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Habitat diversity in the conservation of the grassland Auchenorrhyncha (Homoptera: Cercopidae, Cicadellidae, Cixidae, Delphacidae) of northern Britain

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Abstract

Definition of northern British grassland Auchenorrhyncha habitats was carried out using a classification based on analysis of data from 351 sites, involving 121 species, located between Greater Manchester and northern Scotland. Ten habitats were identified showing little influence of geographical position and exhibiting a basic upland-lowland trend. Other factors influencing habitat and species assemblage distribution were soil water, vegetation structure and land cover. An analysis of the species data with satellite-derived land cover data indicated that the lowland covers of tilled land, coast and urban and the upland covers of heath grassland and shrub heath were most important in affecting both species and assemblage distribution. The large-scale survey of grassland sites provided new information on both the ecology and distribution of individual Auchenorrhyncha species. Some were limited to specific habitat types but a considerable number were generalist species found in most or all of the 10 habitat types but showing preferences within upland to lowland or wet to dry site gradients. The ability to generate a subtle grassland Auchenorrhyncha habitat classification with large-scale survey results from standardised and reproducible sampling increases the potential for using habitat diversity for the conservation of grassland Auchenorrhyncha. Habitat preservation would also ensure that species richness (biodiversity) is maintained and that the habitats of rare species are conserved.

Introduction

Environmental interest dictates that there needs to be a number of monitoring mechanisms to quantify change and assess conservation status. The distribution of organisms and their relationship to geographical or landscape features has been advocated for assessment purposes. Conservation interests have tended to steer most invertebrate research into work on the effects of such factors as climate and land use change on invertebrate species and habitat distribution. There has been considerable research on butterflies but their use in environmental monitoring in Britain is limited by habitat availability (Warren et al. 2001; Hill et al. 2002) whilst ground beetles have been advocated as being useful in assessments of land use change (Niemelä 2000).

There have been reports of Auchenorrhyncha species distribution in a number of countries (e.g. Liang and Fletcher 2003) and into the species found on different types of grasslands (Morris 2000; Ott and Carvalho 2001). Some species have proved to be important in the conservation of specific grassland types (Bouchard et al. 2001;

Sauer and Maurer 2001) and there has been surveys covering a range of grasslands (Eyre et al. 2003a; Nickel and Hildebrandt 2003).

The identification and classification of land cover types over large areas has increased with the application of satellite imagery. A number of countries have been covered including Great Britain (Fuller et al. 1994a). The use of satellite-derived land cover data for work with invertebrates include the assessment of pest status and damage (Grilli and Gorla 1997) and conservation assessments at the landscape scale with butterflies and dragonflies (Fuller et al. 1998; Wessels et al. 2000).

The relative paucity of distribution data for British Auchenorrhyncha species, highlighted in the review of Kirby (1992), means that this group, along with a considerable number of other invertebrate groups, does not receive a great deal of interest by the statutory conservation agencies. There are two Auchenorrhyncha species listed as candidates for Biodiversity Action Plans (Department of Environment 1995a), so alternative approaches will be required for the conservation of grassland Auchenorrhyncha in the United Kingdom. Habitat types have been identified using invertebrate species assemblage data for a number of groups, especially beetles (e.g. Luff et al. 1992; Blake et al. 2003) and these have been used as a basis for conservation assessments (Foster and Eyre 1992; Eyre and Luff 2002). This paper uses a database which is an expansion of that used by Eyre et al. (2001a) to identify grassland Auchenorrhyncha assemblages in northern England and Scotland using 351 site lists. The relationship of these assemblages and of species to satellite-derived land cover data is examined using multivariate classification and constrained ordination techniques, as an aid to explaining assemblage distribution. The application of survey data, habitat classifications and habitat diversity in the conservation of grassland Auchenorrhyncha is discussed, as are some aspects of species ecology.

Methods

Data

Records of 121 Auchenorrhyncha species from 351 sites in northern England and Scotland were used for analysis. Sampling for Auchenorrhyncha was carried out between 1989 and 2003. The number of sites sampled on different grassland types in northern England, southern and northern Scotland are shown in Table 1. Most of the northern England data were from sites in the north-east, with some spoil sites in West Yorkshire and some damp pasture sites in Greater Manchester. The Scottish data was mainly a mixture of moorland, rough grassland and riverside sites distributed throughout the country north to the extreme north-west. The data were generated using a mixture of the pitfall trapping method outlined by Luff (1996), with 5–10 traps (8.5 cm diameter, 10 cm deep, part filled with preservative) used between May and September, and either two suction samples (Stewart and Wright 1995) or two sweep samples taken in July and August. The nomenclature follows Holzinger et al. (2003).

The land cover information was based on Landsat Thematic Mapper-based data released in the Countryside Information System (CIS) (Department of Environment 1995b) as a list of the number of hectares of cover per 1 km national grid square of 17 cover types and unclassified pixels. The data were derived from images generated between 1987 and 1990 (Fuller et al. 1994b). The 17 land classes in the CIS were reduced to 12 classes for these analyses (see Eyre et al. 2003b, c). Three sea and coast covers were merged to form a coastal cover; urban, suburban and inland bare ground were combined to produce an urban cover type; the shrub heath and shrub/grass heath were combined to produce one shrub heath cover. The 12 cover types were bog, bracken, coniferous woodland, deciduous woodland, heath grassland, shrub heath, managed grassland, inland water, urban, tilled land, rough grass and coast. The proportions of each of the 12 cover types in each 1km square with sites were used in the analyses.

Analysis

Classification of the species data was carried out using fuzzy set clustering (Bezdek 1981), based on a DECORANA ordination (Hill 1979). This method has been applied consistently to invertebrate site assemblage data (e.g. Eyre et al. 2001a) and enables the most parsimonious groups to be derived from data that consists of irregular gradients (Equihua 1989). The square scores on the

Table 1. The number of sites sampled for Auchenorrhyncha on different grassland types in northern England, southern and northern Scotland.

Grassland type	Region	Number of sites
Moorland	Northern England	95
	Southern Scotland	20
	Northern Scotland	8
Unmanaged rough grassland	Northern England	35
	Southern Scotland	8
	Northern Scotland	12
Rough pasture	Northern England	46
	Southern Scotland	13
Riversides	Northern England	16
	Southern Scotland	11
	Northern Scotland	23
Spoil, post-industrial	Northern England	36
Coast	Northern England	28

three axes of the ordination were used for the classification. Constrained ordination was carried out using canonical correspondence analysis (CANOCO Version 4, Ter Braak and Šmilauer 1998) with the species and land cover data. Automatic forward selection of the 12 land cover variables within CANOCO was used and their significance calculated using Monte Carlo permutation tests. This version of CANOCO produces a species-environment table showing the weighted averages with respect to each standardised environmental variable, in this case the twelve cover types. This table indicates the relationship, or lack thereof, between cover types and species. A weighted average of 0.50 or over was used to indicate a strong relationship between individual species and land covers, as in Eyre and Luff (2004).

Results

Ordination of the species data generated an axis 1 (eigenvalue 0.443) with moorland sites in north-east England opposite riverside and coastal dune sites, also in northern England. Axis 2 (eigenvalue 0.310) shows variation between coastal dune sites around Teesmouth in northern England near the origin and riverside and damp grassland sites in northern Scotland at the other end, indicating some possible geographical differences in addition to those of habitat. Sites shaded by shrubs and trees were near the origin of axis 3 (eigenvalue 0.237) opposite to wet and damp riverside and grassland, with sites at both ends of the axis from all over the sampling area.

Classification of the ordination scores, based on the species ordination, produced 10 species assemblages. The frequency of occurrence of species in these 10 groups is shown in Table 2. The 35 sites in group 1 were all north-eastern English wet mainly grass moorland with some heather *Calluna*. *Neophilaenus lineatus*, *Streptanus marginatus* and *Cicadula quadrinotata* were characteristic species in group 1 with the presence of heather indicated by *Ulopa reticulata* and of wet areas by *Cicadella viridis*. The highest incidence of *U. reticulata* was in the 36 sites of group 2, with no *C.viridis*, showing a habitat of dry moorland dominated by heather. These sites were found throughout north-east England and both the north and south of Scotland. *C. viridis* in group 3, together with *N. lineatus*, again indicated wet moorland but there was fewer *S. marginatus* and *C. quadrinotata* than in group 1. These were grass moorland sites with little or no heather and a distribution pattern similar to that of sites in group 2. The 47 sites in group 4 were also distributed throughout north-east England and all of Scotland and contained a mixture of the moorland species found in groups 1, 2 and 3 and more lowland species such as *Aphrodes makarovi* and *Anoscopus albifrons*. These were sites on the boundary of moorland where the peat and mineral soil meet.

Group 5 comprised 46 mainly damp lowland sites with a high incidence of *Philaenus spumarius*, *A. makarovi*, *A. albifrons* and *Streptanus sordidus*. Sites in this group were found from Greater Manchester to the north of Scotland. The 30 sites in group 6 were also damp and a mixture of riversides and lowland pasture also distributed throughout the survey area. There were less *A. albifrons* and *S. sordidus* and more *Anoscopus flavostriatus* than in group 5 and the presence of *Aphrophora alni* in a third of the sites indicated shaded by shrubs and trees. The highest incidence of *A. alni* was in the 22 sites of group 7, with *P. spumarius* and *A. makarovi* also characteristic. These grasslands had the most shade from shrubs and trees, generally on well drained soils, and were found from north-east England to the north of Scotland. The 28 sites in group 8 were a mixture of lowland riversides, spoil areas and coastal dunes, were very well drained but had considerable vegetation cover. The species with the highest incidence were again *A. makarovi* and *A. albifrons*, occurring with species of drier grasslands such as *Euscelis incisus* and *Anaceratagallia venosa*. Most of the sites in group 8 were in northern England and southern Scotland but there were a few by rivers in northern Scotland. Group 9 had 32 sites from throughout the survey area and were riversides, spoil, coastal, lowland pasture and rough grass. These sites differed from those in group 8 by have less vegetation cover and a mixture of well drained and damp soils with less *A.makarovi* and *A. albifrons*, more *A. flavostriatus* and the highest incidence of *Megophthalmus scanicus*. Group 10 had 30 sites that were mainly spoil or dune coast with sparse vegetation and very dry. They were confined to north-east England with *Anaceratagallia venosa* and *Doratura stylata* characteristic species.

The constrained ordination results, relating the species assemblages to land cover variables, are summarised in Table 3. The low eigenvalues and cumulative percentage variances are indicative of how ‘noisy’ the data set was. However, there were strong species/environment correlations with all three axes, which together accounted for 55% of the variance explained by the environmental data. Table 4 shows the correlation coefficients of the environmental variables with three axes of the constrained ordination whilst Table 5 lists the land cover variables, the variance explained by each and their statistical significance. The tilled land, urban, coast and deciduous woodland covers had the strongest positive relationships with axis 1, with the first two the most important. These were opposite the negative relationships with axis 1 of the upland covers of heath grassland and bog. The only strong correlation with axis 2 was a positive one with the coast whilst the strongest with axis 3 was negatively with shrub heath and positively with urban. Tilled land explained the most additional variance with the coastal variable also explaining a considerable amount of additional variance. The urban variable, another lowland cover, explained more of the variation than any of the upland covers, with shrub heath and heath grassland the upland covers explaining most additional variance.

The relationship between the species in Table 2 and the 12 land cover variables, shown as weighted averages, are given in Table 6, with averages of 0.50 and above considered as strongly indicative of a relationship. Five species had strong positive and five negative relationships with the bog cover but the major upland cover influencing species distribution was heath grassland with 15 negative and seven positive strong relationships. Eight species had strong negative relationships with shrub heath, the other main upland cover, and four were positively related. The lowland cover with the greatest effect was tilled land, with 12 and 10 species with strong negative and positive preferences respectively. The pattern with the urban cover was six negative and 11 positive whilst there were seven positively related species with the coastal cover but no strong negative relationships.

Discussion

Both the ordination and classification of the Auchenorrhyncha species data produced interpretable and useful results, even though the amount of variance explained in the constrained ordination was low. In general, the variance explained in the analyses of large-scale invertebrate survey data is only about 10% (e.g. Eyre and Luff 2004) but the slightly lower amount explained with this Auchenorrhyncha data may be related to the number of generalist species in the data set, occurring throughout the habitats surveyed. The results indicated that there was relatively little geographical influence in the distribution of species assemblages. There may have been some south-north variation on axis 2 of the ordination but this may have been a reflection on the distribution of habitat types. Only one moorland assemblage (group 1) and one dominated by sand dune sites (group 10) were limited to sites in northern England whilst the other eight groups had sites located throughout the survey area. The classification was more comprehensive and subtle than that in Eyre et al. (2001a), with fine differences observed between both moorland and lowland grassland habitat types. The primary factor influencing species assemblage and habitat distribution was altitude with a major split between the peat-based upland and the mineral soil lowland habitats. Within these two main groups of habitats it was apparent that habitat differences were caused by the amount of substrate water and vegetation architecture with differences in the amount of vegetation and in shading by trees and

Table 2. The frequency of occurrence (%) of Auchenorrhyncha species in the 10 groups derived from the classification (minimum >20% in one group). Species order is as axis 1 of the ordination.

Species	Group									
	1	2	3	4	5	6	7	8	9	10
Neophilaenus exclamationis	54	–	9	–	–	–	–	–	–	–
Kelisia ribauti	37	3	13	–	–	10	9	–	–	–
Arocephalus punctum	40	–	16	2	–	–	–	–	–	7
Aphrodes bicinctus	31	6	18	2	4	–	–	–	–	–
Streptanus marginatus	94	44	58	19	–	7	9	4	3	–
Ulopa reticulata	43	61	11	11	–	3	–	–	–	–
Cicadula quadrinotata	97	58	69	13	11	7	5	4	–	–
Jassargus sursumflexus	49	8	27	26	–	–	–	–	–	–
Jassargus distinguendus	83	42	60	57	7	3	2	–	–	–
Dikraneura variata	57	19	60	36	9	–	–	7	–	7
Psammotettix nodosus	51	19	33	17	–	3	–	14	–	23
Verdanus abdominalis	34	14	53	40	11	7	–	11	–	13
Javesella discolor	23	53	16	15	9	–	18	4	3	10
Conomelus anceps	71	25	69	51	54	43	9	4	3	–
Javesella dubia	23	–	22	–	11	27	5	–	–	–
Planaphrodes bifasciata	89	81	69	64	26	20	18	36	28	43
Cicadella viridis	40	–	47	36	57	33	14	–	6	–
Macustus grisescens	86	69	84	51	72	43	5	61	41	53
Neophilaenus lineatus	97	64	91	68	78	67	45	46	47	53
Muellerianella fairmairei	3	8	27	53	26	30	18	–	6	–
Deltocephalus pulicaris	3	14	22	28	15	7	–	18	–	4
Conosanus obsoletus	26	11	51	45	59	37	5	29	13	40
Forcipata citrinella	–	–	–	4	–	3	32	–	–	–
Streptanus sordidus	14	8	44	53	74	53	32	29	19	3
Arthaldeus pascuellus	–	8	27	53	48	27	14	14	19	7
Philaenus spumarius	46	61	69	57	87	87	82	54	59	50
Macrosteles sexnotatus	9	14	27	4	30	10	5	18	22	13
Cicadula aurantipes	–	3	2	4	22	23	18	–	3	–
Balclutha punctata	–	6	2	11	13	10	32	4	3	–
Anoscopus albifrons	14	47	47	64	76	43	32	75	53	80
Elymana sulphurella	–	3	7	6	13	3	–	21	9	3
Streptanus aemulans	–	–	22	40	65	47	27	29	34	17
Macrosteles viridigriseus	–	–	–	2	11	27	9	–	9	–
Javesella pellucida	–	–	4	6	28	23	–	4	13	–
Errastunus ocellaris	–	–	7	26	35	27	–	18	38	13
Criomorphus albomarginatus	–	6	7	13	7	–	–	29	19	17
Aphrophora alni	–	–	–	4	4	30	41	–	6	–
Aphrodes makarovi	–	8	18	74	80	90	64	82	53	80
Aphrodes flavostriatus	–	–	2	19	48	63	18	18	53	10
Psammotettix confinis	–	–	4	15	2	–	–	25	25	17
Cixius distinguendus	–	–	–	–	–	–	23	–	–	–
Eupteryx aurata	–	–	–	–	4	13	23	–	–	–
Evacanthus interruptus	–	–	–	2	17	43	41	4	22	–
Megophthalmus scanicus	–	–	9	17	39	33	14	61	72	60
Psammotettix frigidus	–	6	4	2	2	–	–	29	6	60
Megamelodes quadrimaculatus	–	–	2	–	–	–	–	–	–	23
Euscelis incisus	–	–	–	–	20	10	3	57	47	60
Anaceratagallia venosa	–	3	–	4	9	10	–	50	31	73
Eupelix cuspidata	–	3	–	–	2	–	–	39	22	60
Muirodelphax aubei	–	–	–	–	–	–	–	4	–	47
Agallia brachyptera	–	–	–	–	7	–	–	32	28	47
Doratura stylata	–	–	–	–	–	–	–	7	6	67

shrubs. Cherrill and Rushton (1993) and Sanderson et al. (1995) found that soil moisture and vegetation composition were determinants of Auchenorrhyncha assemblage distribution on northern England uplands and these factors obviously influenced the classification of the northern British data. The basic upland-lowland split and the effects of soil water and land cover on assemblage distribution has also been seen with ground beetles in northern England (Luff et al. 1992) and throughout Britain (Eyre et al. 2003b).

Grassland Auchenorrhyncha species richness has been shown not to be related to plant species diversity (Huusela-Veistola and Vasarainen 2000; Koricheva et al. 2000) but Kruess and Tscharntke (2002) found more species richness on extensive rather than intensive pastures and that vegetation height was a major factor in affecting species diversity. The management of coastal grasslands, especially grazing, also affects Auchenorrhyncha distribution and diversity (Hildebrandt 1995; Meyer and Reinke 1996). Within the landscape Jonsen and Fahrig (1997) found that cicadellid species richness increased with an increase of land cover diversity and Nickel and Hildebrandt (2003) consider Auchenorrhyncha to be suitable indicators of biotic conditions in grasslands. The intensity of landscape management appears to be important in Auchenorrhyncha assemblage distribution and may explain the importance of tilled land, coastal and urban covers in influencing habitat diversity in northern Britain.

One advantage of carrying out large-scale, standardised surveys is that a more objective understanding of invertebrate species habitat preferences is generated. In northern Britain, species confined to very specific habitats can be identified, such as *Neophilaenus exclamationis* in the uplands and *Muirodelphax aubei* and *Doratura stylata* on coastal sand dune sites whilst trends in the distribution of generalist species can be observed. *Planaphrodes bifasciata* was more abundant in upland habitats and *A. makarovi* found more in lowland sites whilst *Conomelus anceps* had a greater preference for wetter habitat types than did *Anoscopus albifrons*. Knowledge of the distribution and habitats of some species, where information was previously sparse, was also generated. *Psammotettix frigidus*, thought to be a scarce upland species (Kirby 1992), was found consistently on both sand dune and brownfield sites, with few upland records in the northern British data set. These large-scale surveys are likely to increase the knowledge of the fauna with, for instance, the recording of *Elymana kozhevnikovi* new to the

Table 3. Eigenvalues, cumulative explained variance (%), cumulative species environment relationship (%) and species/environment correlations, for the first three constrained ordination axes.

	Axis 1	Axis 2	Axis 3
Eigenvalues	0.353	0.190	0.130
Cumulative % variance	3.7	5.6	7.0
Cumulative species/environment relationship	28.9	44.5	55.2
Species environment correlations	0.908	0.812	0.790

Table 4. Correlations between the land cover variables and the first three axes of the constrained ordination.

	Axis 1	Axis 2	Axis 3
Bog	−0.40	0.04	−0.06
Bracken	−0.06	0.05	−0.14
Coniferous woodland	−0.03	−0.17	−0.16
Deciduous woodland	0.35	−0.25	−0.15
Heath grassland	−0.61	0.12	0.22
Shrub heath	−0.16	−0.23	−0.36
Managed grassland	0.04	−0.21	−0.01
Inland water	0.01	−0.24	−0.21
Urban	0.59	0.23	0.33
Tilled land	0.68	−0.15	0.19
Rough grass	0.05	0.25	−0.11
Coast	0.38	0.67	−0.22

Table 5. The additional variance explained by each land cover variable in the constrained ordination, the variance ratios (*F*) and the significance (*p*), listed in order of automatic forward selection by CANOCO.

	Additional variance explained	*F*	*p*
Tilled land	0.24	8.82	<0.005
Coast	0.21	7.89	<0.005
Urban	0.13	5.01	<0.005
Shrub heath	0.11	4.22	<0.005
Heath grassland	0.08	3.28	<0.005
Rough grass	0.08	3.24	<0.005
Inland water	0.08	3.01	<0.005
Coniferous woodland	0.07	2.69	<0.005
Deciduous woodland	0.07	2.69	<0.005
Managed grassland	0.07	2.66	<0.005
Bracken	0.06	2.31	<0.010
Bog	0.03	1.34	<0.105

Table 6. Species-environment table showing the weighted averages, with respect to standardised land cover.

Species	Bog	CoW	DeW	HeG	ShH	MaG	Urb	TiL	RoG	Coa
Neophilaenus exclamationis	0.45	−0.32	**−0.58**	**0.51**	**−0.51**	0.44	**−0.55**	**−0.61**	0.29	−0.29
Kelisia ribauti	**0.60**	−0.31	−0.27	0.35	0.11	0.08	**−0.53**	**−0.60**	0.15	−0.29
Arocephalus punctum	0.26	−0.30	−0.49	0.45	−0.18	0.18	−0.38	**−0.52**	0.26	−0.12
Aphrodes bicinctus	0.35	−0.36	−0.47	0.29	**−0.52**	**0.60**	0.31	−0.48	0.31	−0.29
Streptanus marginatus	0.44	−0.09	−0.41	**0.72**	−0.24	−0.13	**−0.53**	**−0.64**	−0.14	−0.28
Ulopa reticulata	**0.64**	−0.14	−0.46	**0.99**	0.40	**−0.58**	**−0.53**	**−0.71**	−0.27	−0.29
Cicadula quadrinotata	0.47	−0.30	−0.45	**0.77**	−0.29	−0.03	**−0.52**	**−0.55**	−0.12	−0.29
Jassargus sursumflexus	0.06	0.35	−0.49	**0.91**	0.14	−0.32	**−0.54**	**−0.67**	−0.01	−0.29
Jassargus distinguendus	**0.52**	0.16	−0.20	0.31	0.40	−0.10	−0.48	**−0.65**	0.05	−0.29
Dikraneura variata	0.23	−0.05	−0.44	**0.61**	−0.14	0.03	−0.40	**−0.59**	0.13	−0.14
Psammotettix nodosus	0.14	−0.19	−0.18	0.45	−0.09	−0.13	−0.10	−0.39	0.24	0.16
Verdanus abdominalis	0.38	0.10	−0.11	0.26	0.07	−0.05	−0.29	**−0.50**	−0.06	−0.10
Javesella discolor	**0.56**	0.18	−0.20	**0.52**	0.14	−0.27	−0.47	−0.34	−0.18	−0.22
Conomelus anceps	0.18	−0.02	−0.14	0.30	0.13	0.07	−0.29	−0.43	−0.08	−0.29
Javesella dubia	0.16	−0.32	−0.24	0.01	**−0.50**	**0.54**	−0.38	−0.03	−0.28	−0.29
Planaphrodes bifasciata	0.26	0.11	−0.26	0.34	0.12	0.33	−0.08	−0.37	−0.05	−0.01
Cicadella viridis	−0.14	0.06	−0.14	0.16	−0.01	0.30	−0.18	−0.36	0.12	−0.29
Macustus grisescens	0.04	−0.06	−0.12	0.24	−0.06	−0.06	−0.10	−0.10	−0.06	0.05
Neophilaenus lineatus	0.11	−0.09	−0.14	0.14	−0.04	−0.07	−0.03	−0.18	−0.03	0.03
Muellerianella fairmairei	−0.02	**0.54**	0.03	0.30	**0.65**	−0.38	−0.28	−0.38	−0.27	−0.29
Deltocephalus pulicaris	0.19	−0.17	0.25	0.07	**0.52**	−0.10	−0.40	0.17	−0.04	−0.29
Conosanus obsoletus	0.06	0.07	−0.20	−0.03	0.01	0.06	0.02	−0.23	0.07	0.22
Forcipata citrinella	**1.26**	0.29	0.22	**−0.52**	**1.87**	**−0.87**	−0.39	**−0.72**	0.18	−0.29
Streptanus sordidus	−0.14	0.12	−0.06	−0.12	0.16	0.19	−0.09	0.02	−0.01	−0.12
Arthaldeus pascuellus	−0.06	0.32	0.07	−0.19	0.32	0.09	−0.05	−0.17	−0.08	−0.05
Philaenus spumarius	0.01	−0.07	0.03	0.01	−0.01	0.03	−0.01	0.06	−0.12	−0.11
Macrosteles sexnotatus	−0.17	−0.19	0.18	0.04	−0.40	0.18	−0.05	**0.59**	0.04	−0.29
Cicadula aurantipes	−0.15	−0.31	0.36	0.04	0.38	0.11	0.01	−0.23	0.07	−0.29
Balclutha punctata	−0.23	0.32	0.31	−0.38	**0.96**	−0.28	0.15	−0.10	−0.02	−0.29
Anoscopus albifrons	−0.15	0.02	0.03	−0.10	0.07	−0.05	0.12	0.16	0.08	0.09
Elymana sulphurella	−0.05	0.02	0.15	−0.33	−0.27	0.21	**0.51**	0.24	0.25	0.20
Streptanus aemulans	−0.28	0.15	0.21	−0.36	−0.04	0.41	−0.04	0.38	0.01	−0.18
Macrosteles viridigriseus	−0.16	−0.36	−0.35	−0.45	0.21	**0.68**	0.16	0.19	**−0.54**	−0.12
Javesella pellucida	**−0.53**	0.14	**0.55**	0.03	0.46	0.31	0.28	0.41	−0.17	−0.29
Errastunus ocellaris	−0.38	−0.07	0.17	−0.11	−0.23	0.14	0.42	0.38	−0.23	−0.09
Criomorphus albomarginatus	−0.24	0.41	0.33	−0.43	−0.09	−0.04	0.22	0.32	0.08	0.21
Aphrophora alni	0.31	−0.03	**0.65**	**−0.51**	0.34	0.15	−0.26	0.01	−0.19	−0.29
Aphrodes makarovi	−0.15	0.06	0.27	−0.37	0.07	0.02	0.19	0.44	−0.11	0.05
Anoscopus flavostriatus	−0.35	0.18	0.47	**−0.51**	−0.29	0.48	−0.08	**0.63**	−0.26	−0.20
Psammotettix confinis	**−0.50**	0.14	0.02	−0.41	−0.03	−0.37	**0.76**	1.14	−0.07	−0.16
Cixius distinguendus	−0.37	−0.12	−0.14	**−0.65**	**0.94**	−0.22	−0.38	**−0.56**	−0.14	−0.29
Eupteryx aurata	−0.45	−0.27	0.16	**−0.63**	**−0.50**	**0.90**	−0.07	**0.67**	−0.32	−0.29
Evacanthus interruptus	−0.24	0.07	0.41	**−0.69**	−0.20	**0.69**	−0.27	**0.59**	0.10	0.22
Megophthalmus scanicus	−0.34	−0.14	0.19	**−0.51**	−0.16	−0.05	**0.53**	**0.69**	−0.06	0.32
Psammotettix frigidus	−0.37	0.01	−0.13	**−0.51**	−0.22	−0.30	**0.82**	**0.62**	**0.55**	**0.89**
Megamelodes quadrimaculatus	−0.41	−0.38	**−0.58**	**−0.72**	**−0.59**	**−0.91**	**2.08**	−0.07	**1.83**	**3.08**
Euscelis incisus	**−0.50**	−0.15	0.42	**−0.61**	−0.48	0.05	**0.71**	**1.31**	0.07	0.14
Anaceratagallia venosa	−0.33	−0.26	**0.67**	**−0.74**	−0.36	0.05	**0.60**	**0.83**	0.24	**0.62**
Eupelix cuspidata	−0.48	−0.35	0.12	**−0.71**	−0.47	−0.15	**1.21**	**0.60**	0.17	**1.33**
Muirodelphax aubei	**−0.65**	−0.28	**−0.58**	**−0.85**	**−0.54**	**−0.67**	**1.37**	−0.03	**1.36**	**3.23**
Agallia brachyptera	−0.47	−0.32	**0.71**	**−0.75**	**−0.54**	−0.06	**1.08**	**0.92**	0.25	**0.75**
Doratura stylata	**−0.53**	−0.29	0.09	**−0.77**	**−0.54**	−0.35	**1.22**	0.32	**0.88**	**2.15**

CoW – Coniferous woodland; DeW – Deciduous woodland; HeG – Heath grassland; ShH – Shrub heathland; MaG – Managed grassland; Urb – Urban; TiL – Tilled land; RoG – Rough grass; Coa – Coast.
Species order is as in Table 2 and averages of 0.50 and above are emboldened. There were no averages of 0.50 and above with bracken and inland water.

British fauna, on upland sites on both sides on the England/Scotland border with sparse grassy vegetation on thin mineral soils (Eyre et al. 2004).

Eyre et al. (2001a) pointed out that the present knowledge of British Auchenorrhyncha species distribution is not sufficient for the generation of rarity and other indices used for site conservation assessments with water and ground beetles (Foster and Eyre 1992; Eyre and Luff 2002). Whilst rarity is probably the most important conservation criterion (Ratcliffe 1977), biodiversity, usually as species richness, has recently become prominent. Another approach may be to base conservation on habitat diversity, especially for the less 'popular' invertebrate groups. If habitats can be defined and conserved, species richness and, at least some extent, rare species conservation, are also likely to be covered. However, there is a requirement to define habitats in terms of invertebrate assemblages, not plants (e.g. Drake et al. 1998). Subtle habitat definition was possible with the northern British Auchenorrhyncha data, as it has been for a number of beetle families and groups (Foster and Eyre 1992; Eyre et al. 2001b, 2002; Blake et al. 2003). There is no standard number of invertebrate habitats in any survey area. Eyre et al. (2003a) found that there were more Hemiptera (bug) habitats on an area of moorland in southern Scotland than either rove beetle or spider habitats but that there were more ground beetle habitats. Auchenorrhyncha are easily sampled by standardised and reproducible methods, usually during sampling for other terrestrial invertebrates such as ground and rove beetles. There is mounting evidence that Auchenorrhyncha could be a useful group in the assessment of environmental quality and change (Nickel and Hildebrandt 2003) and they should play a part in grassland conservation assessment.

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References

Bezdek J.C. 1981. Pattern Recognition with Fuzzy Objective Algorithms. Plenum Press, New York.

Blake S., McCracken D.I., Eyre M.D., Garside A. and Foster G.N. 2003. The relationship between the classification of Scottish ground beetle assemblages (Coleoptera, Carabidae) and the National Vegetation Classification of British plant communities. Ecography 26: 602–616.

Bouchard P., Hamilton K.G.A. and Wheeler T.A. 2001. Diversity and conservation status of prairie endemic Auchenorrhyncha (Homoptera) in alvars of the Great Lakes region. Proc. Entomol. Soc. Ontario 132: 39–56.

Cherrill A.J. and Rushton S.P. 1993. The Auchenorrhyncha of an unimproved moorland in northern England. Ecol. Entomol. 18: 95–103.

Department of Environment 1995a. Biodiversity: The UK Steering Group Report. Volume 2: Action Plans. HMSO, London.

Department of Environment 1995b. Countryside Information System, Version 5.23. Department of Environment, London.

Drake M., Clements D., Eyre M., Gibbs D. and Kirby P. 1998. Invertebrates and Their Habitats in Natural Areas. Vol. 1, Midland and Northern Areas; Vol. 2, Southern Areas. English Nature Research Reports, No. 298. English Nature, Peterborough.

Equihua M. 1989. Fuzzy clustering of ecological data. J. Ecol. 78: 519–534.

Eyre M.D. and Luff M.L. 2002. The use of ground beetles (Coleoptera: Carabidae) in conservation assessments of exposed riverine sediment habitats in Scotland and northern England. J. Insect Conserv. 6: 25–38.

Eyre M.D. and Luff M.L. 2004. Ground beetle (Coleoptera, Carabidae) species associations with land cover variables in northern England and southern Scotland. Ecography 27: 417–426.

Eyre M.D., Foster G.N., Luff M.L. and Staley J.R. 2003c. An investigation into the relationship between water beetle (Coleoptera) distribution and land cover in Scotland and north-east England. J. Biogeogr. 30: 1835–1849.

Eyre M.D., Luff M.L. and Lott D.A. 2002. The importance of exposed riverine sediments for phytophagous beetles (Coleoptera) in Scotland and northern England. Aquat. Conserv. Marine Fresh. Ecosyst. 12: 553–566.

Eyre M.D., Luff M.L. and Phillips D.A. 2001b. The ground beetles (Coleoptera, Carabidae) of exposed riverine sediments in Scotland and northern England. Biodiv. Conserv. 10: 403–426.

Eyre M.D., Luff M.L., Staley J.R. and Telfer M.G. 2003b. The relationship between British ground beetles (Coleoptera, Carabidae) and land cover. J. Biogeogr. 30: 719–730.

Eyre M.D., Luff M.L. and Woodward J. 2003a. Grouse moor management: habitat and conservation implications or invertebrates in southern Scotland. J. Insect Conserv. 7: 21–32.

Eyre M.D., Woodward J.C. and Luff M.L. 2001a. The distribution of grassland Auchenorrhyncha assemblages (Homoptera: Cercopidae, Cicadellidae, Delphacidae) in northern England and Scotland. J. Insect Conserv. 5: 37–45.

Eyre M.D., Woodward J.C. and Luff M.L. 2004. *Elymana kozhevnikovi* Zachvatkin (Hemiptera, Cicadellidae) in Britain: identification, distribution and habitat. Br. J. Entomol. Nat. Hist. 17: 15–23.

Foster G.N. and Eyre M.D. 1992. Classification and ranking of water beetle communities. UK Nat. Conserv. 1: 1–110.

Fuller R.M., Groom G.B. and Jones A.R. 1994a. The Land-Cover map of Great Britain – an automated classification of Landsat Thematic Mapper data. Photogramm. Engin. Remote Sens. 60: 553–562.

Fuller R.M., Groom G.B. and Wallis S.M. 1994b. The availability of Landsat TM images of Great Britain. Int. J. Remote Sens. 15: 1357–1362.

Fuller R.M., Groom G.B., Mugisha S., Ipulet P., Pomeroy D., Katende A., Bailey R. and Ogutu-Ohwayo R. 1998. The integration of field survey and remote sensing for biodiversity assessment: a case study in the tropical forests and wetlands of Sango Bay, Uganda. Biol. Conserv. 86: 379–391.

Grilli M.P. and Gorla D.E. 1997. The spatio-temporal pattern of *Delphacodes kuscheli* (Homoptera: Delphacidae) abundance in central Argentina. Bull. Entomol. Res. 87: 45–53.

Hildebrandt J. 1995. Investigations on the leafhopper (Hemiptera: Auchenorrhyncha) fauna of an estuary grassland with agricultural impact and fluctuating inundations. Faun. Ökol. Mitteil. 7: 9–45.

Hill J.K., Thomas C.D., Fox R., Telfer M.G., Willis S.G., Asher J. and Huntley B. 2002. Responses of butterflies to twentieth century climate warming: implications for future ranges. Proc. R. Soc. Lond., B 269: 2163–2171.

Hill M.O. 1979. DECORANA – A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging. Ecology and Systematics. Cornell University, Ithaca, New York.

Holzinger W.E., Kammerlander I. and Nickel H. 2003. The Auchenorrhyncha of Central Europa – Die Zikaden Mitteleuropas. Volume 1: Fulgoromorpha, Cicadomorpha excl. Cicadellidae. Brill, Leiden.

Huusela-Veistola E. and Vasarainen A. 2000. Plant succession in perennial grass strips and effects on the diversity of leafhoppers (Homoptera, Auchenorrhyncha). Agric. Ecosyst. Environ. 80: 101–112.

Jonsen I.D. and Fahrig L. 1997. Response of generalist and specialist insect herbivores to landscape spatial structure. Lands. Ecol. 12: 185–197.

Kirby P. 1992. A review of the scarce and threatened Hemiptera of Great Britain. UK Nat. Conserv. 2: 1–267.

Koricheva J., Mulder C.P.H., Schmid B., Joshi J., Huss-Danell and K. 2000. Numerical responses of different trophic groups of invertebrates to manipulations of plant diversity in grasslands. Oecologia 125: 271–282.

Kruess A. and Tscharntke T. 2002. Contrasting responses of plant and insect diversity to variation in grazing intensity. Biol. Conserv. 106: 293–302.

Liang A.P. and Fletcher M.J. 2003. Review of the Australian aphrophorid spittlebugs (Hemiptera:Aphrophoridae). Aust. J. Entomol. 42: 84–93.

Luff M.L. 1996. Environmental assessments using ground beetles (Carabidae) and pitfall traps. In: Eyre M.D. (ed.), Environmental Monitoring, Surveillance and Conservation using Invertebrates. EMS Publications, Newcastle upon Tyne, pp. 42–47.

Luff M.L., Eyre M.D. and Rushton S.P. 1992. Classification and prediction of grassland habitats using ground beetles (Coleoptera, Carabidae). J. Environ. Manag. 35: 301–315.

Meyer H. and Reinke H.-D. 1996. Changes in the biocoenotic structure of the invertebrate fauna of saltmarshes caused by different sheep grazing intensities. Faun.-Ökol. Mitteil. 7: 109–152.

Morris M.G. 2000. The effects of structure and its dynamics on the ecology and conservation of arthropods in British grasslands. Biol. Conserv. 95: 129–142.

Nickel H. and Hildebrandt J. 2003. Auchenorrhyncha communities as indicators of disturbance in grasslands (Insecta, Hemiptera) – a case study from the Elbe flood plains (northern Germany). Agric. Ecosyst. Environ. 98: 183–199.

Niemelä and J. 2000. Biodiversity monitoring for decision-making. Ann. Zool. Fenn. 37: 307–317.

Ott A.P. and Carvalho G.S. 2001. The assembly of the Homopteran (Hemiptera: Auchenorrhyncha) of grasslands at Viamao County, Rio Grande do Sul State, Brazil. Neotrop. Entomol. 30: 233–243.

Ratcliffe D.A. (ed.) 1977. A Nature Conservation Review. Cambridge University Press, Cambridge.

Sanderson R.A., Rushton S.P., Cherrill A.J. and 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.

Sauer S.B. and Maurer E.D. 2001. Notes on the distribution, behavior and life history of Attenuipyga vanduzeei (Osborn and Ball) (Hemiptera : Cicadellidae) in Wisconsin. Am. Mid. Nat. 146: 434–438.

Stewart A.J.A. and Wright A.F. 1995. A new inexpensive suction apparatus for sampling arthropods in grassland. Ecol. Entomol. 20: 98–102.

Ter Braak C.J.F. and Šmilauer P. 1998. CANOCO Reference Manual and User's Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Centre for Biometry, Wageningen.

Warren M.S., Hill J.K., Thomas J.A., Asher J., Fox R., Huntley B., Roy D.B., Telfer M.G., Jeffcoate S., Harding P., Jeffcoate G., Willis S.G., Greatorex-Davies J.N., Moss D. and Thomas C.D. 2001. Rapid responses of British butterflies to opposing forces of climate and habitat change. Nature 414: 65–69.

Wessels K.J., Reyers B. and Jaarsveld A.S. van 2000. Incorporating land cover information into regional biodiversity assessments in South Africa. Anim. Conserv. 3: 67–79.