1998. P. A. Selden (ed.). *Proceedings of the 17th European Colloquium of Arachnology, Edinburgh 1997.*

The structure of spider communities in limestone quarry environments

James R. Bell, W. Rod Cullen and **C. Philip Wheater**

Department of Environmental and Geographical
Sciences, Manchester Metropolitan University,
Manchester, M1 5GD, UK

Summary

Upland limestone spider communities have not been extensively studied. Spiders of three habitats—a natural daleside, naturally regenerated disused quarries, and quarry faces which have undergone landform replication—have been investigated using pitfall traps as part of a long-term monitoring programme. Catch data of 2055 individuals, representing 77 species from 12 families, is presented for the years 1992 and 1995. No relationship was found between the number of spider species and individuals and the age of the sites. Changes in the species composition were evident between 1992 and 1995. These tended to be greatest for recently disturbed sites and smallest for mature natural daleside habitats. This may be attributed to survival of a population and weather-mediated differences in immigration from surrounding habitats. Additionally, the availablitity of overwintering habitat such as large rocks and moss may explain differences between some sites. Three families were found to be dominant across the sites: Linyphiidae, Lycosidae and Agelenidae, with five species making up 49.5 % of the sample. The autecology of these species is discussed in relation to their distribution.

Introduction

In Britain, upland spider communities can be found west of the Tees–Exe line between 300–1300 m where the physical conditions are often harsh due to an extremely variable climate, steep unstable slopes and thin soils (Ratcliffe, 1977). These communities often contain species which are common at lower altitudes and are characterized by the dominance of the Linyphiidae (Downie *et al.*, 1995). Spiders of the uplands are receiving increasing attention, but largely on acid grassland (e.g. Coulson & Butterfield, 1986; Sanderson *et al.*, 1995) with relatively little data on calcareous communities (Duffey, 1963).

Upland grasslands may be altered in a minor way through ploughing and reseeding (Luff & Rushton, 1989) but habitat disturbance by quarrying may fundamentally transform the habitat (Bradshaw & Chadwick, 1980). The immediate effect of quarrying on invertebrate communities and their subsequent recovery over time has only recently received scrutiny (Cullen & Wheater, 1995; Wheater & Cullen, 1997). Here, we present data on the effect of quarrying on spiders and the response of these communities to severe habitat disturbance.

Study sites

The 14 study sites are located 3 km east of Buxton in and around Tunstead quarry (Grid ref. SK 745105) in the White Peak. Three main limestone habitats were investigated: natural daleside (NDs), naturally regenerated disused quarries (DQs), and quarry faces which have undergone landform replication (RBs) (Table 1).

Great Rocks Dale (NDs) is geomorphologically representative of 5% of the dalesides in the area, containing prominent rock buttresses, headwalls and both bare and vegetated scree slopes. The disused quarries (DQs) are distributed around the periphery of the main quarry. They have a similar structure to the natural daleside except that the headwall is much more abrupt and the vegetation, although generally similar, shows a wide variation of species (Ash, 1986). The landform replication sites (RBs) also

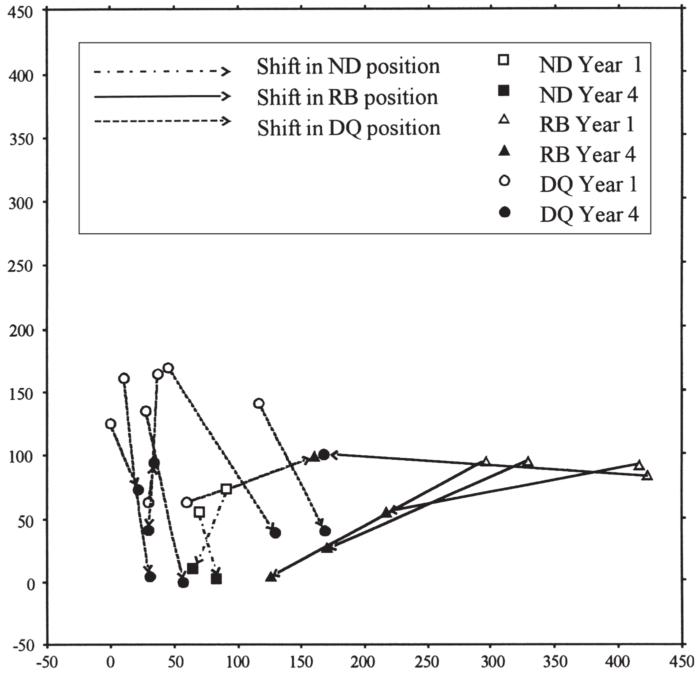

Fig. 1: Biplot of DECORANA axis 1 and axis 2 scores.

have daleside rock features, but these have been created through blasting with high explosives (Gagen & Gunn, 1988; Gagen *et al.*, 1993). A cover material was applied to the resulting scree slopes which were subsequently hydroseeded with a daleside seed mix (Bailey *et al.*, 1992).

Site name	**No. of sites**	**Site Code**	**Last Active**	**NVC code**
Great Rocks Dale	2	NDb	n/a	CG2d
		NDe	n/a	CG2d
Upper End	2	DQ2a	1910	MG1
		DQ2b	1910	MG1
Peak Dale	2	DQ7e	1946	MG1
		DQ7f	1946	MG1
Small Dale	2	DQ8c	1946	MG1
		DQ8d	1946	MG1
Long Sidings	2	DQ1c	1955	MG1
		DQ1d	1955	MG1
Tunstead Quarry	4	RB5a	1988	MG6
		RB5b	1988	MG6
		RB8/9b	1989	MG6
		RB8/9c	1989	MG6

Table 1: Characteristics of the 14 sites under investigation. For a full description of the National Vegetation Classification (NVC) see Rodwell (1992).

There is no public access to any of the study sites and rabbit grazing is a feature of all the vegetated cones and slopes.

Methods

Five plastic pitfall traps (65 × 90 mm) were set per site, each containing 5% formalin solution and 1% detergent. Traps were placed 1.5–2.0 m apart on vegetated scree cones or slopes at each of the 14 sites (Table 1). Pitfall trapping is the only feasible sampling method in this quarry environment, other methods being impracticable due to a loose substrate, short vegetation and limited access to sites because of blasting. Pitfall traps are limited in what they catch (Topping & Sunderland, 1992; Topping, 1993). However, despite known drawbacks, pitfall trap samples provide a good record of the surface-active spider community (Uetz & Unzicker, 1976) over a long period (Curtis, 1980). We present data for the first two weeks of every month over a seven-month collecting season (April–October) for the years 1992 and 1995.

Detrended Correspondence Analysis (DECORANA) is an indirect gradient ordination technique (Hill, 1979), used here to explore the

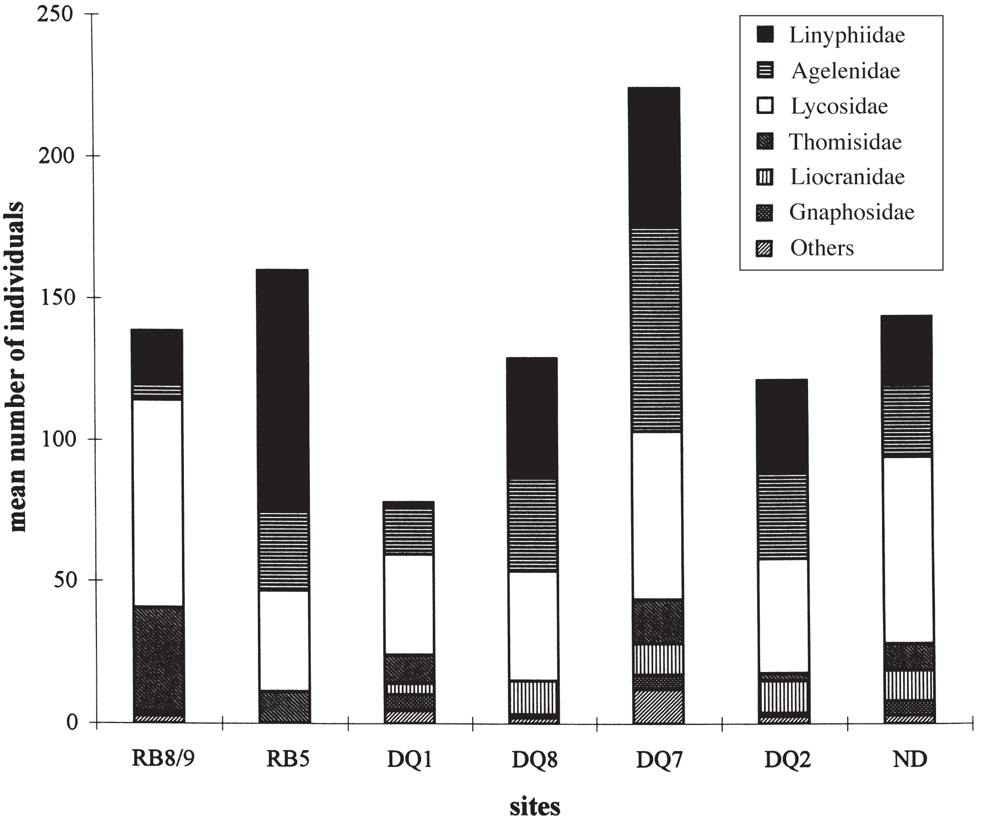

Fig. 2: Mean number of individuals per site in the six commonest families.

differences and similarities between sites in terms of their spider communities. Spearman's rank correlation coefficients were used to explore the relationship between site age and the number of spider species and individuals captured.

Results

Figure 1 shows the DECORANA biplot for all 14 sites in both years (1992 white shapes, 1995 black shapes). Arrows for each site depict the movement over time in ordinational space.

Three clusters can be identified for 1992: the central cluster (NDs and DQ8c and DQ1b), a high cluster (remaining DQ sites), and a right hand cluster (all RB sites). From 1992 to 1995 there is a downward shift for the disused quarries (except DQ8c and DQ1b) and a horizontal movement across towards the main cluster by all landform replication sites. This results in the formation of a single, albeit rather loose, cluster of all the sites.

Three families show high activity: in rank order, Lycosidae; Linyphiidae and Agelenidae. Overall, DQ7 has the highest catch and DQ1 the lowest. No significant relationship ($r^s = 0.036$, $P = 0.93$) was found between the total number of individuals captured and the age of the site. However, at the family level, Thomisidae were only caught in large numbers on RB8/9 and Liocranidae were only caught in ND and DQ sites.

In terms of mean number of species (Fig. 3), the three most active spider families are ordered differently to that seen for the number of individuals (Fig. 2): here, Linyphiidae; Lycosidae and Agelenidae. DQ7 has the highest number of species and DQ1 the lowest. No significant relationship ($r^s = 0.571$, $P = 0.16$) was found between the number of species captured and the age of the site, although it is possible that any real underlying relationship may be obscured by a relatively low sample size.

Table 2 indicates some interesting species distributions with *Pardosa pullata* (Clerck) tolerating the conditions of all the daleside grassland types. *Erigone promiscua* (O. P.-Cambridge) is the most abundant of the pioneer species caught on the RBs. Most species are widely distributed, but common on DQ8,7,2 and the NDs, for example, *Coelotes atropos* (Walckenaer) and *Agroeca proxima* (O. P.-Cambridge). The NDs are herb-rich open swards where species such as *Alopecosa pulverulenta* (Clerck) have healthy populations. Other species such as *Zelotes apricorum* (L. Koch), *Ozyptila atomaria* (Panzer) and *Neon reticulatus* (Blackwall) are amongst the few typical daleside species.

Discussion

Community ecology

The ordination (Fig. 1) identified three clusters in the first year but only one cluster in the fourth year. This re-clustering may be partly explained by 65% of the sites showing a decrease in species number and 79% a decrease in individuals captured between years 1 and 4. A real biological change such as this can affect between-year differences in ordinational space (Rushton & Eyre, 1992). Shifts such as these can be attributed to many different types of ecological gradients, but Rushton & Eyre (1989, 1992) suggested that these movements could be caused by the survival of a population and weather mediated differences in immigration from surrounding habitats. It is possible that a newly established habitat which consists of significant numbers of *Erigone* species, *Meioneta rurestris* (C. L. Koch) and *Pardosa amentata* (Clerck), all of which show a strong tendency for ballooning, will fluctuate widely if food becomes limited, particularly nearing autumn (Richter, 1971; Weyman *et al*., 1994).

The problem of a limited food resource may be compounded on the RB sites by a very poor overwintering habitat due to the very small size of the cover material (3 mm) and a dramatic decline in vegetation cover three years after hydroseeding (Bailey *et al*., 1991). Rock debris and moss, which are common on the ND and DQ sites, are known to be excellent habitats for overwintering spiders because they protect against extreme temperature fluctuations whilst also providing for food (Foelix, 1982; Růžička, 1989). This buffer may allow local colonization from the residual overwintering pool rather than colonization from greater distances and it is suggested that this factor alone may explain much of the variation between years. Further monitoring of all the sites and their movement in ordinational space will verify whether our hypothesis that the RBs will show the greatest shifts between years is correct.

The dominance of the linyphiids and lycosids (Figs. 2–3) is common in upland areas (Downie *et al*., 1995) although the Thomisidae, normally better represented (Hauge & Refseth, 1979; Downie *et al*., 1995). No clear differences were

		RB8/9	**RB5**	**DQ1**	**DQ8**	**DQ7**	**DQ2**	**ND**
Pardosa pullata	mean	28.50	2.50	12.50	22.50	28.50	30.50	12.73
	SD	37.48	3.54	9.19	9.19	24.75	30.41	40.00
Erigone promiscua	mean	8.50	36.00	0.00	0.00	0.00	0.00	0.00
	SD	12.02	50.91	0.00	0.00	0.00	0.00	0.00
Alopecosa pulverulenta	mean	6.00	1.00	0.50	0.00	2.50	3.50	55.00
	SD	7.07	1.41	0.71	0.00	3.54	4.95	14.85
Coelotes atropos	mean	0.00	11.00	14.50	32.00	47.50	26.50	13.00
	SD	0.00	9.80	2.12	4.24	17.68	10.61	4.24
Agroeca proxima	mean	0.00	0.00	4.00	12.00	11.00	11.50	9.50
	SD	0.00	0.00	2.83	2.83	8.49	6.36	3.54

Table 2: A selected species list showing the mean number and standard deviation of individuals caught in each of the daleside habitats for the two years.

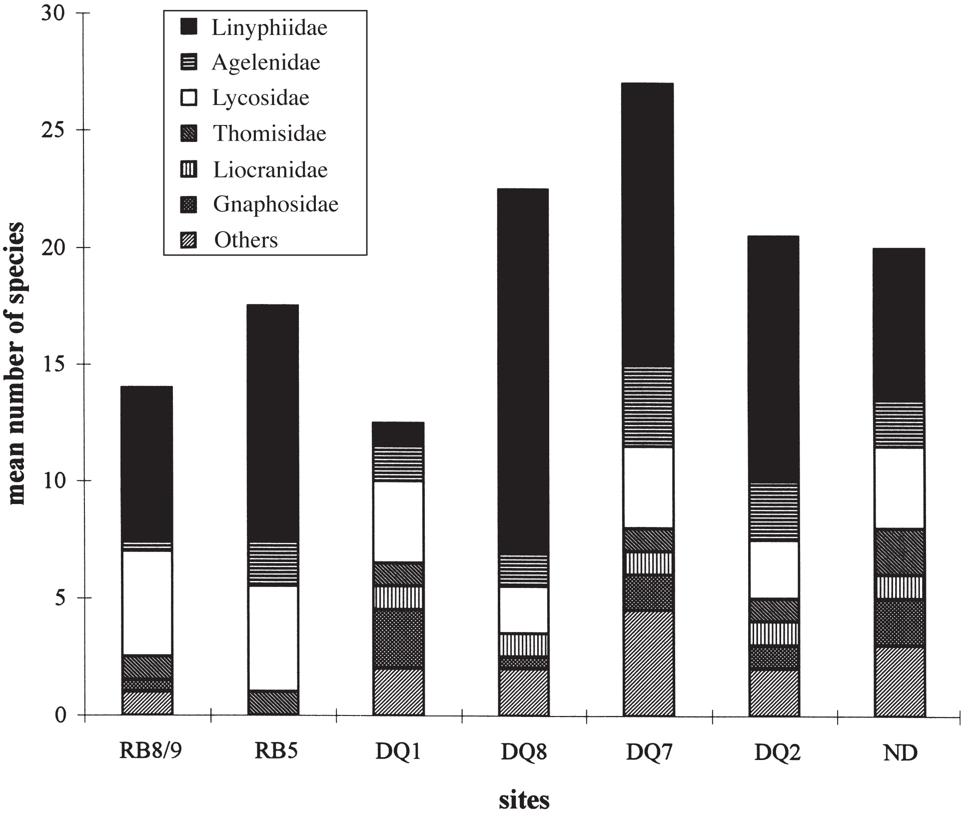

Fig. 3: Mean number of species per site in the six commonest families.

found in the numbers of individuals or species caught between old and new sites. Baines *et al.* (in press) have noted that the age of the site increases the abundance and species richness of spiders, and Luff & Rushton (1989) found that the highest diversity and number of individuals could be found on unimproved upland grasslands. From these two studies we should expect the unimproved "natural" daleside to have more individuals with more species, but this is not apparent: RB8/9 has a similar mean number of species and individuals to the natural daleside. DQ7, a disturbed site 50 years old, has the highest mean number of species and individuals of any site. Time, as an ecological gradient, does not show a linear relationship with a site's mean number of spider species or individuals in this study.

Luff & Rushton (1989) suggest that reseeding and management reduce both the diversity and the number of spiders. However, in antithesis, Baines *et al.* (in press) have suggested that sowing a field margin with a wild flower seed mixture was associated with increased abundance and species richness in the Araneae. In our study, RBs showed no radical differences from mature NDs: spider numbers are not exceptionally different at the community level in seeded RBs in the first eight to nine years after management to those that are considered "natural".

Spider ecology

Table 2 highlights five common species making up 49.5% of the total number of individuals caught.

Pardosa pullata tolerated all grassland types, but was most abundant in the rich sward of the natural daleside. *P. pullata* has been shown to be associated with vegetation structure, particularly vegetation height (Van der Aart, 1973; Jones-Walters, 1988), occurring in taller, fescue-dominated grassland (Duffey, 1962a,b, 1963). *P. pullata* is able to survive high temperatures and humidity (Nørgaard, 1951) and has a good dispersal capability (Richter, 1971) and it is suggested that these are the reasons for finding it in shorter vegetation (Jones-Walters, 1988; McFerran *et al*., 1994) such as those on the RB and DQ1 sites.

Erigone promiscua is the most abundant of the pioneer species on the RB sites, and characteristic of this genus is the ability to withstand high disturbance (De Keer & Maelfait, 1988). A similar habitat is found on embryo dunes (Bell *et al*., 1998) and in common with the RB sites, there was a low diversity of plants and plenty of bare ground.

Alopecosa pulverulenta, is widely distributed, but it occurs in disproportionately large numbers in the natural dalesides. This species is a diurnal-active hunter found in all kinds of open grassland (Kronestedt, 1990), but preferring long structural types (Jones-Walters, 1988). This is indicated by its distribution, which may also be a product of good overwintering habitat for immature spiders where there are plenty of stones (Kronestedt, 1990)

Coelotes atropos is ubiquitous in the disused quarries. In Central Europe, *C. atropos* occurs above 900 m under bark and stones in unspoilt biotopes, such as primeval forests (Sechterová, 1992). Here, *C. atropos* is known to have a highly diverse food spectrum, tackling prey such as Carabidae and Isopoda (Sechterová, 1992). These groups are widely distributed throughout the study area (Cullen, 1995) and it is clear that, despite reports that it is a poor colonist (Sechterová, 1992), *C. atropos* is clearly invading new habitats in search of prey.

Agroeca proxima is similarly distributed, occurring in all sites except the RBs. *A. proxima* indicates a preference for conditions associated with mature habitats rather than younger more intensively managed sites where shade from long vegetation occurs (Jones-Walters, 1988; McFerran *et al*., 1994)

Conclusions

The number of spider species and individuals does not vary in a linear way with age of site. In addition, differences were not found between highly managed and unmanaged sites. However, differences were seen at a family level and at the species level, showing preferences for particular sites. More detailed examination at the species level may identify indicators for these disturbed and managed environments.

Acknowledgements

We wish to thank Steve Cooper and technicians for helping to collect and sort field data.

References

AART, P. J. M. VAN DER 1973: Distribution analysis of wolfspiders (Araneae, Lycosidae) in a dune area by means of principal component analysis. *Neth. J. Zool.* **23**: 266–329.

ASH, H. 1986: *Limestone quarry restoration: Report 1: Soils and vegetation.* London: Department of the Environment.

BAILEY, D. E., GAGEN, P. J. & GUNN, J. 1992: *The revegetation of landforms constructed by restoration blasting. Working Paper 92/01.* Manchester: Manchester Polytechnic.

BAILEY, D. E., GUNN, J., HANDLEY, J. & SHAW, S. 1991: The construction of limestone ecosystems on quarried rock slopes. *In Proceedings of the Environmental Workshop 1991.* Perth: Australian Mining Industry Council: 13–25.

BAINES, M., HAMBLER, C., JOHNSON, P. J., MACDONALD, D. W. & SMITH, H. In press: The effects of arable field margin management on the abundance and species richness of the Araneae. *Ecography.*

BELL, J. R., HAUGHTON, A. J., CULLEN, W. R. & WHEATER, C. P. 1998: The zonation and ecology of a sand-dune spider community. This volume: 261–266.

BRADSHAW, A. D. & CHADWICK, M. J. 1980: *The restoration of the land.* London: Blackwell.

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

CULLEN, W. R. 1995: *The colonization and establishment of surface active invertebrate communities in restoration blasted limestone quarries.* Ph.D. thesis, Manchester Metropolitan University.

CULLEN, W. R. & WHEATER, C. P. 1995: The management of sites influenced by limestone quarrying. *Recycling Derelict Land* **3**: 1–6.

CURTIS, D. J. 1980: Pitfalls in spider community studies (Arachnida, Araneae). *J. Arachnol.* **8**: 271–280.

DE KEER, R. & MAELFAIT, J. P. 1988: Laboratory observations on the development and reproduction of *Erigone atra* Blackwall, 1833 (Araneae, Linyphiidae). *Bull. Br. arachnol. Soc.* **7**: 237–242.

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

DUFFEY, E. 1962a: A population study of spiders in limestone grassland. The field layer fauna. *Oikos* **13:** 15–34.

DUFFEY, E. 1962b: A population study of spiders in limestone grassland. Description of study area, sampling methods and population characteristics. *J. anim. Ecol.* **31**: 571–599.

DUFFEY, E. 1963: Ecological studies on the spider fauna of the Malham Tarn area. *Fld Stud.* **1**: 1–23

FOELIX, R. F. 1982: *Biology of spiders*. 1st ed. Cambridge, MA & London: Harvard University Press.

GAGEN, P. J. & GUNN, J. 1988: A geomorphological approach to limestone quarry reclamation. *In* J. Hooke (ed.). *Geomorphology and public policy*. London: John Wiley: 121–126.

GAGEN, P. J., GUNN, J. & BAILEY, D. 1993: Landform replication on quarried limestone rock slopes in the English Peak District. *Z. Geomorph. (Suppl.)* **87**: 163–170

HAUGE, E. & REFSETH, D. 1979: The spider fauna of 5 alpine and subalpine habitats in the Jotunheimen area, Southern Norway. *Fauna Norv. Ser. B* **26**: 84–90.

HILL, M. O. 1979: *DECORANA—a FORTRAN program for Detrended Correspondence Analysis and Reciprocal Averaging*. New York: Department of Ecology and Systematics, Cornell University.

JONES-WALTERS, L. 1988: *The management of chalk grassland for the conservation of invertebrate populations with special reference to Martin Down and Aston Rowant National Nature Reserves*. EFU Report 32. Peterborough: English Nature.

KRONESTEDT, T. 1990: Separation of two species standing as *Alopecosa aculeata* (Clerck) by morphological, behavioural and ecological characters, with remarks on related species in the *pulverulenta* group (Araneae, Lycosidae). *Zool. Scr.* **19**: 203–225.

LUFF, M. L. & RUSHTON, S. P. 1989: The ground beetle and spider fauna of managed and unimproved upland pasture. *Agric. Ecosyst. Environ.* **25**: 195–205.

McFERRAN, D. M., MONTGOMERY, W. I. & McADAM, J. H. 1994: The impact of grazing on communites of ground dwelling spiders (Araneae) in upland vegetation types. *Biol. Environ.* **94B**, 119–126.

NØRGAARD, E. 1951: On the ecology of two lycosid spiders (*Pirata piraticus* and *Lycosa pullata*) from a Danish sphagnum bog. *Oikos* **3**: 1–21.

RATCLIFFE, D. A. 1977: *A nature conservation review*. Cambridge: Cambridge University Press.

RICHTER, C. J. J. 1971: Some aspects of aerial dispersal in different populations of wolf spiders, with particular reference to *Pardosa amentata* (Araneae, Lycosidae). *In* P. J. Den Boer (ed.). *Dispersal and dispersal power of carabid beetles*. Waginineni: H. Veenman & Zonen: 77–88.

RODWELL, J. S. (ed.). 1992: *British plant communities,* **3**. Cambridge: Cambridge University Press.

RUSHTON, S. P. & EYRE, M. D. 1989: The spider fauna of intensively managed agricultural grasslands. *J. appl. Ent.* **108**: 291–297.

RUSHTON, S. P. & EYRE, M. D. 1992: Grassland spider habitats in north-east England. *J. Biogeogr.* **19**: 99–108.

RŮŽIČKA, V. 1989: Spider (Araneae) communities of rock debris on a typical hillside in the České Středohoři Mts. (North Bohemia). *Acta ent. bohemoslovaca* **86**: 419–431.

SANDERSON, R. A., RUSHTON, S. P., CHERRILL, A. J. & BYRNE, J. P. 1995: Soil, vegetation and space: an analysis of their effects on the invertebrate communities of a moorland in north-east England. *J. appl. Ecol.* **32**: 506–518.

SECHTEROVÁ, E. 1992: On the biology of species of the genus *Coelotes* (Araneae, Agelenidae) in central European Mountains. *Acta ent. bohemoslovaca* **89**, 337–349.

TOPPING, C. J. 1993: Behavioural responses of three linyphiid spiders to pitfall traps. *Entomologia exp. appl.* **68**: 287–293.

TOPPING, C. J. & SUNDERLAND, K. D. 1992: Limitations to the use of pitfall traps in ecological studies exemplified by a study of spiders in a field of winter wheat. *J. appl. Ecol.* **29**: 485–491.

WEYMAN, G. S., SUNDERLAND, K. D. & FENLON, J. S. 1994: The effect of food deprivation on aeronautic dispersal behaviour (ballooning) in *Erigone* spp. spiders. *Entomologia exp. appl.* **73**: 121–126.

WHEATER, C. P. & CULLEN, W. R. 1997: The flora and invertebrate fauna of abandoned limestone quarries in Derbyshire, UK. *Restoration Ecol.* **5**: 77–84.

UETZ, G. W. & UNZICKER, J. D. 1976: Pitfall trapping in ecological studies of wandering spiders. *J. Arachnol.* **3**:101–111.