BIODIVERSITY IN AGRICULTURE. BEETLES IN ADVERSITY?

G N FOSTER, S BLAKE, I S DOWNIE, D I McCRACKEN, I RIBERA
SAC, Environmental Division, Auchincruive, Ayr KA6 5HW, Scotland, UK

M D EYRE
EMS, 13 Manor Grove, Benton, Newcastle upon Tyne NE7 7XQ, England, UK

A GARSIDE
Dundee Museum & Art Gallery, Albert Square, Dundee DD1 1DA, Scotland, UK

ABSTRACT

The use of ground beetles (Coleoptera, Carabidae) as indicators of biodiversity is discussed. Pitfall trap data from 359 sites in Scotland in a range of natural, seminatural and cultivated habitats were analysed in relation to the rarity status of the species in Scotland. Arable land and grasslands were intermediate between the best and least diverse natural habitat types even though they supported few very rare or habitat-specific species. Managed farmland is an important habitat complex in its own right in Scotland, requiring consideration when developing conservation management policy.

INTRODUCTION

A perception held by many conservationists is that agriculture is damaging for wildlife, and that biodiversity is reduced as a result of modern agricultural practices, in particular the use of pesticides, the increase in autumn-sown arable crops resulting in the loss of winter stubbles, and intensification resulting in loss of marginal habitats. However, the UK Government Panel on Sustainable Development (1996) recognised the importance of agriculture in maintaining special habitats, and many species of bird are dependent on farmland habitats (Royal Society for the Protection of Birds, 1995). Invertebrate studies on farmland are largely concerned with pests, with pollinating, predatory and parasitic insects, with insects of aesthetic appeal associated with hedgerows, and finally with insects providing food for game birds, mainly in arable headlands. There have been few attempts to compare the species richness and conservation value of insect communities in ordinary farmland with that of natural and semi-natural vegetation. This paper reports preliminary findings based on a large data-set assembled for the ground beetles (Carabidae) in Scotland.

Ground beetles (Carabidae) as a group for biodiversity studies

Ground beetles were chosen as the basis for study because of several features:

- there are 190 species recorded from Scotland, with a wide range of functional types occupying all terrestrial habitats at all altitudes, including those devoid of vegetation;
- the distributions of ground beetles are well known because of the operation of an effective recording scheme (Luff, in press);

- ground beetle habitats and life-cycle traits have been the subject of much research;
- ground beetles are the principal ground predators in crops, attacking many soil and foliar pests, but they include some phytophagous species, in particular seed-eaters, as well as scavengers;
- they are themselves prey items for birds and small mammals;
- some ground beetles have aesthetic appeal, being sufficiently large and photogenic to act as "flagship species";
- standardised survey is possible, using pitfall traps, replicate groups of which usually produce strikingly similar results within any habitat patch (Luff, 1996; Dufrène & Legendre, 1997).

This range of points in favour of ground beetles demonstrates their value as an umbrella group (New, 1997), i.e. indicator taxa for extrapolation to invertebrates in general (Pearson, 1994). Lövei and Sunderland (1996), in reviewing achievements in studies of carabid ecology and behaviour since the major review of Thiele (1977), have drawn attention to the potential of ground beetles as indicator organisms for various assessments, including biodiversity. They recognise the value of the pitfall-trapping technique and accept that it is suitable for studying basic community patterns, but state without evidence that it "should probably not be used to study ... relative species composition or diversity", preferring to reinstate it as an efficient method only after detailed methodological and behavioural studies have been completed, and validated techniques developed. Such perfection is unlikely to be achieved, or if achieved, is unlikely to be usable. We prefer to take advantage of the method's popularity as a passive, objective method of generating summary statistics over a wide range of habitats, always being aware of the risks associated with comparative analyses between habitats.

MATERIALS AND METHODS

A data set was assembled based on pitfall trap catches from over 400 sites in Scotland. Typically a catch was based on the bulked samples from nine pitfall traps operated from late April to late September (e.g. Blake *et al.*, 1996). In the present analysis some catches are based on fewer traps with discontinuities of operation, but all sites were sampled with sufficient intensity to ensure an adequate inventory of species.

Vegetation was classified to National Vegetation Classification (NVC) type (Rodwell, 1991, 1992, 1995). In some cases, the classification was done several years after pitfall sampling had taken place. Sites were excluded from analysis if there was evidence of change in NVC type since trapping or if a site was transitional between two or more NVC types. With these exclusions, and with the inclusion of sites on tilled land, river shingles and bare peat, data from 359 sites were available for analysis, based on 132 species.

Species rarity scores

Where good quality distribution data are available, species can be ranked from rarest to commonest using a count such as the number of 10 × 10 km squares of the National Grid that they occupy. Species are then assigned to 'octaves' (Preston, 1962), i.e. categories of abundance in which the least occurrence doubles from 1 record to records for 128 or more 10 km squares (Table 1).

Various indices can be derived from such rarity scores, the mean quality score (MQS) being the aggregate of scores for the species present divided by their number (Foster *et al.*, 1992). The contribution of species of each rarity score to an assemblage, i.e. the disaggregated MQS, can also produce results of relevance to the biodiversity debate (Foster *et al.*, in press). The present paper is concerned largely with MQS and other indicators of conservation quality such as the number of species present (species richness) and the presence of species nationally recognised as rare.

RESULTS

Species richness

Species richness varied between habitat type, the lowest number of species recorded being 5 at an upland site and the highest, 33, on river shingle (Table 2). The richest sites on average were in moorland dominated by heather (*Calluna vulgaris*) and bracken (*Pteridium aquilinum*). The least species-rich sites were in moorland dominated by purple moorgrass (*Molinia caerulea*) and in woodland, irrespective of the dominant tree type. Arable land and grasslands were intermediate in species richness between the most and least rich natural habitat types.

When mesotrophic grasslands (MG) were considered as separate types, MG1 had the highest average species richness of all habitat types (lower part of Table 2), and sown MG5 grasslands used for grazing (MG5) had a higher average species richness than MG6 and MG7 types used primarily for grazing and silage.

Common species

Nineteen species were caught at more than 100 sites. Of these, five were found in all habitat types and only one, *Pterostichus niger*, had a high level of occurrence (>40%) in each category (Table 3). *P. niger* was typically the largest species associated with grasslands and arable land, *Carabus* spp. and *Cychrus caraboides* having a very low level of occurrence in such habitats.

The smallest common species were *Clivina fossor* and *Bembidion lampros*. They were of frequent occurrence in catches from arable land and grasslands.

Nebria brevicollis, which was the most frequently recorded ground beetle in the national recording scheme (Luff, 1982), was not caught in moorland habitats, being at high frequency only in catches from arable land, grasslands, scrub and woodland.

As might be expected, those habitat categories surveyed most extensively - grasslands, mires and uplands - supported all of the commonest species. Woodlands, however, with only 20 sites sampled, also supported all such species.

Table 1. Allocation of species rarity scores to ground beetles (Carabidae) in Scotland. The commonest species, *Nebria brevicollis,* is recorded from 204 10 x 10 km squares of the National Grid, so it and 12 other species occurring in more than 127 grid squares score 1 point, whilst those 23 species known to occur in only 1 square score 128 points.

No. of squares	>127	64-127	32-63	16-31	8-15	4-7	2-3	1
Species rarity scores	1	2	4	8	16	32	64	128
No. of spp. in each category in Scotland	13	19	31	31	35	18	20	23
% of spp. in each category in present data-set	100	100	100	71	60	61	55	18

Table 2. Species richness of ground beetle assemblages in pitfall catches in different habitat types in Scotland, ranked in order of decreasing mean number of species per site. NVC codes are those of Rodwell (1991, 1992, 1995).

Habitat type	Number of sites	Range of spp. numbers	Mean number spp.
Heather moorland	11	12-24	17.4
Bracken	8	8-25	17.2
Saltmarsh	4	8-23	16.3
Scrub	10	13-20	15.5
Swamps, mainly S4 and S28	26	6-21	15.5
Dunes	12	7-32	15.2
Bare peat	15	10-22	14.4
Arable	20	10-29	14.2
All MG grasslands	72	8-25	13.9
Mires	53	6-25	13.5
Shingle	24	5-33	13.4
Heathland, mainly H10 and H12	18	7-19	12.9
All upland, mainly U4 and U5	45	5-24	12.8
Woodland	20	6-16	11.5
Purple moorgrass moorland	21	7-17	10.8
MG1 grassland	4	15-24	19.5
MG5 grassland	24	11-25	14.6
MG11 grassland	10	11-23	14.2
MG6 grassland	10	9-18	13.8
MG7 grassland	20	8-15	12.0

Table 3. Occurrence of common ground beetles in pitfall catches from different habitat types, as measured by their percentage incidence in sites. Only values above 40% are given.
Cv = heather moorland; Pa = bracken-dominated moorland; Sa = saltmarsh; Sc = scrub; Sw = swamp; Du = dunes; Bp = bare peat; Ar = arable; Gr = mesotrophic grasslands; Mi = mires; Sh = shingle; He = heathland; Up = upland; Wo = woodland; Mo = purple moorgrass moorland.

	Cv	Pa	Sa	Sc	Sw	Du	Bp	Ar	Gr	Mi	Sh	He	Up	Wo	Mo
Agonum muelleri								55	70						
Amara plebeja			50	60				70	67						
Bembidion lampros	55	50	50	60			53	50	66						
Calathus melanocephalus				50		100		40	65			67	79		
Carabus problematicus	100	88		50	54	58	87			56		83	58		71
Carabus violaceus	91	88		50			40					44	65		62
Clivina fossor			50		62			75	70						
Cychrus caraboides	64	88	50			42								45	43
Leistus rufescens		100	50	40		67				47		56		60	76
Loricera pilicornis		63	100	100	77			85	90	68	42	44		95	
Nebria brevicollis				90		42		95	96	44	54		52	85	
Pterostichus diligens	100	63			69		100			65		42	50		100
Pterostichus madidus	91	100		70	27		73	40	48			50	74	60	62
Pterostichus melanarius			50	50	46			55	76				45		
Pterostichus niger	100	100	100	60	85	42	53	65	69	62	54	61	47	65	81
Pterostichus rhaeticus	55						73			71		44	42		62
Pterostichus strenuus			100	80	92			40	77	47					

Species with a restricted habitat choice

Thirty one species were confined to catches in one habitat type (Table 4). Such "stenoecious" species were mainly members of *Bembidion*, a large genus of small species. Shingle supported 7 *Bembidion* spp. not caught in any other habitat, even when such habitats were investigated close to shingle beds. No species was caught only in either arable or MG7 grasslands.

Table 4. Number of species caught in only one habitat type

Habitat type	No. spp. confined to habitat	No. occurrences of stenoecious spp.
Shingle	9	58
Dunes	5	7
Mires	5	6
Swamp	3	15
Upland	3	3
MG6 grassland	2	3
Bracken	1	1
Heather moorland	1	2
Heathland	1	1
Saltmarsh	1	1

Scarce and threatened species

Of the scarce and threatened carabid beetles reviewed by Hyman & Parsons (1992), one Scottish species is classified as Endangered (Red Data Book List 1), four are Threatened (RDB List 3), 12 are classified as Notable in List A (Na - main criteria being occurrence in 30 or fewer 10 km grid squares in Great Britain, without recognised threat requiring classification as RDB species), and 28 are classified as Notable in List B (Nb - occurring in 31-100 grid squares in Great Britain).

Within the present data-set, 19 Nb species, one Na and one RDB3 were distributed across 14 habitat types (Table 5). Few of these species were found in arable land and grassland, the exceptions being *Amara fulva* on arable land at what is now the Mersehead RSPB Reserve and *Agonum nigrum* on undisturbed MG6 grassland at Caerlaverock NNR. A few more Na and Nb species were excluded from the data-set because the sites in which they were found did not correspond to a particular NVC or to an easily defined unvegetated habitat. For example, *Elaphrus lapponicus* and *Agonum moestum* were confined to a small area of spring-flushed "sheep walk" grassland.

Although some of these species are among the stenoecious species of Table 4, those that were caught more frequently ranged across several habitat types.

Mean quality scores for habitat types

The mean species quality scores for different habitat types ranged from 2.5 for woodland to 5.3 for MG6 grassland (Table 6). The latter value was high because some Caerlaverock NNR sites were classified as MG6 even though they were within tidal influence; reclassifying them as saltmarsh would bring the MQS for MG6 down to 3.3. The overall mean value was 3.57, and this was the level of the main farmland habitat types, arable land and MG7 grassland.

Table 5. Incidence of scarce and threatened species of the present data-set in different habitats. The habitat abbreviations are the same as in Table 3. R3 = Red Data Book 3; Na = Nationally Notable List A; Nb = Nationally Notable List B. These terms are explained in the text.

		Cv	Pa	Sa	Sc	Sw	Du	Bp	Ar	Gr	Mi	Sh	He	Wo	Mo
Agonum ericeti	Nb	7						2			5				3
A. nigrum	Nb									2					
Amara fulva	Nb						1		1			4			
Asaphidion pallipes	Nb											2			
Bembidion bipunctatum	Nb				2							1			
B. laterale	Nb			1											
B. monticola	Nb											1			
B. nigricorne	Nb	2													
B. schueppeli	Na										1	1			
Blethisa multipunctata	Nb					2									
Carabus nitens	Nb	5	2		1			4			12		2		3
Cymindis vaporariorum	Nb	1									1				
Elaphrus uliginosus	Nb										2				
Miscodera arctica	Nb	2	1					5				1			
Notiophilus aestuans	Nb										1				
Patrobus septentrionis	Nb										1				
Pterostichus aethiops	Nb	2			5										1
P. cristatus	Nb											1			
P. oblongopunctatus	Nb												1		
Trechus rivularis	R3	1													
T. rubens	Nb		1									4		3	

Table 6. Mean quality scores of ground beetle assemblages, ranked according to the mean

Habitat type	No. of samples	Minimum	Maximum	Mean for all sites in group
MG6	10	1.8	14.7	5.3
Heather moorland	11	2.3	10.7	5.1
Shingle	24	1.9	10.4	4.9
Dunes	12	2.0	13.6	4.7
MG11	10	2.5	8.6	4.0
Saltmarsh	4	3.2	5.0	3.9
Swamp	26	2.4	8.3	3.7
Mires	53	1.4	16.6	3.6
Bracken	8	1.2	16.6	3.6
Arable	20	1.7	8.5	3.6
MG7	20	1.9	9.5	3.5
Bare peat	15	1.7	4.6	3.4
Upland	45	1.2	12.2	3.2
MG5	24	1.9	7.3	3.1
Purple moorgrass moor	21	1.7	5.3	3.0
Heathland	18	1.8	4.0	2.8
Scrub	10	1.9	4.2	2.6
Woodland	20	1.4	5.3	2.5

Mean quality scores for individual sites

Land dominated by bracken had the lowest and highest individual site MQS. An attempt to identify the factors dictating the occurrence of outlying values resulted in the following:

Two arable sites had particularly high values. These were from a farm, now Mersehead RSPB Nature Reserve, in the extreme south of Scotland. Similarly the one outlying high value for MG11 grassland and the two for dunes were at Mersehead. The high scores at Mersehead were largely associated with the presence of thermophilous species on the northern edge of their range.

The highest value for shingle was in an area surrounded by heather moorland.

The highest value for MG5 grassland was in the poorly drained bottom of a field from which other, low-scoring assemblages had been trapped on sloping, well drained land.

Variation in components of the MQS between habitats

Some habitats supported nearly all of the commonest species (species rarity scores of 1 and 2), whereas grasslands and arable land had just over half (Table 7). Within those habitat types with about 20 sites, shingle and swamp had the highest proportions of the intermediate categories, woodland and moorland having the fewest species. Duneland, as represented by only 12 sites, had two of the rarest species (i.e. previously known to occur in only one 10 km grid square), and MG6 grassland, with ten sites, supported four species with species rarity score 64. The anomaly of the MG6 grasslands with tidal influence has already been indicated; three of the high-scoring species were caught at such sites, the other species being *Bembidion obtusum* which, although common on agricultural land elsewhere, is scarce in Scotland.

Table 7. The percentage of ground beetles in four rarity categories by habitat type. Analysis is confined to those habitats with about 20 sites. Sites are ranked according to the level of occurrence in the categories for common beetles.

Habitat type	% of species occurring in Scotland in four rarity categories based on 10 km grid square counts			
grid square counts	>63	16-63	4-15	1-3
no. spp. available	43	53	62	32
Shingle	91	45	21	2
Swamp	84	42	13	2
Woodland	84	21	6	0
Heathland	81	35	6	0
MG5	59	35	6	2
Arable	56	37	6	2
MG7	53	31	8	2
Purple moorgrass moor	53	23	9	0

DISCUSSION

Concern about biodiversity, as expressed at the "Rio Summit" (United Nations, 1992), was primarily concerned with species extinction and consequent loss of species richness. Therefore, the sheer number of species to be found at a site cannot be regarded as a misleading measure of biodiversity. On this basis, the biodiversity of intensively farmed land, as indicated by an important group of invertebrates, is intermediate between the best and most impoverished natural habitat types. When grassland types are considered separately, those associated with intensive grazing and silage support fewer species than other grasslands or arable land. It should be noted that the present results are based solely on trapping within large tracts of the same habitat. Inclusion of marginal habitats, such as headlands and hedgerows, would increase the estimates of species-richness for farmed sites. When the mosaic of land use associated with many Scottish farming enterprises is taken into account, it should come as no surprise that farmland is intrinsically more species-rich, with more community types, than many similarly sized natural and seminatural areas (Foster *et al.*, in press).

Intensively farmed land does not support large species, except for *Pterostichus niger*. The long-lived larvae of the larger species of ground beetles do not tolerate either the disturbance associated with regular tillage or the sward height reduction associated with grazing and silage. Further, the many small species associated with natural expanses of unvegetated land do not tolerate the conditions associated either with arable production or with close swards. Such a restriction on body size might reduce the functional biodiversity of ground beetles within farmland, at the very least reducing the spectrum of prey items and the value of such invertebrates if perceived in terms of the potential for pest control.

Arable land and grasslands do not support stenoecious species or many scarce and rare species, as classified according to British distribution. When species are rated according to their known occurrence within Scotland, however, arable land and farmed grassland support relatively few of the most common species and more of the species of intermediate rarity than habitat types such as woodland and moorland.

Arable land and grasslands still occupy an intermediate position between natural habitats when rated for Mean Quality Score. MQS may be regarded as another measure of biodiversity in that it represents the contribution of a site (as measured from its pitfall catch) to the biodiversity of the region for which the individual species rarity scores are calculated. On this basis it is entirely logical that farm habitat types should fare well in comparison to many unfarmed habitats. Arable land, for example, occupies only 13% of Scotland's land surface, and any species primarily associated with it must be rarer, say, than those associated with the more extensive tracts of moorland.

Species richness and MQS should be treated as part of an array of factors on which to assess biodiversity. Interpretation based on MQS alone does have some dangers. For example, how does one rate two sites, both with the same rare species, but one with many more common species? Fortunately such situations are uncommon, being confined to shingles within the present data set. Yet another measure of biodiversity, the aggregate of the rarity scores for all species found at a site, is often abused in assessing invertebrate conservation values because of failure to take into account the effects of sampling effort. The use of MQS avoids this problem.

Finally it might be noted that this survey based on pitfall trapping has caught all of the species in the first three of seven rarity categories of species, more than half of those in the next three and has detected a fifth of those species in the final, most rare category (Table 1). The present pitfall-trapping effort has added three species to the Scottish list, emphasising yet further the value of this technique, which is primarily used because it generates an abundance of robust community statistics.

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