Bull. Br. arachnol. Soc. (2010) **15** (3), 61–68

Spider diversity of an upland calcareous grassland habitat in the Brecon Beacons National Park, UK

Julian Carter
Department of Biodiversity and Systematic Biology,
National Museum of Wales, Cathays Park, Cardiff CF10 3NP
e-mail: Julian.carter@museumwales.ac.uk

Summary

The spider community of an upland calcareous grassland habitat was sampled using a semi-quantitative protocol involving suction sampling and limited pitfall trapping. The sites selected included sheep grazed grassland, non-grazed areas protected by an enclosure, and limestone sinkholes. All adults were identified to species level and the results used to explore the differences in the spider communities from the different microhabitats sampled. The results identified a number of species of potential conservation concern. Statistical analysis showed one of the grassland spider communities to be significantly different from the other sites sampled. Cluster analysis was used to further explore the similarities and differences in the spider species assemblages across the sampled sites.

Introduction

Upland biotopes have a conservation importance for their typical plant and animal species (Usher & Thompson, 1988; Dennis *et al*., 2008). However, the conservation status of such areas is usually derived from botanically determined parameters and not from arthropod assemblages (Telfer & Eversham, 1996). This is a consequence of the difficulty in collecting and identifying arthropod faunas, although with groups such as the spiders this has been partly alleviated with the publication of improved taxonomic guides (e.g. Roberts, 1985, 1987) which has resulted in an increase in ecological interest in the group (Bell *et al*., 2001). As spiders are carnivorous, they should be indifferent to plant species composition, although plant architecture can be important in providing a range of foraging habitats (Gibson *et al*., 1992). As spiders are sensitive to changes in habitat structure (Duffey, 1993) they are potentially a good indicator group for some aspects of management effects. Thus spiders and other invertebrate assemblages have been used to consider the effects of livestock grazing on species diversity in upland semi-natural grassland habitats (e.g. Gibson *et al*., 1992; Cole *et al*., 2005; Dennis *et al*., 2008). Bell *et al*. (2001) provide a comprehensive review of grassland and heathland management for the conservation of spider communities.

This small-scale study reports on the spider biodiversity, and that of the harvestmen and pseudoscorpions, found in a number of microhabitats on an upland calcareous grassland community. The site is a National Nature Reserve (NNR) designated for its geological features and botanical composition. Before this study, no detailed investigation of the surface invertebrate assemblages is known to have been done. Consideration is given to the spider communities sampled from each of the studied sites, comparing sites open to sheep grazing with sites protected from grazing.

Material and methods

Study area

The study was carried out on the Ogof Ffynnon Ddu National Nature Reserve (OFD), which covers about 413 ha and is located above the 300 m contour in the western part of the Brecon Beacons National Park (51°49′49″N, 03°38′44″W, grid ref. SN8615), situated in South Wales, UK. The area was designated as an NNR in 1975 and was established to protect a major portion of the UK's deepest cave system, Ogof Ffynnon Ddu (O'Reilly *et al*., 1969). Since its discovery the cave has been the subject of much research on its formation, its geology and its underground biology (Haycock, 1984; Waltham *et al*., 1997; Jefferson *et al*., 2004). The surface geology and ecology are also important features of the reserve (Haycock, 1984). The surface geology of the

reserve consists of a narrow band of Carboniferous Limestone, forming a series of hummocks or knolls with scree and collapsed pavement along the northern edge of the reserve. Above this is an extensive Millstone Grit plateau, exhibiting shallow crags, boulder scree and extensive areas of pavement. Large areas of the grit slab are bare of vegetation and show good examples of glacial striae. Another important feature found within the reserve is the numerous sinkholes in the area between the gritstone plateau and the limestone hummocks. This range of geology and associated features provides an interesting upland ecology. Calcareous grasslands, acid grasslands, and dwarf shrub heath are intimately mixed, allowing calcifuges and calcicoles to be found growing in close proximity (Brecon Beacons NPA, 2002). In addition, a characteristic flora of bryophytes, lichens and vascular plants inhabit the deep grykes found on the limestone pavement. This has resulted in continual vegetation surveys on the reserve. Since the 1970s permanent vegetation transects have been in place and part of the reserve has been fenced to exclude sheep grazing (Haycock, 1984; Averis & Averis, 1998). Since 1994 livestock grazing outside the permanent enclosures has been set at 300 sheep or 300 ewes with lambs, depending on the time of year.

Owing to the large area of the reserve, and the time it takes to process each field sample, the number of sample sites was limited. These sites were chosen to reflect some of the key habitats on the reserve:

G1: Open upland at around 460 m altitude, bordering between *Nardus stricta* grassland and *Agrostis–Festuca ovina* turf. Open to controlled levels of sheep grazing.

G2: *Agrostis* turf dominated grassland on improved soils at 360 m. Open to sheep grazing and formerly used as vegetable garden plots in the 1960s.

U1: *Calluna/Molinia* open heath at altitude of 460 m. Situated in the enclosure excluding sheep grazing.

S1: Limestone sinkhole at 460 m altitude consisting of mix of *Juncus* and *Sphagnum*. Situated in the enclosure excluding sheep grazing.

S2: Limestone sinkhole at 340 m amongst unimproved grassland used for sheep grazing. Within the sinkhole the vegetation is dominated by a mix of *Juncus* and *Sphagnum* marsh.

Sampling methods

The limitations and bias in arthropod sampling methods have been recognised in previous studies (e.g. Merrett & Snazell, 1983; Norris, 1999; Standen, 2000; Brose, 2002; Borges & Brown, 2003; Brennan *et al*., 2005; Cardoso *et al*., 2008), with semi-quantitative sampling protocols being proposed as the most cost-effective way of sampling spider assemblages, although a standardised method is yet to emerge. In an attempt to use the limited resources effectively this study made use of two key sampling methods, suction sampling and pitfall trapping, to obtain an estimate of species richness (Borges & Brown, 2003).

Suction sampling was done using a modified hand-held garden leaf vacuum unit (Stewart & Wright, 1995) to collect the fauna from the ground and vegetation. Two samples were taken on each site visit, each involving two minutes of suction time from within a defined area of 3×3 m. The samples were placed into plastic clip bags for sorting in the laboratory, where the bags were emptied onto large white trays and the obvious invertebrates quickly collected by hand using a pooter. As the samples contained a lot of vegetation and soil they were then placed in mesh bags and hung in Winkler extraction bags (Owen, 1987) and left for a period of two weeks.

Pitfall trapping was done with clear plastic cups (75 mm wide by 110 mm deep) placed in the ground in a line of five at each site, 1 m apart where the ground allowed, with the rims level with the soil surface. A preservative fluid of propylene glycol with 4% formaldehyde and a trace of detergent was added to each trap. They were covered with lids raised above the ground to prevent rain entry. After two weeks in the field the traps were collected and the contents examined in the laboratory.

The emphasis was on applying equal sampling effort to each sample site so as to allow comparison between them. Sampling was carried out during 2006, with suction samples being taken on three occasions (May, June and September) and pitfall trapping on a single occasion (June). Further pitfall trapping was done in September but samples from two sites suffered extensive damage; the results from the surviving samples were not used in this study.

After collection the samples were sorted into a number of major taxonomic groups including the Araneae, Opiliones and Pseudoscorpiones. A subsample of the Acari was also collected for future identification. All samples were preserved in 80% industrial denatured alcohol (IDA). The taxonomic guides of Roberts (1985, 1987) were used to identify all adult Araneae to species level. The Opiliones and Pseudoscorpiones were identified using Hillyard (2005) and Legg & Jones (1988) respectively. An overview of the distribution and ecology of the species collected was obtained using Harvey *et al*. (2002). Voucher specimens of all identified species have been placed in the collections of the National Museum of Wales (NMWC).

Statistical analysis

In an attempt to assess the value of the data obtained, the community structure was explored using a range of statistical methods, recognising both the limited scope of this study and that choosing suitable statistical tests requires careful consideration (Gotelli & Colwell, 2001). Univariate diversity indices were used to examine differences in spider assemblages between the sample sites. For each site the following were calculated: N (the total abundance of spiders), S (total species richness), H' (species diversity using the Shannon index), J' (species evenness using Pielou's index). To test whether the species diversity, H', between sample sites was significant

	G1	G2	U1	S1	S2
Total species richness, S	43	29	39	40	35
Individuals, N	184	99	119	171	175
Diversity, Shannon index, H′	3.109	2.739	3.333	3.262	3.14
Evenness, Pielou's index, J′	0.827	0.813	0.910	0.884	0.883

Table 1: Richness and diversity indices for the five sample sites.

a bootstrapping test was performed (Hammer & Harper, 2006) using $p<0.05$ as the significance level. Species assemblages between the sample sites were further explored using multivariate analyses. The Morisita similarity index was selected as recommended by Krebs (1989) and visualised using average linkage cluster analysis. In addition the commonly used ordination technique of correspondence analysis (CA), both simple and detrended, was used to further visualise groupings in the sample data (Shaw, 2003). Finally, an analysis of the pooled sample data using rarefaction was carried out to estimate how complete the sampling process had been (Colwell & Coddington, 1994). All statistical calculations were carried out using the free software package PAST (Hammer *et al*., 2001).

Results

A total of 748 adult individuals representing 19 families and 93 species of Arachnida were recorded from the sampled sites. The majority of these (54 species) were spiders of the family Linyphiidae. The species recorded and their abundances are listed in Appendix 1. A number of species were common across the sampling sites. These included the linyphiids *Lepthyphantes mengei* Kulczyński, *L. ericaeus* (Blackwall), *Dismodicus bifrons* (Blackwall) and *Micrargus herbigradus* (Blackwall), and the tiny theridiid spider *Theonoe minutissima* (O.P.-Cambridge). Several lycosid spiders such as *Pardosa pullata* (Clerck) were very common on the more open grassland. The tetragnathid spider *Pachygnatha degeeri* Sundevall was also common in the open grassland whilst *P. clercki* Sundevall was found in the damper environment of the sinkholes.

Other species recorded are uncommon, e.g. the linyphiid spiders *Walckenaeria kochi* (O.P.-Cambridge), *Jacksonella falconeri* (Jackson), *Saaristoa firma* (O.P.-Cambridge), *Hypselistes jacksoni* (O.P.-Cambridge), *Trichopterna thorelli* (Westring) and *Monocephalus castaneipes* (Simon). The lycosid spider *Pirata latitans* (Blackwall) also has a rather local distribution and was found in one of the sinkhole sites. Uncommon species typical of the calcareous habitat included the linyphiid spiders *Walckenaeria atrotibialis* (O.P.-Cambridge), *Pelecopsis parallela* (Wider) and *Metopobactrus prominulus* (O.P.-Cambridge), whilst the harvestman *Anelasmocephalus cambridgei* (Westwood) is another species usually found in calcareous grassland and woodland.

Dawson *et al*. (2010) have carried out a conservation review of the national status of British spiders using International Union for Conservation of Nature (IUCN) categories and additional Lower Risk (Nationally Scarce) categories. Several species found in this study are included in this review: *S. firma* is listed as Vulnerable (VU), while *H. jacksoni*, *J. falconeri* and *W. kochi* are proposed as Lower Risk (Nationally Scarce B). In addition *M. castaneipes* is also listed as VU and is listed in the UK Biodiversity Action Plan (UKBAP 2008) as a priority species.

Species diversity using the Shannon index and Pielou's evenness index is shown in Table 1. The results suggest that the sample sites all have similar diversity (H′) values. However the G1 and G2 grassland sites have lower species evenness (J′), indicating greater dominance by a few species such as the active ground-hunting Lycosidae. Pairwise statistical testing of the diversity values is presented in Table 2. Using a significance level of $p<0.05$ shows that the arachnid taxa compositions of sites G1, U1, S1 and S2 are not significantly different, whereas the grazed site G2 does have a significantly different diversity value. The similarity of the spider faunas from the five sample sites was examined as a whole using the Morisita similarity index and visualised through cluster analysis (Fig. 1) and NMDS ordination. Both showed the same relationship in the spider fauna of the sample sites. Those protected from sheep grazing activity, U1 and S1, had the most similar spider faunas. The two sites open to grazing activity, G1 and G2, also grouped together. S2 was also open to sheep grazing but was found between the two groupings.

	G1	G2	U1	S1	S2
G1	–	0.042	0.123	0.125	0.769
G2	0.748	–	0.000	0.000	0.006
U1	0.000	0.000	–	0.641	0.107
S1	0.001	0.003	0.290	–	0.205
S2	0.002	0.002	0.177	0.941	–

Table 2: Bootstrapped probabilities of equality (p) for the Shannon diversity index, H′ (upper triangle) and Pielou's evenness index, J' (lower triangle).

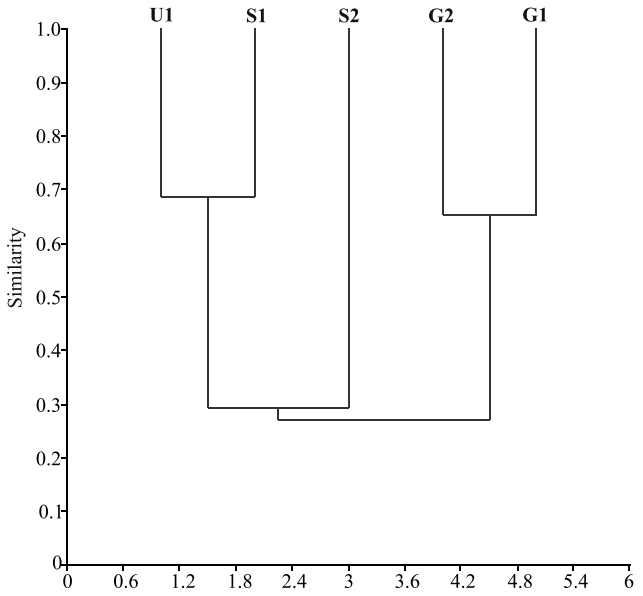

Fig. 1: UPMGA cluster analysis on the five sample sites using the Morisita similarity index.

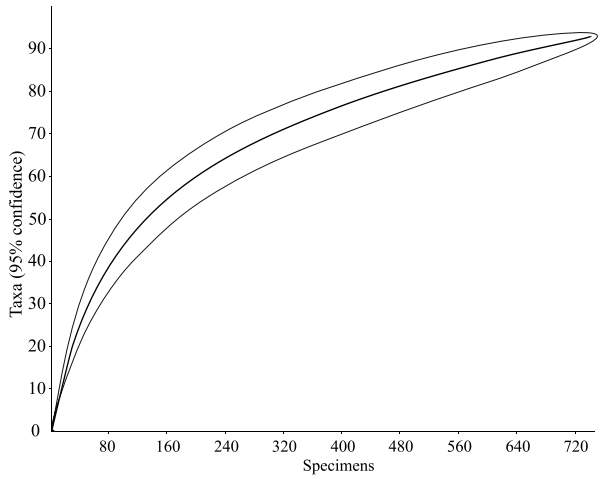

Fig. 2: Rarefaction curve with 95% confidence intervals for the pooled data from all of the OFD samples.

Rarefaction analysis of the pooled sample data from all of the sites shows the rarefaction curve close to flattening out (Fig. 2), suggesting a representative proportion of the spider fauna of the NNR had been sampled. However, looking more closely at the individual sites suggests that the fauna had not been sampled equally within each site (Fig. 3). Sites S1 and S2 appear to have been the most effectively sampled, whilst the curve for G2 suggests the number of taxa collected is more incomplete.

Discussion

In contrast to the underground invertebrate fauna (Jefferson *et al.*, 2004) the surface fauna has not been so well studied on this reserve, hence the main aim of this study was to begin to provide good quality baseline data on the invertebrate communities in this protected upland habitat using the Arachnida as the key study group. This builds on the existing information available and provides a basis for future studies looking at the invertebrate biodiversity of the reserve and the surrounding upland area.

The overall number of both individuals and species collected appears to be limited, although the analysis of the pooled sample data using rarefaction (Gotelli & Colwell, 2001) suggested a good proportion of the possible spider species to be found on the reserve has been sampled. However, such data can only be used as a guideline as rarefaction analysis makes a number of assumptions, such as that the individuals in an environment are randomly distributed, the sample size is sufficiently large, the samples are taxonomically similar, and that all of the samples have been obtained in the same manner. If these assumptions are not met, the resulting curves will be skewed. The limited number of species found can be related to a combination of factors such as the geographical position of the site and the limited range of vegetation cover types, but also to the small number of samples taken and the sampling procedure adopted which was only semi-quantitative in its approach in an attempt to use limited resources efficiently. Riecken (1999) demonstrated that simplified trapping will limit the results, and could reduce the number of species recorded by up to 50%, although the rarefaction data suggest that this is not so dramatic in this study. The two collecting methods used are considered to be complementary and can enable a high proportion of the spider diversity to be sampled. Standen (2000) and Cardoso *et al.* (2008) discuss sampling issues in detail, especially in relation to collecting effort and methods. With limited sample sets it can be questionable whether multivariate techniques should be applied to the data. This study attempted to make the sampling procedures used as equal as possible between sites to allow an overall comparison between the different sample sites, using the concept that multivariate analysis of the data from sampling that has been conducted under standardised conditions can generate meaningful results (Luff *et al.*, 1992). Replication of the sampling sites would also have been desirable, but would have been difficult to achieve in this study owing to resource limitations.

Most of the reserve is open to controlled levels of sheep grazing, although an area within the reserve has been fenced to exclude sheep, in some parts since 1979 (Averis & Averis, 1998). This study did no more than compare the faunal differences between equivalent sites within and outside the enclosure, although there have been numerous studies looking in detail at the effects of stock grazing on invertebrate groups in upland habitats (Bell *et al.*, 2001; Cole *et al.*, 2005; Dennis *et al.*, 2008; Littlewood, 2008). Management regime and site wetness are considered to be the major factors influencing spider communities on grassland sites (Duffey, 1963; Rushton *et al.*, 1987). The results of this project reflect these findings, with the grazed sites G1 and G2 showing greatest similarity to each other, and G2 forming a significantly distinctive community from the other sites sampled. Sites G1 and G2 have a more open vegetative structure, with G2 being the most improved as it was part of former vegetable plots last used in the 1960s. Higher species dominance was suggested from the diversity indices data on these sites, with spiders such as *Pocadicnemis pumila* (Blackwall), *Dismodicus bifrons*, *Pardosa pullata* and *Pachygnatha degeeri* occur-

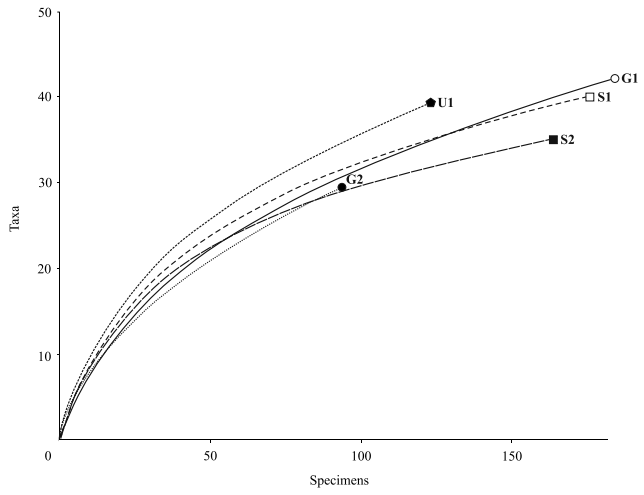

Fig. 3: Rarefaction curves with 95% confidence limits comparing all of the sample sites.

ring in high numbers, especially in G1. The active ground-hunting spiders were caught in high numbers in the pitfall traps. The ungrazed site, U1, showed less dominance by active ground hunters such as the Lycosidae and recorded the highest species evenness value, with only the linyphiids *Lepthyphantes ericaeus* and *Dismodicus bifrons* being found in relatively high numbers. This would reflect the wider range of vegetation structure on this site, which has longer grass and patches of dwarf shrub heath. The sinkhole sites samples, S1 and S2, were of particular interest from the concept of a specialist microhabitat. These important karst features are prominent on the reserve along the limestone exposure, and many overly the known cave system below. Site S1 was located in the enclosure area while S2 was at a lower altitude and open to sheep grazing. The diversity indices for the two sites show similar species diversity and evenness, although the multivariate analysis shows S1 to be more similar to U1. While some of the most abundant species were common to both sinkhole sites, e.g. *Micrargus herbigradus*, *Trochosa terricola* Thorell and the harvestman *Sabacon viscayanum ramblaianum* Martens, other abundant species occurred in only one or the other of the two sinkhole sites. Site S1 had high numbers of *Theonoe minutissima* and *Tegenaria silvestris* L. Koch, whereas S2 had *Antistea elegans* (Blackwall), *Erigonella hiemalis* (Blackwall), *Robertus lividus* (Blackwall), *Pachygnatha clercki*, *Pardosa amentata* (Clerck) and the harvestman *Leiobunum rotundum* (Latreille). It is assumed that the similarity of the overall species diversity of the sinkhole sites may well be due to the formation of a habitat microclimate providing increased shelter and higher humidity levels. However, environmental data need to be collected to verify this. Another key microhabitat on the reserve is the limestone pavement, which is one of the important geological features protected by the NNR designation. The clefts, or grykes, if deep and humid enough, can provide an important habitat for a characteristic flora of bryophytes, lichens and vascular plants that are typically associated with limestone (Brecon Beacons NPA, 2002). Attempts were made to sample this habitat but these were unsuccessful and could not be compared with the other results obtained in this study.

A number of detailed studies on the spider communities of upland Britain have been carried out (e.g. Duffey, 1963; Cherrett, 1964; Coulson & Butterfield, 1986; Downie *et al*., 1995). Such studies have shown that differences in the upland spider communities themselves tended to occur as a result of plant architecture, while diversity declines with altitude owing to a decrease in numbers of non-linyphid species. The results obtained here were comparable to the study of Cherrett (1964) in terms of the overall species composition and vegetative profile, which covers a broadly similar upland habitat. The Linyphiidae are, as expected, the most numerous group, forming 66% of the species composition which compares with values of around 70% obtained in studies such as those by Duffey (1963) and Cherrett (1964), reflecting the sub-montane position of the OFD reserve. However, it is difficult to compare the fauna directly between the different studies owing to differences in trapping intensity, methods used and geography. Species assemblages can also be highly seasonal (Norris, 1999; Luff, 1996) which further complicates any direct comparisons.

The conservation status of British spiders was reviewed by Dawson *et al*. (2010) based on IUCN guidelines. This was compiled using data from the spider recording scheme in the UK, and raised two of the species found in this study to the status of vulnerable (VU), while three others were rated as Nationally Scarce. This reflects the ongoing threats to our biodiversity and further highlights the value of NNRs in the UK.

The OFD reserve protects a small and unique part of the upland environment of South Wales. While much is known about the geology and flora, until this study little work had been done on the invertebrate assemblages of the site. The work presented here starts to fill this gap in our knowledge of the biodiversity of the reserve. The geology of the area affords a mosaic of habitats which includes dwarf shrub heath, calcareous grassland, acid grassland, limestone pavement, sink holes and former industrial areas such as quarries. This provides a good range of habitats to support a range of invertebrate species. Originally the reserve was designated for its geological features and to protect the Ogof Ffynnon Ddu cave system. However, this work and previous studies on the flora and fauna are helping to establish the value of the area in conserving upland invertebrate biodiversity in the Brecon Beacons National Park.

Acknowledgements

I would like to thank Dr Brian Levey for guidance with fieldwork; Dr Tim Rich for advice on the vegetation descriptions; the Friends of Amgueddfa Cymru–National Museums Wales for providing a research grant that enabled this project to be carried out; the Countryside Council for Wales for access to the OFD reserve; and the anonymous referees for their constructive comments.

References

AVERIS, A. B. G. & AVERIS, A. M. 1998: Vegetation survey of Ogof Ffynnon Ddu National Nature Reserve, Powys, 1997. *Countryside Council for Wales science contract report CCW/EA/3*.

BELL, J. R., WHEATER, P. C. & CULLEN, R. W. 2001: The implications of grassland and heathland management for the conservation of spider communities: a review. *J. Zool. (Lond.)* **255**: 377–387.

BORGES, P. A. V. & BROWN, V. K. 2003: Estimating species richness of arthropods in Azorean pastures: the adequacy of suction sampling and pitfall trapping. *Graellsia* **59**(2–3): 7–24.

BRECON BEACONS NPA 2002: *A local biodiversity action plan for the Brecon Beacons National Park, Volume 3*. Brecon Beacons National Park Local Biodiversity Action Plan Steering Group.

BRENNAN, K. E. C., MAJER, J. D. & MOIR, M. L. 2005: Refining sampling protocols for inventorying invertebrate biodiversity: influence of drift-fence length and pitfall trap diameter on spiders. *J. Arachnol.* **33**: 681–702.

BROSE, U. 2002: Estimating species richness of pitfall catches by non-parametric estimators. *Pedobiologia* **46**: 101–107.

CARDOSO, P., GASPAR, C., PEREIRA, L. C., SILVA, I., HENRIQUES, S. S., SILVA, R. R. da & SOUSA, P. 2008: Assessing spider species richness and composition in Mediterranean cork oak forests. *Acta oecol.* **33**: 114–127.

CHERRETT, J. M. 1964: The distribution of spiders on the Moor House Nature Reserve, Westmorland. *J. Anim. Ecol.* **33**: 27–48.

COLE, L. J., McCRACKEN, D. I., DOWNIE, I. S., DENNIS, P., FOSTER, G. N., WATERHOUSE, T., MURPHY, K. J., GRIFFIN, A. L. & KENNEDY, M. P. 2005: Comparing the effects of farming practises on ground beetle (Coleoptera: Carabidae) and spider (Araneae) assemblages of Scottish farmland. *Biodivers. Conserv.* **14**: 441–460.

COLWELL, R. K. & CODDINGTON, J. A. 1994: Estimating terrestrial biodiversity through extrapolation. *Phil. Trans. R. Soc.* (B) **345**: 101–118.

COULSON, J. C. & BUTTERFIELD, J. 1986: The spider communities on peat and upland grasslands in northern England. *Holarctic Ecol.* **9**: 229–239.

DAWSON, I. K., HARVEY, P. R., MERRETT, P. & RUSSELL-SMITH, A. 2010: A review of the scarce and threatened spiders (Arachnida: Araneae) of Great Britain. *Species Status* No. (in press). Joint Nature Conservation Committee, Peterborough.

DENNIS, P., SKARTVEIT, J., McCRACKEN, D. I., PAKEMAN, R. J., BEATON, K., KUNAVER, A. & EVANS, D. M. 2008: The effects of livestock grazing on foliar arthropods associated with bird diet in upland grasslands of Scotland. *J. appl. Ecol.* **45**: 279–287.

DOWNIE, I. S., BUTTERFIELD, J. E. L. & COULSON, J. C. 1995: Habitat preferences of sub-montane spiders in northern England. *Ecography* **18**: 51–61.

DUFFEY, E. 1963: Ecological studies on the spider fauna of the Malham Tarn area. *Fld Stud.* **1**(5): 65–87.

DUFFEY, E. 1993: A review of factors influencing the distribution of spiders with special reference to Britain. *Mem. Qd Mus.* **33**(2): 497–502.

GIBSON, C. W. D., HAMBLER, C. & BROWN, V. K. 1992: Changes in spider (Araneae) assemblages in relation to succession and grazing management. *J. appl. Ecol.* **29**: 132–142.

GOTELLI, N. J. & COLWELL, R. K. 2001: Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecol. Lett.* **4**: 379–391.

HAMMER, Ø. & HARPER, D. A. T. 2006: *Paleontological data analysis*. Blackwell, Malden, USA.

HAMMER, Ø., HARPER, D. A. T. & RYAN, P. D. 2001: PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* **4**(1): 9 pp. <http://palaeo-electronica.org/2001_1/past/issue1_01.htm>

HARVEY, P. R., NELLIST, D. R. & TELFER, M. G. 2002: *Provisional atlas of British spiders (Arachnida, Araneae), Volumes 1 & 2*. Huntingdon: Biological Records Centre.

HAYCOCK, R. J. 1984: Ogof Ffynnon Ddu NNR. *Nature Wales* (N.S.) **3/4**: 34–41.

HILLYARD, P. D. 2005: Harvestmen (3rd edn). *Synopses Br. Fauna* (N.S.) **4**: 1–167.

JEFFERSON, G. T., CHAPMAN, P., CARTER, J. & PROUDLOVE, G. 2004: The invertebrate fauna of the Ogof Ffynnon Ddu cave system, South Wales, UK. *Cave Karst Sci.* **31**(2): 63–76.

KREBS, C. J. 1989: *Ecological methodology*. Harper & Row, New York.

LEGG, G. & JONES, R. E. 1988: Pseudoscorpions (Arthropoda; Arachnida). *Synopses Br. Fauna* (N.S.) **40**: 1–159.

LITTLEWOOD, N. A. 2008: Grazing impacts on moth diversity and abundance on a Scottish upland estate. *Insect Conserv. Divers.* **1**: 151–160.

LUFF, M. L. 1996: Use of carabids as environmental indicators in grasslands and cereals. *Annls zool. fenn.* **33**: 185–195.

LUFF, M. L., EYRE, M. D. & RUSHTON, S. P. 1992: Classification and prediction of grassland habitats using ground beetles (Coleoptera, Carabidae). *J. envir. Managmt* **35**: 301–315.

MERRETT, P. & SNAZELL, R. 1983: A comparison of pitfall trapping and vacuum sampling for assessing spider faunas on heathland at Ashdown Forest, south-east England. *Bull. Br. arachnol. Soc.* **6**(1): 1–13.

NORRIS, K. C. 1999: Quantifying change through time in spider assemblages: sampling methods, indices and sources of error. *J. Insect Conserv.* **3**(4): 309–325.

O'REILLY, P. M. 1969: *Ogof Ffynnon Ddu, Penwyllt, Breconshire*. South Wales Caving Club.

OWEN, J. A. 1987: The 'Winkler extractor'. *Proc. Trans. Br. ent. nat. Hist. Soc.* **20**: 129–132.

RIECKEN, V. 1999: Effects of short term sampling on ecological characterisation and evaluation of epigeic spider communities and their habitats for site assessment studies. *J. Arachnol.* **27**: 189–195.

ROBERTS, M. J. 1985: *The spiders of Great Britain and Ireland*. Vol. 1: Atypidae to Theridiosomatidae. Harley Books, Colchester.

ROBERTS, M. J. 1987: *The spiders of Great Britain and Ireland*. Vol. 2: Linyphiidae and check list. Harley Books, Colchester.

RUSHTON, S. P., TOPPING, C. J. & EYRE, M. D. 1987: The habitat preferences of grassland spiders as identified using Detrended Correspondence Analysis (DECORANA). *Bull. Br. arachnol. Soc.* **7**(6): 165–170.

SHAW, P. J. A. 2003: *Multivariate statistics for the environmental sciences*. Hodder Arnold.

STANDEN, V. 2000: The adequacy of collecting techniques for estimating species richness of grassland invertebrates. *J. appl. Ecol.* **37**: 884–893.

STEWART, A. J. A. & WRIGHT, A. F. 1995: A new inexpensive suction apparatus for sampling arthropods in grassland. *Ecol. Ent.* **20**: 98–102.

TELFER, M. G. & EVERSHAM, B. C. 1996: Ecology and conservation of heathland Carabidae in eastern England. *Annls zool. fenn.* **33**: 133–138.

UKBAP 2008: *UK list of priority species and habitats*. <http://www.ukbap.org.uk/NewPriorityList.aspx>

USHER, M. B. & THOMPSON, D. B. A. (eds) 1988: *Ecological change in the uplands*. Blackwell Scientific Publications, Oxford.

WALTHAM, A. C., SIMMS, M. J., FARRANT, A. J. & GOLDIE, H. S. 1997: *Karst & Caves of Great Britain*. Geological Conservation Review, Volume 12.

Appendix 1

List of species and their abundances. Conservation status: VU = Vulnerable; NSB = Nationally Scarce B (Dawson *et al*., 2010). For sites G1, G2, U1, S1, S2, see text.

	Status	G1	G2	U1	S1	S2	Total
Araneae							
Agelenidae							
Tegenaria silvestris L.Koch		1	0	0	10	0	11
Textrix denticulata (Olivier)		0	0	3	2	0	5
Araneidae							
Araneus diadematus Clerck		0	0	1	0	0	1

Appendix 1

Continued

	Status	G1	G2	U1	S1	S2	Total
Clubionidae							
Clubiona reclusa O.P.-Cambridge		0	0	1	0	0	1
Clubiona trivialis C.L.Koch		0	0	1	0	0	1
Clubiona diversa O.P.-Cambridge		2	1	2	2	2	9
Gnaphosidae							
Drassodes cupreus (Blackwall)		1	0	0	0	0	1
Hahniidae							
Antistea elegans (Blackwall)		0	0	0	1	20	21
Hahnia nava (Blackwall)		0	0	0	1	0	1
Linyphiidae							
Agyneta subtilis (O.P.-Cambridge)		3	0	0	0	0	3
Agyneta decora (O.P.-Cambridge)		0	0	0	0	1	1
Allomengea scopigera (Grube)		0	0	1	0	0	1
Bathyphantes gracilis (Blackwall)		0	2	2	1	0	5
Bathyphantes nigrinus (Westring)		0	0	0	1	2	3
Bolyphantes luteolus (Blackwall)		4	0	5	4	0	13
Centromerita concinna (Thorell)		1	0	0	0	0	1
Centromerus dilutus (O.P.-Cambridge)		1	0	0	3	1	5
Ceratinella brevipes (Westring)		3	0	6	2	0	11
Dicymbium nigrum (Blackwall)		4	3	0	0	0	7
Diplocephalus latifrons (O.P.-Cambridge)		0	0	0	0	1	1
Dismodicus bifrons (Blackwall)		10	2	11	9	3	35
Erigonella hiemalis (Blackwall)		0	5	0	0	13	18
Floronia bucculenta (Clerck)		0	0	1	0	0	1
Gonatium rubellum (Blackwall)		0	0	0	1	0	1
Gonatium rubens (Blackwall)		1	0	4	0	0	5
Gongylidiellum vivum (O.P.-Cambridge)		0	1	0	3	1	5
Hypomma bituberculatum (Wider)		1	0	1	0	1	3
Hypselistes jacksoni (O.P.-Cambridge)	NSB	1	0	1	0	0	2
Jacksonella falconeri (Jackson)	NSB	0	0	0	1	0	1
Lepthyphantes mengei Kulczyński		8	4	7	4	7	30
Lepthyphantes tenuis (Blackwall)		0	1	1	0	4	6
Lepthyphantes ericaeus (Blackwall)		2	1	10	12	6	31
Lepthyphantes zimmermanni Bertkau		1	0	5	3	0	9
Lepthyphantes flavipes (Blackwall)		0	0	0	0	2	2
Lophomma punctatum (Blackwall)		0	0	0	0	1	1
Meioneta beata (O.P.-Cambridge)		1	0	0	0	0	1
Meioneta saxatilis (Blackwall)		1	3	0	2	0	6
Metopobactrus prominulus (O.P.-Cambridge)		1	0	0	0	0	1
Micrargus herbigradus (Blackwall)		4	2	1	12	7	26
Minyriolus pusillus (Wider)		0	0	0	1	0	1
Monocephalus fuscipes (Blackwall)		0	1	1	0	0	2
Monocephalus castaneipes (Simon)	VU	0	0	1	0	0	1
Oedothorax gibbosus (Blackwall)		0	0	0	0	2	2
Oedothorax fuscus (Blackwall)		1	7	0	0	1	9
Oedothorax retusus (Westring)		0	16	0	0	2	18
Pelecopsis parallela (Wider)		0	1	0	0	0	1
Peponocranium ludicrum (O.P.-Cambridge)		5	0	1	4	0	10
Pocadicnemis juncea Locket & Millidge		1	0	0	2	0	3
Pocadicnemis pumila (Blackwall)		10	0	1	6	2	19
Saaristoa abnormis (Blackwall)		0	0	0	1	4	5
Saaristoa firma (O.P.-Cambridge)	VU	0	0	0	1	0	1
Silometopus elegans (O.P.-Cambridge)		1	1	0	2	1	5
Tallusia experta (O.P.-Cambridge)		0	0	0	4	0	4
Tapinocyba praecox (O.P.-Cambridge)		0	0	1	0	0	1
Tiso vagans (Blackwall)		0	1	0	0	0	1
Trichopterna thorelli (Westring)		0	2	0	0	0	2
Walckenaeria unicornis O.P.-Cambridge		2	1	0	0	0	3
Walckenaeria acuminata Blackwall		1	1	0	4	0	6
Walckenaeria atrotibialis (O.P.-Cambridge)		1	0	0	0	0	1
Walckenaeria cuspidata Blackwall		0	0	1	0	0	1
Walckenaeria kochi (O.P.-Cambridge)	NSB	0	0	0	1	0	1
Walckenaeria vigilax (Blackwall)		1	0	0	1	0	2
Mimetidae							
Ero cambridgei Kulczyński		1	1	0	3	2	7
Liocranidae							
Phrurolithus festivus (C.L.Koch)		0	1	0	0	0	1

Appendix 1

Continued

	Status	G1	G2	U1	S1	S2	Total
Lycosidae							
Alopecosa pulverulenta (Clerck)		11	1	0	0	0	12
Pardosa amentata (Clerck)		0	0	0	0	15	15
Pardosa pullata (Clerck)		37	13	4	0	9	63
Pardosa nigriceps (Thorell)		7	0	0	0	0	7
Pirata latitans (Blackwall)		0	0	0	0	3	3
Trochosa terricola Thorell		6	1	4	11	7	29
Trochosa ruricola (Degeer)		0	2	0	4	0	6
Salticidae							
Euophrys frontalis (Walckenaer)		3	2	5	2	0	12
Heliophanus flavipes (Hahn)		1	0	0	0	0	1
Segestriidae							
Segestria senoculata (Linnaeus)		0	0	1	0	0	1
Tetragnathidae							
Metellina merianae (Scopoli)		0	0	0	1	0	1
Pachygnatha degeeri Sundevall		22	21	4	0	0	47
Pachygnatha clercki Sundevall		0	0	0	0	15	15
Theridiidae							
Enoplognatha ovata (Clerck)		0	0	0	0	1	1
Pholcomma gibbum (Westring)		0	0	3	1	1	5
Robertus lividus (Blackwall)		5	0	1	0	10	16
Theonoe minutissima (O.P.-Cambridge)		2	0	7	14	0	23
Thomisidae							
Ozyptila atomaria (Panzer)		6	0	3	0	0	9
Xysticus erraticus (Blackwall)		1	0	0	0	0	1
Xysticus cristatus (Clerck)		0	0	3	0	0	3
Opiliones							
Leiobunidae							
Leiobunum rotundum (Latreille)		0	0	0	0	11	11
Nemastomatidae							
Nemastoma bimaculatum (Fabricius)		1	0	0	4	0	5
Phalangiidae							
Megabunus diadema (Fabricius)		0	0	1	0	0	1
Mitopus morio (Fabricius)		0	0	2	0	8	10
Paroligolophus agrestis (Meade)		0	0	1	0	0	1
Sabaconidae							
Sabacon viscayanum ramblaianum Martens		7	1	7	18	7	40
Trogulidae							
Anelasmocephalus cambridgei (Westwood)		0	0	0	8	0	8
Pseudoscorpiones							
Neobisiidae							
Neobisium muscorum (Leach)		0	0	6	9	0	15