski or Bray–Curtis coefficient distance measure) that constructs a map of the samples based on the underlying similarity matrix was undertaken; this was plotted as an MDS plot which provides a representation of the overall similarity among the sites across many dimensions.

An indicator species analysis was calculated that assesses species contributions/responses to management type analysis using a Monte Carlo test of significance with 5000 permutations (Dufrêne & Legendre, 1997). This method combines species abundance and occurrence. A species' uniqueness to a particular habitat and its frequency of being present in a particular habitat is expressed as a percentage in comparison with other species in sampled habitats (Dufrêne & Legendre, 1997). A suitable percentage should be above 70% (Van Rensberg *et al.*, 1999; McGoech *et al.*, 2002; Haddad *et al.*, 2010). All analyses were then repeated, but with singletons removed.

Results

A total of 1145 individuals were collected of which 558 were adults. The spiders caught represent 86 species from 60 genera and 43 families (Appendix B). The most abundant families were the Lycosidae (64.3%), Gnaphosidae (9.0%), Zodariidae (5.3%), Linyphiidae (4.7%) and Salticidae (3.1%) (Table 2; Appendix D). The most abundant species were an undetermined Lycosidae sp. 1 (Lycosidae, 15.9%), Lycosidae sp. 2 (Lycosidae, 15.2%) and a *Proevippa* species (Lycosidae, 12.7%) (Appendix C and D). These species constituted more than 40% of the total abundance.

Most species were represented by only a few individuals (C). A total of 37 species were represented by singletons and 17 species by doubletons. The two reserve sites represented most of the species recorded and the greatest abundance per species in addition to having 14 spider species exclusively found on the reserve (Appendix C). Yet, in the camp where grazing pressure was increased (camp 7) spider number and diversity dropped (Table 3). Surprisingly, the study site burnt annually also held a high number of species. The farms burnt biennially, in addition to the communal lands, held the lowest abundance per species. An abundance curve for all study sites indicates that spider numbers were low following burning events in early summer, but recovered towards the end of summer (Fig. 3).

No significant difference was recorded between sites based on individual species present or total number of individuals within each species located (Kruskal–Wallis one-way ANOVA: H = 5771, d.f. = 4, chi-square probability = 0.146, $P > 0.05$). Diversity estimates indicated no clear differences between sites based on species richness, species evenness and species diversity measures (Table 3).

Table 2. Family composition of ground-dwelling spiders collected from all five study sites.

Family	Total collected	% of total	Total species	% of total
Amaurobiidae	1	0.09	1	1.16
Araneidae*	2	0.17	2	2.32
Clubionidae*	3	0.26	1	1.16
Corinnidae	27	2.34	8	9.3
Cyrtaucheniidae	5	0.44	2	2.32
Gnaphosidae	102	8.98	9	10.4
Hahniidae	1	0.09	1	1.16
Idiopidae	5	0.44	2	2.32
Linyphiidae	53	4.7	11	12.7
Liocranidae	29	2.53	1	1.16
Lycosidae	737	64.3	13	15.12
Nemesiidae	3	0.26	1	1.16
Orsolobiidae	1	0.09	1	1.16
Palpimanidae	19	1.66	1	1.16
Philodromidae	6	0.52	4	4.65
Phyxelididae	2	0.17	1	1.16
Prodidomidae	1	0.09	1	1.16
Salticidae	35	3.05	5	5.81
Scytodidae	2	0.17	1	1.16
Selenopidae	1	0.09	1	1.16
Sparassidae	3	0.26	1	1.16
Tetragnathidae*	2	0.17	2	2.32
Theraphosidae	2	0.17	2	2.32
Theridiidae	19	1.66	5	5.81
Thomisidae	23	2.01	4	4.65
Zodariidae	61	5.33	5	5.81
Total	1145		86	

Species indicated with * are plant dwellers that accidentally landed in pit traps.

Table 3. Species diversity analyses of the spider communities among the five study sites.

Study site	*N*	Sp	S	E	H	D	SD
Annual farm	246	47	47	0.775	2.98	0.91	±7.3
Biennial farm	148	34	34	0.819	2.89	0.91	±4.5
Communal	201	32	32	0.769	2.66	0.88	±7.1
Reserve 3	288	48	48	0.675	2.62	0.83	±12.4
Reserve 7	262	44	44	0.752	2.85	0.89	±8.7

N, total number of individual; Sp, total number of species; S, richness = number of non-zero elements in row; E, evenness = H/ ln (Richness); H, diversity = −sum (Pi*ln(Pi)) = Shannon‘s diversity index; D, Simpson‘s diversity index for infinite population = 1−sum (Pi*Pi), where Pi = importance probability in element i (element I relativised by row total); SD, standard deviation on the mean number of individuals per species.

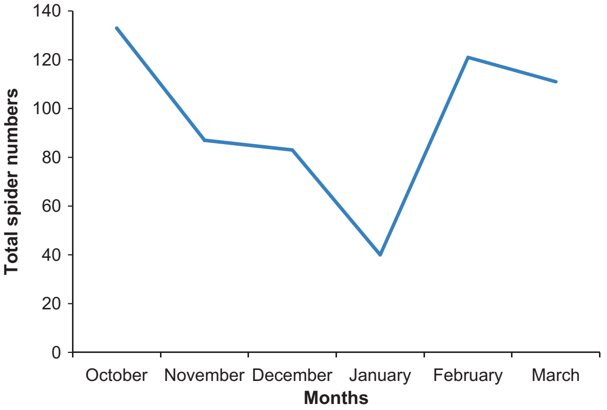

Fig. 3. Spider abundance curve for all study sites during the study period.

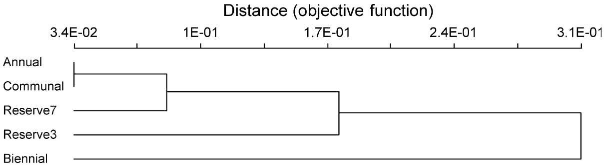

Fig. 4. Bray Curtis cluster analysis indicating similarity between sites based on spider species presence and absence (this includes the presence of the species alone).

Cluster analysis was performed using Sørensen distance measure rather than Euclidean, as Sørensen gives less weight to outliers or singletons of which this study had numerous. The analysis was also performed after removing all singletons, but the results remained the same. Cluster analysis based on spider species presence and absence (Fig. 4), grouped the communal land with the reserve's camp 7 and then to the reserve's camp 3. Both the reserve camp 3 and the communal lands have mixed stocking rates and are not burnt every year. There is a noticeable difference between farms that are burnt annually and heavily grazed than to grasslands that are burnt every 2 years and grazed moderately. Again, the study site burnt biennially grouped separately.

According to the MDS ordination analysis based on spider species diversity on all the sites investigated (Fig. 5), the results were similar to the cluster analyses in that reserve camp 7 was more closely linked with farms burnt annually and with communal lands than to reserve camp 3 and the farm burnt biennially. Farms burnt every 2 years separate apart from any association with other study sites. Those habitats exposed to more intense grazing, such as the communal lands and the farm burnt annually, cluster closer to one another.

A two-way cluster dendrogram analysis (also using Sørensen distance measure) was performed firstly including all species (86 species, Fig. 6) and then again, but removing single species occurrence (44 species included, Fig. 7). When all species including singletons were analysed, certain groups of assemblages were evident (Fig. 6). Nevertheless, on removing these singletons, the evidence of assemblages relating to particular habitats fell away and only the biennial farm and annual farm had a few

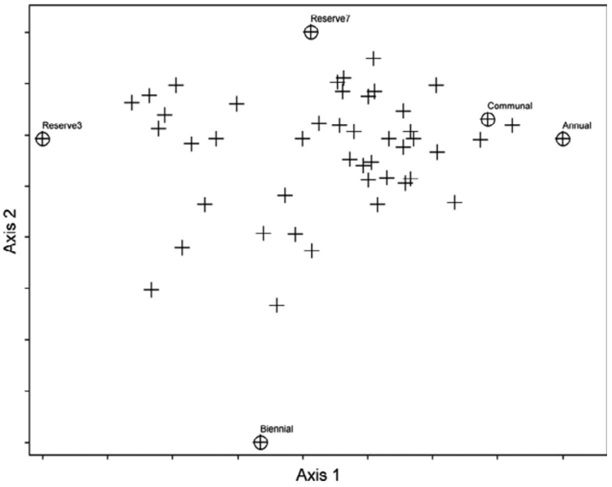

Fig. 5. Ordination analysis (Bray Curtis, distance measure is Sørensen) of spider diversity between sites. Crosses represent species and triangles represent sites. Samples with similar species composition are more closely clustered.

species associated with these habitats. The indicator species analyses revealed a number of species that can be regarded as potential indicators for specific grassland habitats (Table 4), however, after performing a Monte Carlo test of significance of observed maximum indicator value for species, these species were not found to be significant. The large indicator values are probably influenced by the abundance of certain dominant species.

Habitat structure has been described as an important aspect of spider assemblage structure (Gibson *et al.*, 1992a). Because of this, a correlation analysis was undertaken to note any association between spider numbers and the density of vegetation, as determined by the disc pasture meter. A negative correlation was observed between the density of the vegetation and the number of spiders sampled (Table 5); however, in each case this correlation was not significant, but it does imply that spider numbers are increased with reduced vegetation cover.

Discussion

Grazing is considered a disturbance effect at ecosystem scale (Dupre & DIekmann, 2001; Dı́az *et al.*, 2007) and has been recorded to influence species richness, assemblage structure and competition among species (Dupre & DIekmann, 2001; Mucina *et al.*, 2006; Bilyeu *et al.*, 2007). Spiders are no exception, as pasture farming was found to influence negatively spider numbers and community composition within British (Gibson *et al.*, 1992a), Hungarian (Horvа́th *et al.*, 2009), and African savannah ecosystems (Warui *et al.*, 2005). This is in contrast to our results where different levels of grazing and frequency of burning had no measurable effect on ground-dwelling spider abundance or assemblage structure. Only when rare or single species occurrence was included in the analyses, did we find an association of certain species with habitat types (see Fig. 7). The implications on spider assemblage and community structure based on various forms of grassland management through burning frequency and grazing intensity are discussed below.

Spider abundance and species prevalence

Invertebrate communities often reflect the health or state of the ecosystem (Cameron *et al.*, 2003) and predatory invertebrates, such as spiders, can possibly be indica-

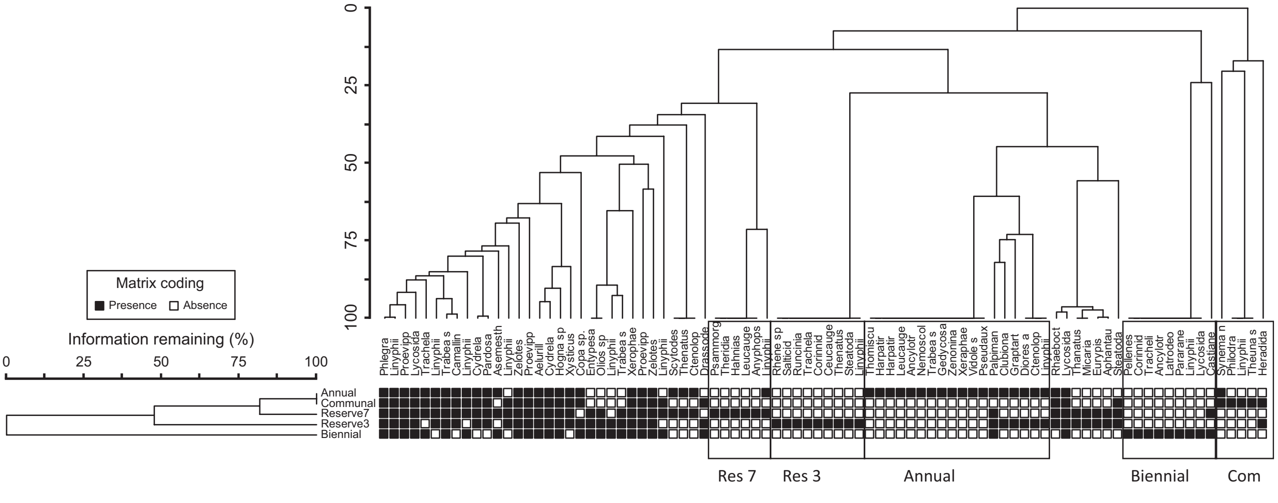

Fig. 6. Two-way cluster dendrogram depicting spider species diversity indicating the contribution each species has or groups of species have to community structure within each study site. This analysis includes single occurrences of a species on a site. Study sites include the reserve camp 7 (Res 7), reserve camp 3 (Res 3), annually burnt site (Annual), biennially burnt site (Biennial) and the communally grazed site (Com).

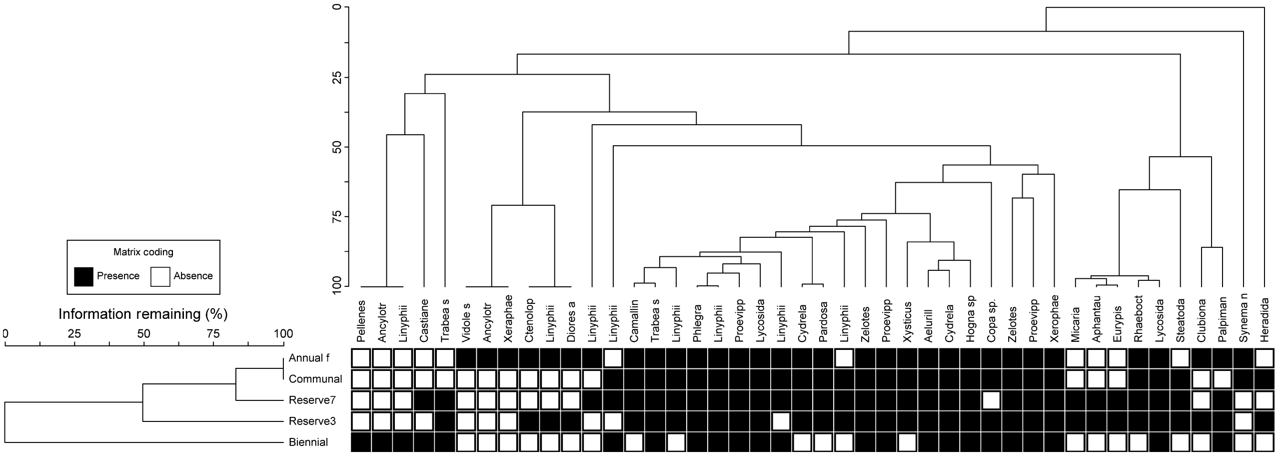

Fig. 7. Two-way cluster dendrogram excluding single occurrences of a species on a site.

tive of the prevalence or abundance of prey items. Certain species of spiders have feeding preferences for particular prey items and often the condition of the habitat may reflect the prevalence or abundance of the availability of prey items (Harwood *et al.*, 2001). As such, variations in the presence or absence of spiders and the structure of their communities can reveal underlying trends within the ecosystem. In this study, spider presence and absence did not differ significantly between the five study sites at both family and species levels. Moreover, specific families could not directly be associated with specific grassland management regimes, but certain trends were apparent at species level.

Species belonging to the family Lycosidae strongly dominated spider abundance in these grasslands (see Table 2). Jocqué and Alderweireldt (2005) hypothesise that the Lycosidae may have co-evolved with grasslands based on their relative rareness in dense forests and their appearance in the fossil record during the Miocene corresponds with the spread of grasslands. This family has also been found in large numbers in other habitat types such as semi-arid regions (e.g. Lotz *et al.*, 1991) and forest areas (Dippenaar-Schoeman & Wassenaar, 2002), but may be rare in habitats such as pine plantations (e.g. Van den Berg & Dippenaar-Schoeman, 1988) and Karoo regions (Haddad & Dippenaar-Schoeman, 2005). All the same, moderate grazing favoured wolf spiders (Lycosidae) that are more sun loving and their presence and numbers may be influenced by the amount of sunshine (Dippenaar-Schoeman & Wassenaar, 2002). In more intensively grazed habitats that are also frequently burnt, conditions for wolf spiders are favoured, and this may therefore be

Table 4. Percentage indicator values (>70%) of spider species for five different grassland managed sites relative to spider presence within each habitat and the number of individuals present in each habitat.

Species	Annual farm	Biennial farm	Communal land	Reserve camp 3	Reserve camp 7	Total individuals	% indicator	*P*
Entypesa sp. 1	0	1	0	1	1	3	75	0.390
Olios sp. 1	0	1	0	1	1	3	75	0.390
Drassodes sp. 1	0	1	1	1	0	3	75	0.417
Camillina procurva	1	0	1	1	2	5	73	0.298
Linyphiidae sp. 2	1	0	1	1	3	6	77	0.298
Linyphiidae sp. 4	1	1	2	0	2	6	77	0.190
Xysticus mulleri	7	0	4	3	4	18	76	0.102
Palpimanus transvaalicus	4	1	0	12	2	19	77	0.477
Pardosa sp. 1	3	0	10	4	8	25	78	0.309
Cydrela sp. 1	19	8	5	4	6	42	82	0.207
Zelotes lightfooti	23	7	24	5	7	66	75	0.286
Trabea sp. 5	0	33	0	31	14	78	87	0.192
Proevippa sp. 2	32	13	33	26	41	145	87	0.192
Lycosidae sp.2	5	10	8	107	44	174	76	0.482
Lycosidae sp.1	50	18	51	9	54	182	79	0.102

P, Monte Carlo test for significance.

Table 5. Correlation analyses of mean values per study site of spider numbers against grass density (% grass), disc pasture meter (DPM) and vegetation cover (% veg).

	Mean	SD	*r*	*P*
% Grass	83.3	5.46	−0.85	0.07
DPM	5.55	1.31	−0.80	0.10
% Veg	86.8	4.45	−0.83	0.08

reflected in their numbers. Although not significant, there was a negative association with grassland vegetation density and cover observed in these grasslands where species of wolf spiders may be reduced where grass cover is increased. In addition, studies in agroecosystems have indicated that lycosids are apparently able to colonise disturbed habitats very quickly (Dippenaar-Schoeman, 1979; Van den Berg *et al*., 1991), and are possibly very successful invaders of burnt areas. Such findings may be useful in understanding how the spider communities in this study were structured, as some of the spiders were only found in particular sites. Indeed, the presence of overgrazed grasslands in the Steenkampsberg grasslands is high and more suited to this family of spiders. Vegetation structure, microclimatic factors and soil type may also have an influence on the local abundance of this particular group (Haddad & Dippenaar-Schoeman, 2005).

The Gnaphosidae were the second dominant group in this study and have been recorded to be the most abundant group among surveys in Southern Africa, especially in arid and semi-arid regions (Lotz *et al*., 1991; Haddad & Dippenaar-Schoeman, 2002, 2005). Indeed, it is one of the largest spider families recorded globally with regard to species and genera described (Platnick, 2012). It is a typical ground-dwelling family that can be expected to be collected in large numbers by pitfall traps left overnight, since the majority of species in this family are active nocturnal search and pursuit ground hunters. The Linyphiidae were the fourth most abundant group found in this study and they are the second most diverse family recorded globally. Eleven of the twelve species recorded in this study were not identified down to genus level as the majority of species of this family, of generally very small spiders, have yet to be described. These small spiders are known to balloon regularly (Greenstone *et al*., 1987) and have therefore very good colonisation properties and may be expected in recently burnt and heavily disturbed habitats. Pearce *et al*. (2005) found both the Linyphiidae and Lycosidae to dominate ballooning activity and ground densities in soya bean fields. Gibson *et al*. (1992a) found the Linyphiidae to be the dominant group in heavily grazed pastures in England, which is characteristic of disturbed areas. Therefore, numbers could be expected to be high in the Steenkampsberg grasslands, as much of this habitat is heavily grazed and frequently burnt.

Morris (1990) suggested that managed grasslands often contain fewer individuals and species of invertebrates and highlighted the importance of architectural effects (vegetation and soil structure) of the habitat in influencing colonisation (Bristowe, 1941; Duffey, 1966). Our study found that habitats with increased vegetation cover and density represented spider communities with fewer individuals; however, this deduction can only be made for ground-dwelling species as we did not sample plant-dwelling or web-building species. It is further likely that those families of ground-dwelling species where high numbers of individuals were recorded have the ability to burrow and escape fire. The study site that was burnt annually has the second highest number of species recorded and it may be possible that fire does not play a large role in reducing ground-dwelling spiders within these grasslands. Indeed, Tainton and Mentis (1984) suggested that soil invertebrates are weakly affected by fire because soil temperatures are usually relatively low and they probably avoid fire by escaping underground or by using refugia within or adjacent to the burn area. Even so, we recorded a large reduction in the prevalence of individuals during peak fire season (December and January) and a higher re-colonisation trend following the fire season over all the habitats investigated (see Fig. 3). As such, fire may also directly influence individual survivorship and indirectly affect individuals through altering resource levels and patch conditions (Hobbs & Huenneke, 1992). This aspect needs to be investigated more extensively within these high altitude grasslands, but it remains that spider numbers did increase rapidly following burning events.

Using Turnbull's (1973) terms 'dominant', 'influents' and 'accessories' in describing the abundance of spiders in this study; the families Lycosidae, Gnaphosidae, Corinnidae and Linyphiidae can be regarded as 'dominant' (these families had the most number of species collected >7); Salticidae, Theridiidae and Zodariidae as 'influents' (families with fewer species collected <7) and the other 19 families as 'accessories' (families with the fewest species collected <5). In this study, the presence or absence of a particular species may not be indicative of specific habitat requirements from a habitat specialist, as no particular species was significantly associated with any form of grassland management. It is indeed also likely that specimens were missed within other sites, thus we cannot conclude that a species that was not captured in our sampling was completely absent from a given site.

Within conserved grasslands, the impacts of grazing on spider assemblages were reflected but not with an extensive drop in spider diversity (see Table 3). In Verloren Valei nature reserve camp 3, managed with infrequent burning and low grazing levels, reflected the most suitable management strategy for spiders, as it held the highest diversity when compared to other study sites. Camp 7 in Verloren Valei is now managed with high number of indigenous ungulates and did differ from reserve camp 3 in reducing both diversity and abundance of ground-dwelling spiders, due to increased grazing pressure. Yet, the reduction was not dramatic, although the species found in this grazed camp were more similar to those found on commercially grazed and more frequently burnt habitats. Therefore, even within grasslands under formal conservation with a lower burning frequency, overstocking can reduce spider species richness and abundance; but probably more importantly, change spider species diversity, although this was not conclusively ascertained in this study. Horváth *et al.* (2009) suggested that a controlled management practice based on moderate grazing may result in a more species-rich spider assemblage as it increases habitat diversity which in turn, increases spider species numbers (Pozzi *et al.*, 1998). These studies, however, focused on web-builders where vertical vegetation structure is of greater importance.

Community structure

Multivariate analyses (ordination and cluster analyses) revealed that those habitats frequently burnt with moderate to high grazing levels reflected similar assemblages of ground-dwelling spider species (communal lands and the study site burnt annually) (see Fig. 5). This assemblage structure was also evident in performing a two-way cluster analyses based on species present between all the habitats sampled, with each habitat reflecting groups of dominant species. Nonetheless, a number of singleton or rare species were observed that tended to skew the data and analyses towards clustering groups or assemblages of spiders towards specific grassland management regimes (see Fig. 6). Upon removing these single occurrences from the analyses, no groups clustered around specific management practices (see Fig. 7). Furthermore, the indicator species analyses revealed the dominant species (most number of individuals) as the best indicators. Nonetheless, they were highly prevalent in most sites sampled and these few species made up the majority of spiders sampled in this study. The indicator species analyses proposed by Dufrêne and Legendre (1997) may then not be suitable when comparing habitats where most species are only represented by very few individuals, but rather make use of a two-way cluster analyses that gives all species equal weight.

This study did find that specific species commonly reoccur in habitats that follow similar management practices, such as those farms that were heavily grazed and more frequently burnt. A number of single species occurrences did occur in protected grasslands, but this remains inconclusive to justify if these species were limited to these protected grasslands, and if a possibility exists whereby we may be losing specific species of ground-dwelling spiders that are more common in protected grasslands. We can also not say with confidence whether the various forms of grassland management practices were responsible for the occurrence of these rare individuals. Yet, it seems that with intensive grazing practices commonplace within the grasslands, this transformation is providing more suitable habitat to species that would not normally occur in these grasslands in such high numbers.

As was found in Hungarian pastures (Batary *et al.*, 2008; Samu *et al.*, 2010; Szinetár & Samu, 2012) and Dutch grasslands (Kleijn *et al.*, 2006), grazing did not seem to have any measurable effect on either the presence of ground-dwelling spider species or their community composition in these moist highland grasslands. This study is a first in recording the ground-dwelling spider diversity in the moist highland grasslands of the Mpumalanga escarpment, a number of species ranges have now been extended where they were previously not recorded and a few species recorded in this study have yet to be described.

Conclusions and recommendations

This study has provided for a preliminary inventory of the ground-dwelling spider species within this montane escarpment grassland habitat (see Appendix B). It has not, however, conclusively illustrated the association or cluster of certain species to particular habitats associated with prevailing grassland management practices. There is preliminary evidence to suggest that some species may have a preference for certain habitats and that some spider families tend to increase in number when grass sward density and cover is reduced. It is likely that that both grazing and fire (burning) change the structural complexity of this shorter grassland type less than would have been in ecosystems such as savannah, where more intense grazing was observed to change noticeably spider species composition (e.g. Warui *et al.*, 2005). This larger change in habitat structure within other ecosystems, through a simplification of vegetation structure and possibly plant diversity and fire, has a direct impact on both the physical and chemical properties of soil litter and so may also reflect a more obvious change in spider diversity within those ecosystems but not so within this highland grassland habitat type.

It is relatively simple to monitor spider assemblages in response to management practices, however, the biological requirements and the taxonomic status for many of the taxa recorded in this study remains unknown. As such, it remains problematic to suggest which groups or assemblages of the arachnids clearly reflect the effects of a management practice that can promote biodiversity conservation or individual spider species. Yet, this study has not conclusively demonstrated that spiders as a group do reflect management practices in moist highland grasslands, as stated by Gibson *et al.* (1992a) within other ecosystems. Batary *et al.* (2008), Samu *et al.* (2010) and Szinetár and Samu (2012) found similar results within Hungarian pastures where levels of grazing did not impact the diversity or species richness of ground-dwelling spiders. Yet, this was not the case with web-builders where vertical vegetation structure was influenced heavily by grazing intensity (Horváth *et al.*, 2009). Ground-dwelling spider community attributes could not clearly be linked to vegetation structure or even species composition in this study, but it is suggested that a management system designed to promote spider diversity should encompass grasslands that are grazed or cut at intervals, not too short to decrease plant species diversity, but long enough to allow architectural diversity to develop that promotes invertebrate conservation (Gibson *et al.*,1992b). This recommendation can be regarded as an applied version of the hypothesis that intermediate levels of disturbance tend to maximise diversity (Connell, 1979; Huston, 1979).

Singleton species occurrence dominated this study and the possibility exists that the survey undertaken in this study was insufficient and the habitat under sampled as suggested by Coddington *et al.* (2009). Indeed, high singleton frequencies characterise the majority of tropical arthropod surveys (Coddington *et al.*, 2009) and undersampling is often clearly reflected when high singleton species are present in biological data sets (McGill, 2003). This has implications towards conservation management plans as one cannot make deductions from an incomplete inventory. It is therefore suggested that further studies should be designed to include seasons (Warui *et al.*, 2004), years or even multiple years that would yield a more complete inventory so that conservation based decisions can be deduced from a more accurate biodiversity assessment. It is further suggested that studies expand to include a wider array of grassland management regimes to ascertain any associations with habitat variables. In addition, studies should incorporate web-builders that inhabit the vertical vegetation component to complement a comprehensive spider survey for the region, which is currently lacking. Moreover, there is a clear need for further taxonomic description for many species and the need for a better autecological knowledge and understanding of their biology and their association with vegetation structure and plant species diversity.

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APPENDICES

Appendix A. Grazing equivalents of all ungulates and grazing intensity represented as hectares per large animal unit for all study sites.

	Communal lands	Biennial farm	Annual farm	Reserve camp 7	Reserve camp 3	
Total ha	208.4	447.6	205.2	1740	4150	LAU equivalents
Cattle	172	228	164	0	0	1
Horses	2.73	0	0	0	0	1.1
Goats	11.3	0	0	0	0	5.03
Sheep	8.5	0	0	0	0	4.9
Blesbuck	0	0	0	26.7	46.7	4.4
Black Wildebeest	0	0	0	40.2	0	2.17
Zebra	0	0	0	375.3	0	1.51
Total LAU	194.5	228	164	442.2	46.7	
ha/LAU	1.07	1.9	1.2	3.9	88.8	

Indigenous ungulates include the following: Blesbuck (*Damaliscus dorcas phillispi*), Black Wildebeest (*Connochaetes gnou*) and Zebra (*Equus burchelli*).

Appendix B. Spider species checklist according to family and life trait category. Those families with an * are not regarded as ground-dwelling species and probably accidentally landed in pit traps.

Family	Genus and species	Guild
Amaurobiidae*	*Pseudauximus* sp. 1	Retreat-web spider
Araneidae*	*Nemoscolus* sp. 1	Orb-web
	Pararaneus cyrtoscapus Pocock, 1898	Orb-web
Clubionidae	Clubiona sp. 1	Sac spider
Corinnidae	*Castianeira* sp. 1	Free-living ground dweller
	Cetonana sp. 1 (new)	Free-living ground dweller
	Corinnidae sp. 1	Free-living ground dweller
	Copa sp. 1	Free-living ground dweller
	Graptartia mutillica Haddad, 2004	Free-living ground dweller
	Trachelas pusillus Lessert, 1923	Free-living ground dweller
	Trachelas sp. 1	Free-living ground dweller
	Trachelinae sp. 1	Free-living ground dweller
Cyrtaucheniidae	*Ancylotrypa* sp. 1	Ground burrow dweller (trapdoor spider)
	Ancylotrypa brevipalpis Hewitt, 1916	Ground burrow dweller (trapdoor spider)
Gnaphosidae	*Aphantaulax signicollis* Tucker, 1923	Free-living ground dweller
	Asemesthes sp. 1 maybe new	Free-living ground dweller
	Camillina procurva Purcell, 1908	Free-living ground dweller
	Drassodes sp. 1	Free-living ground dweller
	Micaria sp. 1	Free-living ground dweller
	Xerophaeus bicavus Tucker, 1923	Free-living ground dweller
	Xerophaeus sp. 2	Free-living ground dweller
	Zelotes lightfooti Purcell, 1907	Free-living ground dweller
	Zelotes uquathus Fitzpatrick,2008	Free-living ground dweller
Hahniidae	*Hahnia tubicola* Simon, 1898	Sheet-web spider
Idiopidae	*Ctenolopus oomi* Hewitt, 1913	Ground burrow dweller (trapdoor spider)
	Ctenolopus sp. 2 (new)	Ground burrow dweller (trapdoor spider)
Linyphiidae	Linyphiidae sp. 1	Sheet-web spider
	Linyphiidae sp. 2	Sheet-web spider
	Linyphiidae sp. 3	Sheet-web spider
	Linyphiidae sp. 4	Sheet-web spider
	Linyphiidae sp. 5	Sheet-web spider

Appendix B. *Continued.*

Family	Genus and species	Guild
	Linyphiidae sp. 6	Sheet-web spider
	Linyphiidae sp. 7	Sheet-web spider
	Linyphiidae sp. 8	Sheet-web spider
	Microlinyphia sterilis Pavesi, 1883	Sheet-web spider
	Linyphiidae sp. 10	Sheet-web spider
	Linyphiidae sp. 11	Sheet-web spider
Liocranidae	*Rhaeboctesis trinotatus* Tucker, 1920	Free-living ground dweller
Lycosidae	*Pardosa crassipalpis* Purcell, 1903	Free-living ground dweller
	Trabea purcelli Roewer, 1951	Free-living ground dweller
	Trabea sp. 4	Free-living ground dweller
	Trabea sp. 5	Free-living ground dweller
	Proevippa fascicularis Purcell, 1903	Free-living ground dweller
	Proevippa albiventris Simon, 1898	Free-living ground dweller
	Proevippa sp. 2	Free-living ground dweller
	Lycosidae sp. 1	Free-living ground dweller
	Lycosidae sp. 2	Free-living ground dweller
	Lycosidae sp. 5	Free-living ground dweller
	Geolycosa sp. 3	Free-living ground dweller
	Hogna sp. 5	Free-living ground dweller
	Zenonina albocaudata Lawrence, 1952	Free-living ground dweller
Nemesiidae	*Entepesa schoutdeni* Benoit, 1965	Ground burrow dweller (trapdoor spider)
	Entepesa sp. 2	Ground burrow dweller (trapdoor spider)
Orsolobiidae	*Afrilobus australis* Griswold and Plantnick, 1987	Free-living ground dweller
Palpimanidae	*Palpimanus transvaalicus* Simon, 1893	Free-living ground dweller
Philodromidae	*Thanatus dorsolineatus* Jézéquel, 1964	Free-living plant dweller
	Thanatus vulgaris Simon, 1870	Free-living plant dweller
	Thanatus sp. 2	Free-living plant dweller
	Philodromus sp.1	Free-living plant dweller
Phyxelididae	*Vidole sothoana* Griswold, 1992	Ground retreat-web ground
Prodidomidae	*Theuma* sp. 1 (new)	Free-living ground dweller
Salticidae	*Aelurillus* sp. 1	Free-living ground dweller
	Pellenes sp. 1	Free-living ground dweller
	Phlegra sp. 1	Free-living ground dweller
	Rhene sp. 1	Free-living ground dweller
	Salticidae sp. 3	Free-living ground dweller
Scytodidae	*Scytodes* sp.	Free-living ground dweller
Selenopidae	*Anyphops* sp. 1	Free-living ground dweller
Sparassidae	*Olios* sp. 1	Free-living plant dweller
Tetragnathidae	*Leucauge festiva* Blackwall, 1866	Orb-web spider
Theraphosidae	*Harpactira* sp.	Ground burrow dweller (baboon spider)
	Harpactirella sp.	Ground burrow dweller (lesser baboon spider)
Theridiidae	*Euryopis* sp. 1	Free-living ground dweller
	Latrodectus geometricus C.L. Koch, 1841	Cob-web dweller
	Steatoda sp. 1	Cob-web dweller
	Steatoda capensis Hann, 1990	Cob-web dweller
	Theridion sp. 1	Cob-web dweller
Thomisidae	*Runcinia grammica* L. Koch, 1937	Free-living plant dweller
	Synema nigrotibiale Lessert, 1919	Free-living plant dweller
	Thomisus australis Comellini, 1957	Free-living plant dweller
	Xysticus mulleri Lawrence, 1952	Free-living ground dweller
Zodariidae	*Cydrela schoemanae* Jocqué, 1991	Free-living ground dweller
	Cydrela sp. 2	Free-living ground dweller
	Diores annettae Jocqué, 1990	Free-living ground dweller
	Heradida sp. 1	Free-living ground dweller
	Psammorygma aculeatum Karsch, 1878	Free-living ground dweller

Appendix C. Individual number of ground-dwelling spider species located within each of the five study sites.

Species	Annual farm	Biennial farm	Communal land	Reserve 3	Reserve 7
Rhene sp. 1	0	0	0	1	0
Salticidae sp. 3	0	0	0	1	0
Thomiscus australis	1	0	0	0	0
Runcinia grammica	0	0	0	1	0
Psammorgna aculeatum	0	0	0	0	1
Trachelas sp. 1	0	0	0	1	0
Corinnidae sp. 2	0	1	0	0	0
Trachelinae sp.	0	1	0	0	0
Corinnidae sp. 1	0	0	0	1	0
Harpactira sp. 1	1	0	0	0	0
Harpactirella sp. 1	1	0	0	0	0
Leucauge festiva	1	0	0	1	1
Philodromus sp.	0	0	1	0	0
Thanatus vulgaris	0	0	0	1	0
Theridion sp. 1	0	0	0	0	1
Latrodecetus geometricus	0	1	0	0	0
Steatoda capensis	0	0	0	1	0
Pararaneus cyrtoscapus	0	1	0	0	0
Linyphiidae sp. 9	0	0	1	0	0
Linyphiidae sp. 11	0	0	0	1	0
Trabea purcelli	1	0	0	0	0
Geolycosa sp. 3	1	0	0	0	0
Lycosidae sp. 5	0	1	0	0	0
Zenonina albocauda	1	0	0	0	0
Hahnia tubicola	0	0	0	0	1
Pseudauximus sp.	1	0	0	0	0
Anyphops sp.	0	0	0	0	1
Theuma sp. 1	0	0	1	0	0
Nemoscolus sp. 1	1	0	0	0	
Pellenes sp. 1	0	2	0	0	0
Graptartia mutillica	1	0	0	1	0
Scytodes sp. 1	1	0	0	0	1
Thanatus dorsolineatus	0	0	0	1	1
Thanatus sp. 2	1	0	0	0	1
Ancylotrypa brevipalpis	0	2	0	0	0
Ctenolophus sp. 2	1	0	0	0	1
Linyphiidae sp. 10	0	1	0	1	0
Linyphiidae sp. 7	0	2	0	0	0
Micaria sp.	0	0	0	1	1
Vidole sothoana	2	0	0	0	0
Synema nigrotibiale	1	0	2	0	0
Heradida sp. 1	0	0	2	1	0
Castianeira	0	2	0	0	1
Entypesa schoutedeni	0	1	0	1	1
Olios sp. 1	0	1	0	1	1
Ancylotrypa sp. 1	3	0	0	0	0
Ctenolophus oomi	2	0	0	1	0
Clubiona sp. 1	1	0	0	2	0
Linyphiidae sp. 1	2	0	0	1	0
Xerophaeus.sp. 2	3	0	0	0	0
Asemesthes sp. 1	1	1	0	0	1
Aphantaulax signicollis	0	0	0	2	1
Drassodes sp. 1	0	1	1	1	0
Trachelas pusillus	1	1	1	0	1
Linyphiidae sp. 6	1	0	0	0	3
Linyphiidae sp. 5	0	1	2	0	1

Appendix C. *Continued.*

Species	Annual farm	Biennial farm	Communal land	Reserve 3	Reserve 7
Euryopis sp. 1	0	0	0	3	2
Camillina procurva	1	0	1	1	2
Linyphiidae sp. 2	1	0	1	1	3
Linyphiidae sp. 4	1	1	2	0	2
Diores annettae	5	0	0	2	0
Zelotes uquathus	1	3	1	1	1
Cydrela sp. 2	1	0	3	1	3
Linyphiidae sp. 3	0	0	3	1	4
Xerophaeus bicavus	1	3	1	2	3
Steatoda sp. 1	0	0	3	5	3
Phlegra sp. 1	3	2	2	2	3
Copa sp. 1	9	3	1	1	0
Linyphiidae sp. 8	4	3	3	2	4
Xysticus mulleri	7	0	4	3	4
Aelurillus sp. 1	7	3	2	3	4
Palpimanus transvaalicus	4	1	0	12	2
Proevippa fascicularis	1	7	5	4	2
Pardosa crassipalpis	3	0	10	4	8
Rhaeboctesis trinotatus	2	0	2	19	6
Trabea sp. 4	5	3	6	7	12
Proevippa albiventris	16	2	12	1	3
Cydrela schoemanae	19	8	5	4	6
Hogna sp. 5	15	8	7	8	5
Zelotes lightfooti	23	7	24	5	7
Trabea sp. 5	0	33	0	31	14
Proevippa sp. 2	32	13	33	26	41
Lycosidae sp. 2	5	10	8	107	44
Lycosidae sp. 1	50	18	51	9	54
Total individuals per site	246	148	201	288	262
Total species unique to this site	12	8	3	9	5

Appendix D. Spider family prevalence per site.

Family	Annual Farm	Biannual Farm	Communal	Reserve camp 3	Reserve camp 7	Total
Amaurobiidae	1	0	0	0	0	1
Araneidae	1	1	0	0	0	2
Clubionidae	1	0	0	2	0	3
Corinnidae	11	8	2	4	2	27
Cyrtaucheniidae	3	2	0	0	0	5
Gnaphosidae	30	15	28	13	16	102
Hahniidae	2	0	0	1	1	4
Idiopidae	1	0	0	0	1	2
Linyphiidae	9	8	12	7	17	53
Liocranidae	2	0	2	19	6	29
Lycosidae	130	95	132	197	183	737
Nemesiidae	0	1	0	1	1	3
Palpimanidae	4	1	0	12	2	19
Philodromidae	1	0	1	2	2	6
Phyxelididae	2	0	0	0	0	2
Prodidomidae	0	0	1	0	0	1
Salticidae	10	7	4	7	7	35

Appendix D. *Continued.*

Family	Annual Farm	Biannual Farm	Communal	Reserve camp 3	Reserve camp 7	Total
Scytodidae	1	0	0	0	1	2
Selenopidae	0	0	0	0	1	1
Sparassidae	0	1	0	1	1	3
Tetragnathidae	1	0	0	1	1	3
Theraphosidae	2	0	0	0	0	2
Theridiidae	0	1	3	9	6	19
Thomisidae	9	0	6	4	4	23
Zodariidae	25	8	10	8	10	61
Total	246	148	201	288	262	1145