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

# Spider biodiversity on Scottish agricultural land

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## Summary

In an ongoing study, a number of sites of varying agricultural land use, ranging from intensive arable fields, through grasslands, to extensive upland heather moorland, were sampled to study biodiversity. The principal aim is to provide a means of predicting the impact of changing land use, or land management, on biodiversity of plants, selected invertebrate groups and birds. During 1996, spiders were collected by pitfall trapping, and a set of environmental, landscape and management variables measured, from 50 sites throughout mainland Scotland. The relationships between spider species diversity and species composition against a defined management intensity gradient are investigated. Some initial findings are presented and the implications for biodiversity conservation on farmland considered.

## Introduction

Agriculture is the primary land use in Scotland today, covering about 76% of the land area (SOAEFD, 1996). It uses a wide variety of different management intensities, ranging from the homogeneous and intensively managed arable-dominated landscapes of the east coast to extensive grouse moorland in the uplands and the traditional crofting communities of the north and west. This management gradient has considerable influence on the local flora and fauna, affecting all aspects of their ecology, behaviour and distribution (McLaughlin & Mineau, 1995).

The biodiversity of invertebrate communities on agricultural land is important both in terms of pest control and conservation. With these in mind, this project was established with the aim of providing a means of predicting the impacts of changes in land use, or land management, on the biodiversity of plants, selected invertebrate groups and birds (Abernethy *et al*., 1996). This paper presents some initial results from this study, examining the responses of the ground-layer spider fauna from a large number of sites in Scotland, against a range of agricultural land uses and management practices, focusing on the overall spider species diversity and species composition. The applicability of using these data for the development of predictive models is discussed. The outcome will ultimately provide essential information on the impact of agricultural policy changes on a broad spectrum of wildlife within a range of ecosystems in Scotland.

## Sites and methods

Fifty sites were sampled from seven localities throughout mainland Scotland during 1996 (Fig. 1) covering a land-use gradient of arable crops, through intensive pasture and silage


Fig. 1: Map showing location of sampling areas in Scotland during 1996 (black circles) and new areas chosen for sampling during 1997 (open circles). Repeat sampling of selected 1996 sites will be carried out at Crianlarich and Crieff during 1997. See Table 1 for number of sites and land-use type in each area sampled during 1996.

| Location | Central grid ref. | No. of sites | Principal land use |
|---|---|---|---|
| Skerray | NC 66 62 | 10 | Crofting |
| Tain | NH 84 79 | 7 | Mixed |
| Dalwhinnie | NN 63 86 | 3 | Heather moorland |
| Crianlarich | NN 35 30 | 9 | Hill farming |
| Crieff | NN 94 24 | 15 | Mixed |
| East Linton | NT 56 76 | 4 | Arable |
| Auchincruive | NS 37 23 | 2 | Dairy |

Table 1: Number of pitfall trap sites at each sampling location (with approximate national grid reference for the centre of the sampling location) and the principal land-use type.

fields, to upland extensive sheep grazing and crofting. Examples of heather moorland and gorse pasture were also included, but forestry was excluded. Table 1 gives a brief description of the location and principal land use for each area.

Eight broad management variables were recorded at each site: soil disturbance, cutting, grazing, inorganic fertilizer, organic manure levels, pesticides, sward type and age. Each was assigned a score on a four-point scale, from 0–3 in ascending order of intensity (e.g. Soil disturbance—1: only harrowed once in previous three years; 2: ploughed once in previous three years; 3: ploughed twice or more in previous three years. Cutting—1: topping only; 2: one complete cut and removal of vegetation; 3: two or more complete cuts and removal of vegetation). From these scores, a cumulative Management Intensity Index (MII) was compiled (giving a possible range of 0 to 24) for each site (following Blake *et al*., 1996).

Ground-layer spiders were collected using 9 pitfall traps (plastic cups, 75 mm diameter) placed 2 m apart in a straight line at each site. The trapping fluid used was propylene glycol and each trap was covered by a wire mesh (15 mm diameter) to prevent capture of small mammals and to reduce trap interference from farm livestock. In total, 450 pitfall traps were operated on 50 sites, serviced at roughly 4-week intervals (from May to September 1996). The material from all 9 traps at each site was collected and bulked prior to identification.

Between-site variation in species diversity was determined using log spider species richness (S), and Detrended Correspondence Analysis (DCA: Hill, 1979) was used to determine variation in species composition between the sites and across the management gradient. All species found were used in the DCA as percentage of the catch at each site, a common procedure for the analysis of pitfall captures (see Luff, 1996 and references therein). Sites were classified into ecological groups in ordination space using fuzzy clustering techniques (Equihua, 1990).

## Spiders

The use of pitfall traps for between-site comparisons within spider communities (especially when considering such a range of habitat types) poses well known problems of variations in trap

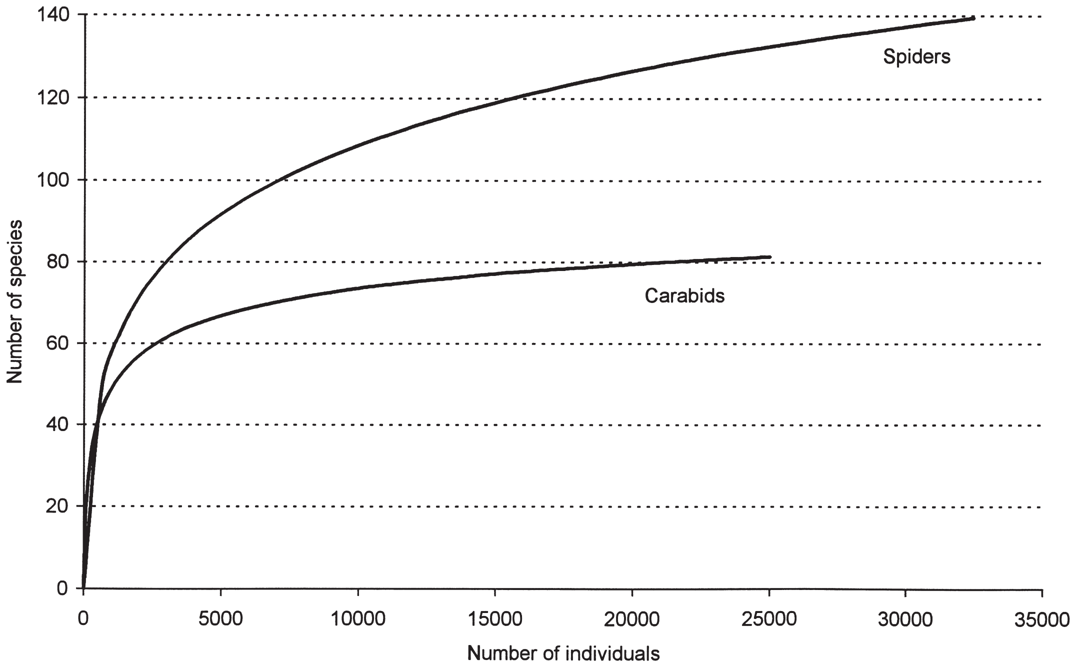


Fig. 2: Species-abundance (rarefaction) curves of the total spiders and carabid beetles trapped; 50 sites combined from 1996.

efficiency between the different habitats (see Toft & Riedel (1995) for an extensive discussion). Most criticism of their use occurs where workers use pitfall data to estimate species densities between highly variable habitats, which was not the principal aim of this survey. For this type of extensive study, pitfall traps can be considered an acceptable method of estimating the species represented at each site. Alternatives recommended for more intensive studies were considered (e.g. suction sampling), but proved unsuitable for extensive sampling because they are labour intensive and they have their own between-habitat catch variability (Sunderland & Topping, 1995). We have continued to use pitfall traps for this study because of their ease of use and low maintenance, and because they provide good data for surveys focusing on habitat species richness. Despite the large number of reviews which condemn pitfall traps, their authors have failed to suggest a better alternative.

The species-richness data was log transformed to make the data normal. This transformation may also contribute to reducing any bias introduced as a result of the variation in trapping efficiency from different habitats. In total, 33,123 individual adult spiders of 140 species from 16 families were captured during 1996. Numbers of specimens at each site ranged from 42 to 1572 and the species richness ranged from 10 to 56, after accumulating the season's catch.

Estimation techniques (rarefaction: Krebs, 1989) suggest that the pitfall traps have sampled a large proportion of the available species, and that any between-site bias in unrecorded species will be relatively low in relation to the complete dataset, to which the management intensity is being compared (as described in Sunderland *et al.*, 1995). Figure 2 shows the species-abundance curve using rarefaction for the spiders from all sites combined over the year, also giving a comparison with the carabid beetle data from the same traps. The curves show the spiders have not reached an obvious plateau, suggesting that using pitfall traps the estimated maximum number of species still has not been attained. Estimates based on doubling the

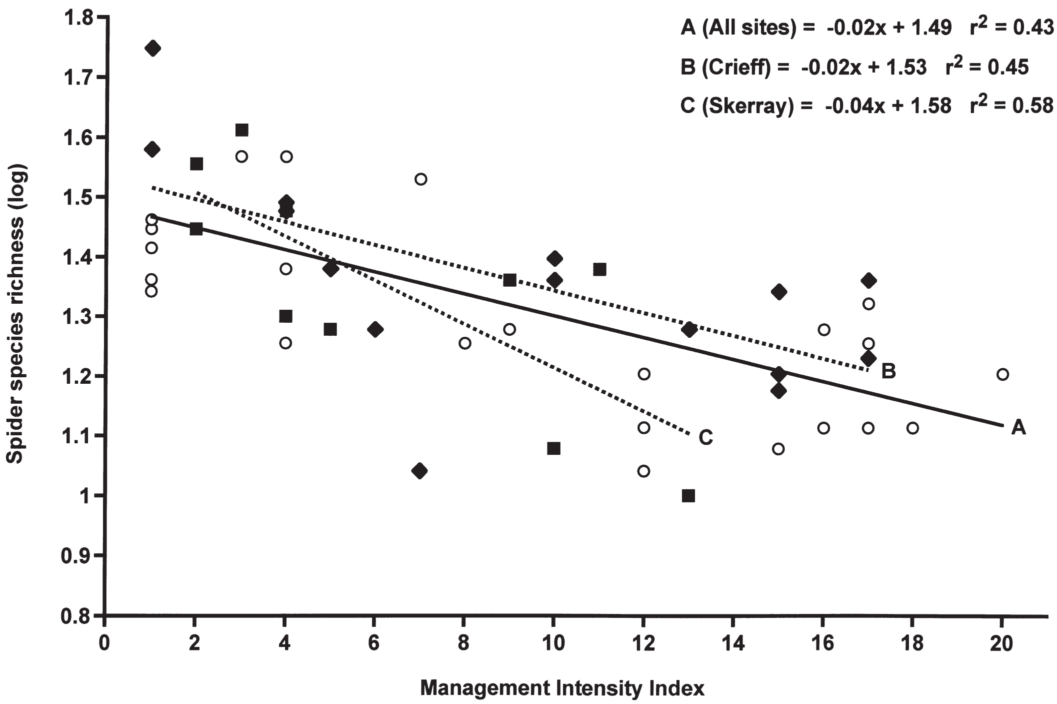


Fig. 3: The relationship between spider species richness (log) and management intensity at **A** 50 sites throughout Scotland (all data points); **B** 14 sites near Crieff (filled squares only); **C** 10 sites near Skerray (filled diamonds only).

number of specimens taken (an extra 33,000 specimens) using a modification of the model described by Colwell & Coddington (1994), $S_{(est.)} = 154$, gave an addition of 14 species. The carabids show a better trapping response: estimates for an extra 26,000 specimens gave $S_{(est.)} = 85$, an addition of only 2 species on the actual numbers taken (Abernethy *et al.*, 1997).

## Results

Species richness (log) was found to decrease significantly with increasing management intensity (Fig. 3) as defined by the Management Intensity Index ($r = -0.66$, d.f. = 49, $P < 0.001$). This trend was emphasized firstly by the lack of relationship between logS and the log number of individuals taken from each site ($r = 0.18$, d.f. = 49, ns), and secondly, when the influence of altitude was removed, the correlation between logS and MII was still significant, although lower ($r = -0.43$, d.f. = 49, $P < 0.01$), suggesting that management was the primary influence in decreases in logS across the 50 sites. Management had a similar influence on the number of families (not log) of spider found at each site ($r = -0.83$, d.f. = 49, $P < 0.001$).

To ensure that the species-management relationship was not an artefact of geographical location (e.g. sites from Skerray may have a lower total species pool than sites in central Scotland), the species-management relationship was investigated for the Skerray and Crieff areas (both with 10 or more sites and a wide range of management regimes). Species richness was found to decrease significantly with increasing management within both areas (Skerray: $r = -0.76$, d.f. = 9, $P < 0.01$; Crieff: $r = -0.67$, d.f. = 14, $P < 0.01$), as shown in Figure 3.

Figure 4 shows the sites ordinated and classified, using Detrended Correspondence Analysis and fuzzy clustering based on their spider fauna,

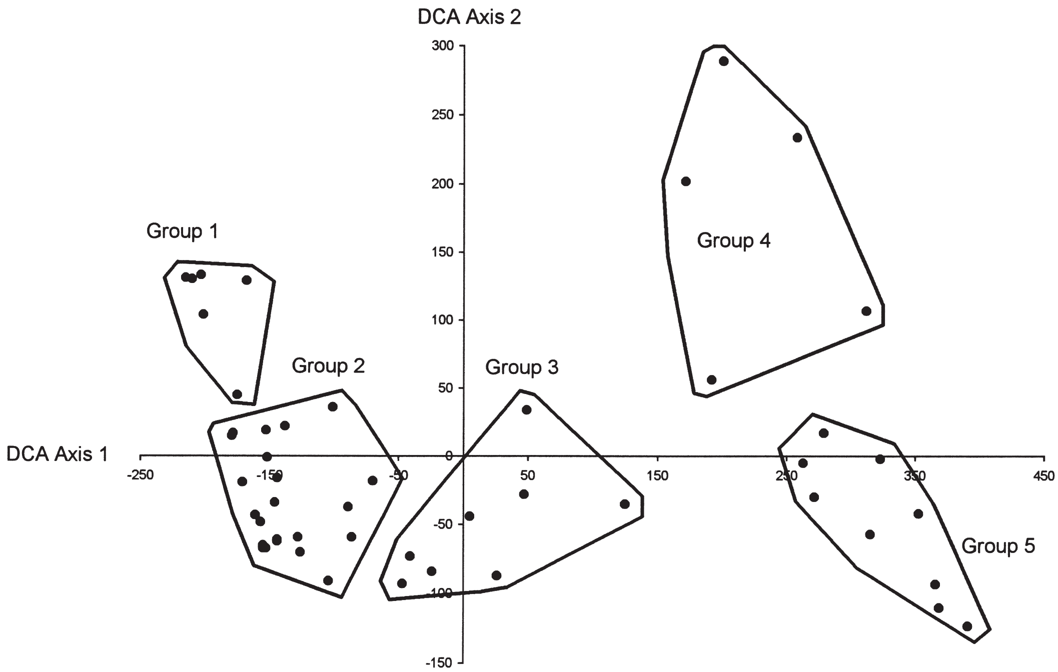


Fig. 4: DCA ordination of 50 sites based on their spider fauna, overlaid with fuzzy clustering groupings. Eigenvalues: Axis 1 = 0.79; Axis 2 = 0.45.

into five groups (Eigenvalues: Axis 1 = 0.79, Axis 2 = 0.45; fuzzy partition coefficient = 0.65). Table 2 shows the number of sites and the habitat characteristics within each fuzzy group. There is a good separation of the sites into ecologically sensible groupings. Most of the sites within each group are similar in their habitat characteristics from a spider perspective, indicating an ecologically robust classification of the data. Some outliers are present in each group, an artefact of fitting a hard classification to continuous ordination axes, though the

| **Fuzzy groupings** | **Mean S (range)** | **Characteristics of sites** | **Mean MII (±SE)** |
|---|---|---|---|
| Group 1 ($n = 6$) | 15 (12–19) | High-intensity arable and high disturbance set-aside with coarse grass | 16.0 ± 1.9 |
| Group 2 ($n = 22$) | 18 (16–20) | Low-intensity arable and high disturbance grassland (by mowing or stock) | 12.0 ± 0.9 |
| Group 3 ($n = 8$) | 24 (18–33) | Upland or northern grassland. Includes two small-scale arable sites within crofts | 5.8 ± 1.2 |
| Group 4 ($n = 5$) | 28 (21–36) | Upland or northern wet pasture sites. Includes wet flushes, valley mire, and *Juncus*-dominated sites | 2.2 ± 0.7 |
| Group 5 ($n = 9$) | 31 (25–40) | Upland sites dominated by heather. Also includes gorse- and bracken-dominated sites | 2.7 ± 0.7 |
| **ANOVA** | $F_{4,45} = 10.1$ $P < 0.001$ | | $F_{4,45} = 21.8$ $P < 0.001$ |

Table 2: Mean spider species richness (S) with range, habitat characteristics and the mean Management Intensity Index (MII) for the five fuzzy clustered groups. Mean S and range derived from back transforming log data used for ANOVA.

classification also shows strong similarities to the group characteristics found for the sites during vegetation analysis (Abernethy *et al.*, 1997).

The mean species richness of the sites within each fuzzy grouping is shown in Table 2, and was found to vary significantly between the five groups, increasing along DCA Axis 1, lowest in group 1 (15 species; intensive arable), increasing to more than double this number in group 5 (31 species; mainly heather). The site scores along Axis 1 were also found to be negatively correlated with the management gradient ($r = -0.78$, d.f. = 49, $P < 0.001$), indicating that management influenced the species composition of the fauna. This trend was also reflected in the mean MII value for each fuzzy group shown in Table 2.

## Discussion

Spiders are one of the major predatory groups within the agroecosystem, and are intrinsic in maintaining the ecological balance of pest species (see Wise, 1993 and references therein). Their biodiversity within this system is therefore important in providing a stable and natural method of pest control. A more diverse and stable species pool also ensures a proportion of the predatory fauna will adapt to otherwise catastrophic changes in farming practice.

It is well documented that species diversity within agricultural habitats has decreased as a direct result of several decades of agricultural development (see Potter (1997) and Potts (1997) for general reviews). Indeed, the number of studies showing a negative response from within the invertebrate community to more singular management methods (e.g. increasing grazing, pesticide use or cutting) are too numerous to mention here. The results of this initial study also showed a significant decrease in spider species diversity and a change in the species composition with increasing overall management intensity. Family composition also showed a characteristic response to the management gradient (e.g. highly disturbed sites typically contained mostly Linyphiidae species, while more stable sites sampled had higher proportions of non-linyphiid families). Other environmental factors (vegetation, soil and landscape variables) will certainly have an important and additional influence on this community response, but it is considered that the management gradient defined here has the most important and direct influence. Indeed, the results indicate that the influence of management is more important even than geographical location for determining spider diversity (Fig. 3) and species composition (geographically distinct but similarly managed sites were pooled together in Figure 4, whilst broad management groups were dissimilar).

When considering how variations in land use affect invertebrate biodiversity, it is, however, important that the focus is not simply put on changes in species richness. The conservation quality of sites is also determined by the "value" of the species present. One way of determining this is by considering rarity status of each species at a variety of levels, such as local, national and international, and using these to establish an overall "rarity" or "quality score" for each site.

Further analysis of the spider datasets presented here will concentrate on the relationships between management intensity and the conservation value of the spider fauna present. In addition, an attempt will be made to develop a mathematical model which relates all of these various factors to each other and ultimately allows an accurate prediction of the spider (and other groups) biodiversity on farmland to be made. Indeed, the findings from this study suggest that the spider fauna is sensitive enough for use in the modelling process, and several new and repeated sites (Fig. 1) will be sampled to test the model accuracy.

## Acknowledgements

We are particularly grateful to the many landowners who gave both permission to sample on their land and information about their land management. We are also grateful to N. Hammond and A. Harris for assistance with fieldwork and invertebrate sorting, and to J. Stewart for confirming difficult specimens. Thanks are also due to A. Adam, S. Blake, R. W. Furness, K. J. Murphy and W. L. Wilson for useful discussions on the project work, and P. Dennis for comments on the manuscript. SAC receives financial support from the Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD).

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