Ann. Zool. Fennici 33: 157–163
Helsinki 14 June 1996

ISSN 0003-455X

Assessing the potential for environmental monitoring using ground beetles (Coleoptera: Carabidae) with riverside and Scottish data

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Received 7 September 1995, accepted 14 March 1996

Ground beetle survey data were used to produce three habitat classifications; a national and a local riverside classification generated by hand searching and a Scottish classification from a pitfall trap survey. The classifications provided a clear picture of the habitats of the assemblages sampled, even when the data were from a number of sources, and were especially good with data from standardised sampling. Species rarity scores were derived from distribution records from either national or local surveys. These were used to generate site rarity values by summing species scores and dividing by the number of species. These were used as a measure of site quality and provided a mechanism for ranking sites within habitat groups. This methodology worked at the local, regional and national scales and it appears that there is great potential for the use of ground beetle data from structured, standardised surveys in assessing environmental quality.

1. Introduction

Invertebrates need to be utilised in the estimation of site and conservation quality (Ratcliffe 1986). Considerable effort has been applied to sampling ground beetles, usually with pitfall traps, in the Netherlands (Turin *et al*. 1991), Belgium (see Maelfait *et al*. 1994), the United Kingdom (Eyre & Luff 1990a, Luff *et al*. 1992, Luff 1996a) and to a lesser extent in other European countries (see Eyre & Luff 1990b, Stork 1990, Desender *et al*. 1994).

Quantification of site quality based on species rarity scores derived from distribution records was advocated by Foster (1991) for use in assessing wetlands throughout Britain with water beetle species. Eyre and Rushton (1989) used this approach with water beetle and ground beetle data in north-east England to rank sites within habitat classifications (Eyre *et al*. 1986, Luff *et al*. 1989). There is a requirement for sites to be ranked within habitat types derived from classifications since it would be inappropriate to compare, for instance, the quality of coastal sites with that of upland sites and within conservation bodies in the UK one objective is to preserve good examples of habitat type. Rarity is a highly 'political' conservation criteria easily understood by the public (Ratcliffe 1986) and one of the best criteria to use in site assessment.

There has been a number of investigations into the ground beetles of river sediments (e.g. Andersen 1968, Ravizza 1968, Plachter 1986, Fowles 1989) and work on a variety of habitats in northern England (e.g. Luff *et al*. 1992, Eyre 1994, Eyre & Luff 1994) using a standard pitfall trapping procedure. However, there have been no previous attempts to produce habitat classifications for either riverside habitats or for other regions using standard procedures. The production of a new ground beetle atlas for the United Kingdom (Luff 1996b) has allowed for the estimation of species rarity on larger scales than that used by Eyre and Rushton (1989) when outlining the quantification of conservation criteria at the local level.

It is now apparent that there is a growing interest in the use of a number of groups of other invertebrates than ground beetles, such as hoverflies (Castella & Speight 1996), molluscs (Castella *et al*. 1994) and aculeate Hymenoptera (Archer & Burn 1995), for assessing the effects of land use change and for conservation purposes. For a group of invertebrates to be used regularly in this field, it would be an advantage if a standard approach could be generated which would operate at different scales covering a range of habitat types. This paper is an attempt to assess the potential of using ground beetles in environmental and conservation assessments with data from local, regional and national sources.

2. Materials and methods

2.1. Data

Three data sets were used; (1) a compilation of riverside ground beetle species lists from throughout the United Kingdom and Ireland, (2) records from pitfall trapping in Scotland and (3) local lists from a survey of one riverside in England.

1: A total of 194 ground beetle species lists, with at least four species each, from exposed riverine sediments in the United Kingdom and Ireland were assembled from a number of recorders interested in this habitat type. 80% of the data came from three areas of the United Kingdom (north-east England, Wales and midland England), sampled between 1980 and 1992. The remainder of the data were from Scotland, Ireland and from other river catchments elsewhere in England. These data was mainly generated by hand searching but there were also eight pitfall trap samples included.

2: 100 sites in eastern Scotland were sampled for ground beetles between 1987 and 1994 using pitfall traps (8.5 cm diameter, 10 cm deep) part-filled with ethylene glycol as a preservative. Nine traps per site were used in a line with 2 m spacing. Sampling was carried out from May to October with the traps emptied at monthly intervals.

3: A total of 141 sites on and near the River Soar in Leicestershire in midland England were sampled for ground beetles between 1991 and 1994 using a standardised hand searching method. Stretches of riverside sediment and abandoned channels were searched for a period of 30 minutes, in spring when the weather was fine and there was no interference with sampling efficiency.

2.2. Analysis

2.2.1. Classification

Classification was carried out using the first three site ordination scores (DECORANA – Hill 1979) as a basis for fuzzy set clustering (Bezdek 1981). This classification technique has proved to be the most appropriate in this sort of work and has been used regularly with ground beetle data (e.g. Eyre 1994, Eyre & Luff 1994). Presence/absence data were used with the national and local riverside data (as in Luff *et al*. 1989) whilst the percentage of each species in the total recorded was used with the Scottish pitfall trap data (as in Luff *et al*. (1992).

2.2.2. Site rarity values

Species rarity scores for species in the national riverside and Scottish pitfall trap data sets were derived from distribution records in the national ground beetle atlas (Luff 1996b). The scores for the national riverside data were based on the number of national 10 km squares each species was recorded from in Britain. They were on a geometric scale (1 = 256 or more squares, 2 = 128–255 squares, 4 = 64–127 squares, 8 = 32–63 squares, 16 = 16–31 squares, 32 = 8–15 squares, 64 = 4–7 squares, 128 = 2–3 squares and 256 = 1 square). The rarity scores for the Scottish species were based on the number of squares each species were recorded from in Scotland. The scores used were 1 to 64 (1 = 64 or more squares, 2 = 32–63 squares, 4 = 16–31 squares, 8 = 8–15 squares, 16 = 4–7 squares, 32 = 2–3 squares and 64 = 1 square). The same scores were used for species in the local riverside data set but they were based on the number of tetrads (2 × 2 km) each species was recorded from in Leicestershire.

To calculate site Species Quality Factor (SQF), species rarity scores in a list were summed and then divided by the number of species in the list. To indicate which sites were of the highest quality, a calculation of rarity association was carried out (see Eyre & Rushton 1989). The Rarity Quality Factor (RQF) was calculated using the scores of 2 and above in a list. To reduce any bias caused by the presence of one rare species in a list, if there was only one of the highest score, this was reduced to the next highest score. Scores of 2 or more were then summed and added to the total used to calculate the SQF. This grand total was divided by the number of species to give the RQF. The greater the difference between SQF and RQF, the greater the rarity association.

3. Results

3.1. Classification

3.1.1. National riverside data

Five groups were identified from the national riverside data set and the frequency of occurrence of species in the groups is given in Table 1. The largest variation in this data set, as shown by the ordination, was between rough sediments with no vegetation by fast flowing small rivers running off upland areas and vegetated, silt sediments by slow flowing, lowland rivers. The second axis of the ordination was related to sediment particle size with sand sites near the origin and rough, boulder sites at the other end.

Group 1 had 38 sites with most from Wales (35) and others from north Yorkshire, Northumberland and Ireland. These sites were by small rivers with fast flowing water and were composed of a good mixture of sediment particle sizes with little or no vegetation. There were 27 sites in group 2, mainly from north-east England (19) with others from Wales, Scotland and Ireland. These sites were similar to group 1 sites, by rivers of a similar size, but had more boulders and little vegetation. The main differences in species composition seemed to be due to regional distribution trends with characteristic species such as *Nebria gyllenhali* and *Bembidion tibiale* mainly limited to the northern England sites. Group 3 had 28 sites, mostly in north-east England (19) and some Welsh and Irish. These sites were by larger rivers than those in groups 1 and 2 with slower flow but had a similar mixture of sediment types. The presence of species such as *Elaphrus cupreus* and *Pterostichus nigrita* indicated that there was some vegetation cover. The 32 sites in group 4 were a mixture of sites from the English Midlands (19), north-east England (8), Wales (4) and one from southern England. These sites were located next to slow-flowing rivers with sand sediments including some silt and larger sediment particles. Group 5 was a large group of 69 sites all with silty sediments and considerable vegetation, from lowland, midland England except for one Irish site.

3.1.2. Scottish pitfall trap data

The ordination, on which the classification of the Scottish data was based, showed a major difference along axis 1 between the dune sites near the origin and *Phragmites* marsh sites at the other end. The secondary variation was related to a mixture of cover type and altitude since it was between lowland woods and upland moor sites. The classification yielded

Table 1. Frequency of occurrence (%) of species in the five groups from the fuzzy clustering of the national riverside data set (minimum 20% in one group). Species order is as in the first axis of DECORANA.

Species	Group				
	1	2	3	4	5
Bembidion andreae	34	30	–	–	–
Lionychus quadrillum	21	–	–	–	–
Bembidion stomoides	–	26	11	–	–
Bembidion monticola	3	29	7	–	–
Bembidion atrocoeruleum	92	89	14	6	–
Bembidion tibiale	18	74	50	3	–
Bembidion decorum	74	44	21	19	–
Nebria gyllenhali	–	48	57	6	–
Bembidion schueppeli	–	11	25	6	–
Bembidion punctulatum	66	22	4	42	7
Agonum muelleri	13	11	11	23	1
Agonum assimile	5	19	36	6	6
Bembidion femoratum	13	11	11	26	3
Nebria brevicollis	5	26	43	23	9
Notiophilus biguttatus	–	26	11	13	11
Loricera pilicornis	5	7	46	23	19
Agonum albipes	66	74	86	84	91
Bembidion tetracolum	50	56	68	81	71
Bembidion lampros	13	19	18	42	21
Clivina fossor	34	11	7	19	26
Elaphrus cupreus	–	4	50	–	23
Pterostichus nigrita	3	7	46	29	47
Pterostichus strenuus	5	4	18	39	37
Bembidion guttula	3	7	39	42	71
Pterostichus vernalis	3	4	–	10	24
Elaphrus riparius	3	–	11	48	51
Bembidion aeneum	–	–	18	29	67
Agonum marginatum	3	–	–	19	31
Bembidion biguttatum	–	–	4	29	69
Bembidion lunulatum	–	–	4	16	67
Bembidion dentellum	3	–	–	19	74
Bembidion gilvipes	–	–	–	10	53
Agonum micans	–	–	–	3	46
Bembidion properans	–	–	–	3	24

eight groups and the percentage composition of species assemblages are given in Table 2.

Group 1 contained 12 sand dune and dune grassland sites whilst group 2 contained a mixture of 19 woodland, scrub and tall vegetation sites. The 16 sites in group 3 also contained scrub vegetation as well as dry unmanaged grasslands. Group 4 consisted of 11 upland, heath sites with *Calluna* with 11 open, grassland sites, some managed and some coastal, in group 5. There were 12 unmanaged, damp grassland and heath sites in group 6 whilst group 7 consisted of 12 wet grassland, heath and marsh sites. Group 8 sites were also very wet but had taller vegetation than group 7 sites, especially *Phragmites*.

Table 2. The mean percentage of species in the assemblages of the eight groups from the classification of the Scottish pitfall trap data set (at least 3% in one group). Species order is as the first axis of DECORANA.

Species	Group							
	1	2	3	4	5	6	7	8
Broscus cephalotes	14	–	–	–	–	–	–	–
Calathus mollis	4	–	–	–	–	–	–	–
Calathus erratus	9	–	–	–	–	1	–	–
Calathus fuscipes	21	7	2	–	3	2	–	–
Calathus melanocephalus	10	1	6	2	4	2	–	–
Carabus problematicus	8	1	8	14	–	7	3	–
Amara aenea	4	1	12	–	1	–	2	–
Calathus micropterus	1	–	1	7	–	1	5	–
Amara lunicollis	3	–	6	2	–	–	–	–
Calathus piceus	–	6	–	–	–	–	–	–
Pterostichus madidus	4	30	1	1	6	1	4	–
Carabus violaceus	–	–	–	8	–	–	–	–
Nebria brevicollis	5	26	1	–	14	6	1	1
Pterostichus melanarius	2	1	11	–	12	7	–	1
Notiophilus biguttatus	–	2	1	2	1	2	2	–
Carabus glabratus	–	–	–	17	–	–	1	–
Pterostichus niger	5	1	10	1	6	10	1	1
Leistus rufescens	1	1	6	11	1	9	4	1
Amara plebeja	–	–	1	–	6	2	1	–
Pterostichus rhaeticus	1	4	4	6	–	5	12	1
Agonum dorsale	–	–	–	–	3	–	–	–
Trechus obtusus	–	–	6	2	5	1	–	–
Patrobus assimilis	–	1	–	6	–	–	5	–
Trechus quadristriatus	–	–	2	–	8	–	1	1
Pterostichus strenuus	–	1	8	1	6	5	4	6
Pterostichus diligens	–	–	1	1	–	1	3	1
Loricera pilicornis	–	5	4	9	5	15	15	8
Patrobus atrorufus	–	4	–	–	1	5	1	3
Bembidion tetracolum	–	1	–	–	3	1	–	1
Pterostichus nigrita	–	2	–	–	–	3	21	6
Bembidion guttula	–	–	–	–	–	–	–	5
Bembidion mannerheimi	–	–	1	–	1	1	2	7
Agonum fuliginosum	–	–	–	1	–	4	1	35
Agonum thoreyi	–	–	–	–	–	–	–	3
Elaphrus cupreus	–	–	–	–	–	–	–	8
Agonum gracile	–	–	–	–	–	–	–	5

3.1.3. Local riverside data

The main variation in the local riverside data was between very well vegetated abandoned channel sites and open, sand and shingle sediments. The secondary variation was between a mixture of vegetated sites, both abandoned channels and sediments and open, bare sediments, usually the result of river management procedures or from the effects of cattle on soft sediments. Five groups were derived from the classification. Frequency of occurrence of species in the groups is given in Table 3.

The sites in group 1 were mainly undisturbed abandoned channels with considerable amounts of vegetation and stable water levels. Group 2 sites were also abandoned channels but with fluctuating water levels, less vegetation and more open

Table 3. Frequency of occurrence (%) of species in the five groups from the classification of the local riverside data set (minimum 21% in one group). Species order is as in the first axis of DECORANA.

Species	Group				
	1	2	3	4	5
Agonum thoreyi	88	13	30	5	–
Bembidion clarki	12	44	30	5	–
Agonum fuliginosum	88	72	70	28	–
Pterostichus gracilis	29	3	13	–	–
Agonum livens	6	31	–	–	–
Pterostichus minor	35	50	30	5	–
Agonum obscurum	18	9	26	15	–
Agonum piceum	24	–	9	–	–
Bembidion assimile	35	6	22	3	3
Pterostichus strenuus	41	59	26	46	13
Demetrias atricapillus	35	22	9	10	10
Elaphrus cupreus	59	47	48	28	10
Agonum micans	53	78	78	51	6
Bembidion biguttatum	47	97	48	92	35
Pterostichus nigrita	53	59	67	59	26
Loricera pilicornis	6	28	9	23	6
Bembidion dentellum	24	84	78	82	42
Bembidion gilvipes	12	81	17	56	32
Pterostichus vernalis	6	47	13	33	13
Bembidion obtusum	–	34	–	31	3
Clivina fossor	–	25	–	13	19
Agonum albipes	35	75	70	92	71
Clivina collaris	–	16	4	26	10
Dyschirius luedersi	6	6	26	21	26
Bembidion guttula	18	56	9	82	45
Bembidion properans	12	19	4	13	32
Agonum marginatum	–	9	13	33	35
Trechus quadristriatus	–	6	–	18	45
Bembidion lampros	–	19	–	28	23
Bembidion articulatum	–	16	17	26	35
Bembidion tetracolum	6	28	9	64	74
Bembidion lunulatum	29	28	13	62	84
Bembidion aeneum	6	31	13	67	77
Elaphrus riparius	–	16	26	41	87
Bembidion punctulatum	–	–	–	3	23

patches than group 1 sites. Undisturbed silt riverside sediments with considerable vegetation made up most of the sites in group 3. The sites in group 4 were a mixture of vegetation and open, bare silt, the result of disturbance by river management procedures, such as channel straightening or bank regrading, or by cattle trampling on the soft substrate. Group 5 sites were the naturally disturbed open sand and shingle sediments with little vegetation.

3.2. Site rarity values

The mean Species Quality Factor (SQF) and Rarity Quality Factor (RQF) values, and ranges, of the sites in the groups derived from the three classifications are shown in Table 4. Also shown are the differences between the mean RQF and SQF values for each group.

The highest SQF and RQF values in the five national riverside groups were for sites in group 1, which also had the greatest difference between the two mean values. Sites in Wales were the highest quality sites and had a number of rare species, including *Lionychus quadrillum*. Group 4 had higher mean rarity values than the remaining groups, probably because these sites had more specifically river sediment species and fewer generalist species than sites in groups 2, 3 and 5. Group 5 sites had the lowest rarity values because of the presence of these general species, usually found in damp and wet grassland, whilst the values for groups 2 and 3 were slightly higher and similar. The differences between the mean SQF and RQF values were lowest for group 3 but these differences were also low for groups 2 and 5 and there was less rarity association in these three groups than in groups 1 and 4.

The eight Scottish habitat groups had low mean SQF and RQF values compared with the national riverside data means but were based on different species rarity scores. The highest values were for dune sites in group 1 with the remaining groups having very similar mean values and ranges. Differences between the mean rarity values were largest for group 5 and lowest for groups 4 and 6 but, in general, there was a limited amount of rarity association in all groups. A similar pattern was seen in the mean values, and in the differences between values, for the five groups of local riverside sites. The highest mean values were for undisturbed sediment sites in group 3 but they were only slightly higher than values for the more disturbed sites in group 4. Less disturbed abandoned channel sites in group 1 also had higher means than fluctuating water sites of group 2 but the differences were small.

Table 4. The mean Species Quality Factors (SQF) and Rarity Quality Factors (RQF) values, with ranges, of sites in the groups derived from the classification of the national riverside, Scottish pitfall trap and local riverside data sets, together with mean RQF-SQF differences.

Data set and group	Mean SQF and range		Mean RQF and range		Mean RQF-SQF differences
National riverside					
Group 1	8.08	(2.20–35.00)	12.04	(3.80–52.00)	3.96
Group 2	2.62	(1.00–11.50)	3.76	(1.00–17.00)	1.14
Group 3	2.64	(1.00–7.55)	3.67	(1.00–11.05)	1.03
Group 4	4.31	(1.60–16.33)	6.87	(1.60–29.00)	2.56
Group 5	1.94	(1.20–4.82)	3.04	(1.20–6.93)	1.10
Scottish pitfall trap					
Group 1	2.16	(1.36–5.29)	3.34	(1.79–6.47)	1.18
Group 2	1.59	(1.22–2.12)	2.40	(1.67–3.41)	0.81
Group 3	1.75	(1.21–2.42)	2.83	(1.64–4.32)	1.08
Group 4	1.54	(1.08–2.33)	2.18	(1.08–4.00)	0.64
Group 5	1.67	(1.33–2.62)	3.05	(2.00–4.62)	1.38
Group 6	1.53	(1.25–2.70)	2.21	(1.33–4.52)	0.68
Group 7	1.70	(1.23–2.21)	2.53	(1.69–3.64)	0.83
Group 8	1.75	(1.40–2.11)	2.80	(1.80–3.78)	1.05
Local riverside					
Group 1	2.50	(1.50–8.17)	4.03	(2.10–12.17)	1.53
Group 2	2.28	(1.27–4.54)	3.70	(1.75–8.04)	1.42
Group 3	2.63	(1.50–3.86)	4.33	(2.50–7.00)	1.70
Group 4	2.53	(1.50–5.08)	4.27	(2.50–7.69)	1.74
Group 5	2.44	(1.20–5.33)	3.86	(1.20–9.00)	1.42

4. Discussion

Generation of three sensible habitat classifications using disparate ground beetle data sets indicate that there is potential for using this group to provide habitat structures within which site quality can be assessed. Large, national scale classifications in the United Kingdom (e.g. Eyre & Luff 1990a) will have to be based on unstandardised sampling by a number of recorders until surveys such as the pitfall trapping carried out in the Netherlands (Turin *et al*. 1991) can be organised. These classifications will be relatively crude compared to those with relatively comprehensive coverage of habitat types using methods such as pitfall trapping (e.g. Luff *et al*. 1992, Eyre 1994, Eyre & Luff 1994). Results from the sampling in eastern Scotland presented here do not cover all variation in Scotland but show the potential for a system based on standard sampling in a relatively large area. The subtlety brought about by intensive sampling is shown by the local riverside habitat classification.

Differences in site rarity values were most obvious with the national riverside data but standardised sampling, as used with the Scottish and local riverside data, will lead to regular recording of more abundant species within large species lists. The unstandardised sampling of ground beetle species, as in the national riverside data, inevitability biases towards rare species in shorter lists, giving higher rarity values. These values, however, indicated that there are nationally important riverside sediments for invertebrate conservation, especially in Wales. To get a true ranking of sites within a proper classification at large scale, standardised survey techniques are required. Similar methods have been used in the estimation of wetland site quality using water beetles in both local and national contexts (Foster 1991, Foster & Eyre 1992) and are being applied to the assessment of site quality using aculeate Hymenoptera (Archer & Burn 1995).

Heijerman & Turin (1994) appear to be the only other workers who have tried to quantify the site quality using ground beetle data. The similarity indices they employ seem to be better measures of site typicalness or naturalness than site rarity value but the data on which these indices were based produced a classification of habitat types within which sites could be ranked (Turin *et al.* 1991). Eyre and Rushton (1989) used a group ordination to produce a measurement of typicalness whilst Foster (1992) showed that the use of old site records in recent classifications can be used to indicate the naturalness of present day sites.

If there is to be the application of invertebrate data in environmental assessment, there is a need to develop standard procedures which are understandable by people such as planners and policy makers who are not specialised biologists. The results presented here show that there is considerable potential for the use of ground beetles as determinants of environmental quality, especially given the extent of distribution and ecological knowledge and the relative ease of sampling and identification of most species. There is plenty of ground beetle information in Europe (see Eyre & Luff 1990b, Turin *et al.* 1991, Maelfait *et al.* 1994) which could provide a basis for very large scale work and the potential for an integrated approach covering a number of countries.

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