

Grassland conservation headlands: Their impact on invertebrate assemblages in intensively managed grassland

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Received 22 March 2006; received in revised form 20 December 2006; accepted 2 January 2007

Available online 8 March 2007

Abstract

Grassland conservation headlands were established on intensively managed grassland fields on four farms in Scotland. Vegetation composition and structure, invertebrate activity density (as measured by pitfall trapping), ground beetle assemblage structure and bird utilisation in these grassland conservation headlands were compared with conventional headlands (i.e. areas of headland managed as per the rest of each field). Increased activity densities of Arionidae slugs, heteropteran bugs and homopteran bugs were recorded in the grassland conservation headlands when compared to the conventional headlands. Despite an increase in potential prey, very few birds were observed in the study fields, and the grassland conservation headlands were no richer in birds than the conventional headlands. The vegetation of the grassland conservation headlands was longer and denser than the conventional headland. Hence, while the activity density of potential prey was greater in the conservation headlands, accessibility to prey and foraging conditions for birds may have been poorer. While there was evidence that the ground beetle *Nebria brevicollis* utilised the grassland conservation headland as a summer aestivating site, the activity density of ground beetles in general was found to be lower in the conservation headlands than the conventional headlands. For grassland conservation headlands to reach their full potential, it is suggested that additional measures are taken to open the vegetation structure of such headlands.

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Keywords: Carabidae; Farmland birds; Agri-environment; Field boundaries

1. Introduction

In the UK, one of the main foci of agri-environment schemes is to encourage farmers to adopt environmentally friendly management in the outer margins (headlands) of cereal crops. The establishment of such arable conservation headlands benefits a wide range of arable weeds, invertebrates, birds and mammals.

Despite the biodiversity benefits to be gained from sympathetic management of field edges in arable agri-environment schemes, such an approach had been largely overlooked in schemes targeted at intensively managed grassland (Haysom et al., 1999; 2004). Instead grassland

schemes tend to focus on protecting existing remnants of semi-natural habitats, encouraging traditional cutting and grazing practices, restoring species-rich grasslands or conserving specific species (e.g. corncrake *Crex Crex*) (Plantureux et al., 2005). While such approaches are important, they do little to promote the conservation of biodiversity within intensively managed grasslands. Grassland accounts for 67% of agricultural land in the UK. In Scotland grassland constitute 19% of the total agricultural land area (Defra, 2002a) the majority of which is intensively managed. The adaptation of arable field margin schemes to the grassland situation therefore targets an area of farmland biodiversity concern and has the potential to enhance biodiversity within the Scottish and UK agricultural landscape.

To this end Haysom et al. (1999, 2004) conducted a pilot project using small plots to investigate the effect of different

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cutting regimes on the invertebrate fauna and flora of grassland headlands. This pilot study found that ground beetle (Coleoptera: Carabidae) diversity was greatest in the less frequently cut plots, and that field boundary species moved from the boundaries into the grassland conservation headlands. Many bird prey groups (e.g. caterpillars and sawfly larvae) also benefited from less frequent cutting. A draft agri-environment scheme prescription for grassland conservation headlands was produced as an outcome of this study (Haysom et al., 1999, 2004). The aim of the current study was therefore to test the relevance of this prescription at the field scale and to assess whether the invertebrate impacts were repeatable at such a scale and consider whether any such impacts had an effect on foraging birds.

2. Methods

2.1. Study sites

Five grassland fields, in three geographical locations, were selected for study (Table 1). All fields were typical intensively managed grassland fields encompassing intensive livestock grazing and/or cutting for silage. In each field, one of the headlands was randomly divided into two areas: the conventional headland and the grassland conservation headland (each was 6 m wide with a minimum length of 100 m). Conventional headlands were under the same management regime as the wider field while grassland conservation headlands were closed annually to grazing from 15 April to 15 August and the application of fertilisers and pesticides was not permitted.

Mature grassland headlands were investigated in Dumfries and Galloway and Ayrshire. In Fife, two new grassland conservation headlands were established in April 2000 by fencing off 6 m of the field edge and applying glyphosate (6 l/ha) across the headland in criss-crossed strips 1 m wide. This element of the draft agri-environment prescription was developed in the pilot studies by Haysom et al. (1999, 2004) and was only conducted in the year that the grassland conservation headlands were established. This was intended to help compensate for the high nutrient status of the sward by creating strips of bare ground to encourage structural heterogeneity, natural colonisation and regeneration of other plant species.

Sampling was conducted in three fields (i.e. Wheat Park, Ladies Park and House Park) in 2000, in all five fields in 2002 and in four fields in 2003 (i.e. excluding Factors House). In 2003, House Park was converted to winter wheat and hence only vegetation data from the retained grassland conservation headland and its adjacent field edge were included in the analyses. Sampling was not conducted in 2001 because of biosecurity measures imposed due to the outbreak of foot and mouth disease in the UK (Defra, 2002b).

2.2. Sampling methodology

Ground active invertebrates were sampled by pitfall trapping. In each field, five pitfall transects were established within the following treatments: open field (i.e. 20 m from the study headlands), grassland conservation headland, grassland conservation field edge, conventional headland and conventional field edge. Each transect consisted of nine plastic cups, 75 mm diameter and 100 mm deep, placed at 2 m intervals (Downie et al., 2000). Traps were partly filled with monopropylene glycol as a killing agent and preservative and left *in situ* for a period of 3–4 weeks. Two uplifts (spring: May/June and summer: July/August) were collected at each site. On collection the nine pitfall traps from each of the five treatments were pooled. Both the activity and abundance of invertebrates influence pitfall catches (Greenslade, 1964) and consequently the numbers of invertebrates trapped are referred to as the activity density (Thiele, 1977). The activity density of key bird food invertebrates (i.e. sawfly and lepidopteran caterpillars, heteropteran and homopteran bugs) and agricultural pests (i.e. aphids, Arionidae slugs and Limacidae slugs) was determined. In addition ground beetles were identified to species level.

Vegetation sampling was conducted in summer and autumn each year and focussed along each pitfall transect. Four 1 m × 1 m quadrats were randomly placed along each pitfall transect (at a distance of approximately 1.5 m to either side) and percentage bare ground, number and relative abundance of plant species (recorded on the domin scale: Rodwell, 1991) and frequency of key weed species (i.e. number of *Cirsium* and *Rumex* spp.) recorded. In addition at 10 locations along each transect, vegetation height was measured using the plywood drop disc method (Stewart et al., 2001) and vegetation density by the Robel pole visual obscuration method (Robel et al., 1970).

Table 1
Characteristics of the five study fields where grassland conservation headlands were established

Location	Field	UK Grid Ref.	Established	Field backing feature	Management of conservation headland
Ayrshire	Wheat Park	NS 37 23	1990	Dense hedge	Cut and vegetation removed end March
Dumfries and Galloway	Lochbank	NX 99 74	1997	Sparse hedge/burn	Grazed: September–March
	Factors House	NY 16 73	1997	Mixed woodland	Grazed: September–March
Fife	Ladies Park	NO 26 05	2000	Coniferous woodland	Grazed: September–March
	House Park	NO 26 05	2000	Broken wall/ditch/scrubby hedge	Grazed: September–March

Bird surveys were conducted annually on three occasions from June to September. On each visit the number and species of birds using the backing habitat, grassland conservation headland and conventional headland was noted. Bird occurrences were estimated in each area by following a transect on foot through the plot and all birds flushed or heard within the headland, or within the backing habitat immediately adjacent to the headland were recorded (Bibby et al., 1993).

2.3. Statistical analysis

The structure of the vegetation and ground beetle assemblages was first investigated using detrended correspondence analyses (DCA) taking into account dataset issues (Oksanen and Minchin, 1997). As the vegetation species data were collected on a domin scale it was not possible to summarise the data from the four sampling quadrats in each transect. DCA was therefore conducted on the raw data and the average axes scores were calculated for each group of four quadrat samples following analyses. These centroids were plotted in the resultant DCA ordination to facilitate interpretations. The ground beetle DCAs were conducted on the species relative abundance data (combined for the two uplifts) without the down-weighting of rare species (Hill, 1979). Pitfall transects where only one uplift was collected in a sampling year were omitted from the analyses.

The influence of headland management (i.e. treatment) on the abundance of key invertebrate groups, diversity and abundance of ground beetles, vegetation density and abundance of key weeds (i.e. *Cirsium arvense* and *Rumex obtusifolius*) were investigated by linear mixed models using the method of residual maximum likelihood (REML). Data were log transformed to normalise prior to analyses. Treatment effects were assessed after adjusting for field, year and month effects by fitting the following model in GENSTAT: fixed effects = month + year + treatment; random effects = field/year/month.

3. Results

DCA of the vegetation data found eigenvalues of 0.522, 0.368, 0.267 and 0.214 for axes one to four respectively and the variation accounted for by each axis was 8.1, 5.8, 4.2 and 3.3%, respectively. Treatment had the biggest influence on vegetation structure (Fig. 1), with effects of year, month and geographical location being less important. Open field samples and conventional headland samples tended to have lower axis one scores while conservation headland samples and field edge samples (of both conventional and conservation headlands) tended to have higher scores. The two conservation headland sites that occurred on the left-hand side of the ordination (i.e. Ladies Park, 2000 and House Park 2000) were newly established in 2000 indicating the

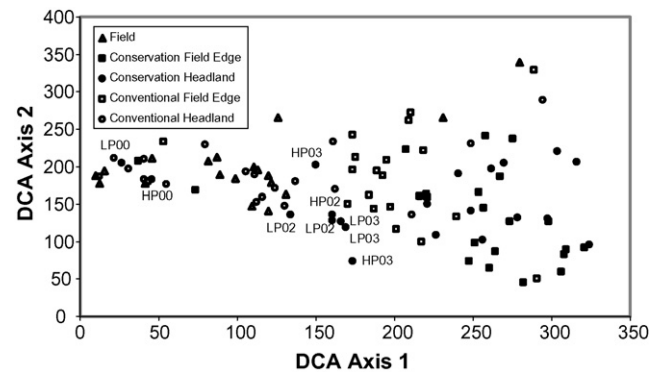


Fig. 1. DCA ordination of the vegetation data for all geographical locations, treatments and years. Centroids, i.e. average DCA scores for the four quadrats collected at each treatment on a particular date, are provided to facilitate interpretation. The newly established headlands (i.e. Lady's Park: LP and House Park: HP) and their year of sampling (i.e. 2000, 2002 and 2003) are indicated.

vegetation structure in the grassland conservation headlands was initially similar to that of the open fields. In 2002 and 2003 the grassland conservation headland samples of these two fields occurred further to the right hand side of the ordination indicating that the vegetation structure was becoming more similar, but not identical, to the mature headland sites.

Annual meadow grass (*Poa annua*) and perennial ryegrass (*Lolium perenne*) were more frequently found in the conventional headland, conventional edge and open field sites when compared to the grassland conservation headlands and conservation field edges (Table 2). White clover (*Trifolium repens*) was more frequently recorded in conventional headlands and open fields than in grassland conservation headlands and field edges (both conventional and conservation). The field edges and the grassland conservation headlands had a greater frequency of rough meadow grass (*Poa trivialis*), creeping velvet grass (*Holcus mollis*), Yorkshire fog (*Holcus lanatus*) and creeping thistle (*C. arvense*) than conventional headlands and open fields. Nettles (*Urtica dioica*) were found to be more abundant in the field edges than any other sampling location. In 2000, perennial ryegrass, meadow grass and white clover dominated the grassland conservation headlands at Ladies Park and House Park indicating that the newly established headland structure was similar to that of the open field. In 2002 and 2003, the frequencies of creeping thistle and rough meadow grass had increased and, as indicated by DCA, the vegetation assemblages were more similar to that of the mature headlands in Dumfries and Galloway and Ayrshire.

The vegetation in the grassland conservation headlands and the field edges (both conventional and conservation) was significantly denser than the conventional headlands and open fields (Table 3). Creeping thistle was significantly more abundant in grassland conservation headlands and conservation field edges than in any other sampling location while the abundance of broad-leaved dock (*R. obtusifolius*) was not influenced by headland treatment (Table 3).

Table 2

Mean vegetation cover ($\pm$ S.E.s) for plant species and mean relative abundance ($\pm$ S.E.s) for ground beetle species in each of the five treatment

	Cons HL	Cons E	Conv HL	Conv E	Field
Vegetation					
<i>Cirsium arvense</i> (L.)	57 $\pm$ 9	50 $\pm$ 8	9 $\pm$ 5	18 $\pm$ 6	3 $\pm$ 2
<i>Phleum pratense</i> L.	46 $\pm$ 9	31 $\pm$ 7	47 $\pm$ 10	19 $\pm$ 5	43 $\pm$ 11
<i>Poa trivialis</i> L.	38 $\pm$ 9	46 $\pm$ 10	4 $\pm$ 3	27 $\pm$ 8	1 $\pm$ 1
<i>Holcus mollis</i> L.	35 $\pm$ 10	38 $\pm$ 10	24 $\pm$ 9	48 $\pm$ 10	16 $\pm$ 9
<i>Lolium perenne</i> L.	35 $\pm$ 9	18 $\pm$ 8	74 $\pm$ 10	60 $\pm$ 10	89 $\pm$ 7
<i>Agrostis stolonifera</i> L.	31 $\pm$ 9	30 $\pm$ 10	36 $\pm$ 11	48 $\pm$ 10	26 $\pm$ 9
<i>Rumex obtusifolius</i> L.	31 $\pm$ 9	17 $\pm$ 6	28 $\pm$ 9	23 $\pm$ 6	29 $\pm$ 7
<i>Elymus repens</i> (L.)	29 $\pm$ 7	48 $\pm$ 9	36 $\pm$ 10	45 $\pm$ 9	36 $\pm$ 10
<i>Ranunculus repens</i> L.	26 $\pm$ 9	24 $\pm$ 8	21 $\pm$ 9	38 $\pm$ 9	32 $\pm$ 10
<i>Holcus lanatus</i> L.	17 $\pm$ 7	30 $\pm$ 10	3 $\pm$ 2	11 $\pm$ 5	1 $\pm$ 1
<i>Poa annua</i> L.	13 $\pm$ 6	10 $\pm$ 5	55 $\pm$ 9	37 $\pm$ 9	45 $\pm$ 10
<i>Urtica dioica</i> L.	12 $\pm$ 5	63 $\pm$ 10	8 $\pm$ 5	37 $\pm$ 9	1 $\pm$ 1
<i>Trifolium repens</i> L.	10 $\pm$ 7	5 $\pm$ 5	38 $\pm$ 11	12 $\pm$ 7	46 $\pm$ 10
Bare ground	24 $\pm$ 8	19 $\pm$ 8	43 $\pm$ 9	40 $\pm$ 10	46 $\pm$ 9
Ground beetles					
<i>Nebria brevicollis</i> (Fabricius)	24 $\pm$ 7	23 $\pm$ 8	10 $\pm$ 2	28 $\pm$ 4	11 $\pm$ 4
<i>Pterostichus strenuus</i> (Panzer)	12 $\pm$ 4	10 $\pm$ 3	5 $\pm$ 1	8 $\pm$ 3	3 $\pm$ 1
<i>Loricera pilicornis</i> (Fabricius)	9 $\pm$ 4	5 $\pm$ 1	12 $\pm$ 4	5 $\pm$ 2	10 $\pm$ 2
<i>Pterostichus melanarius</i> (Illiger)	9 $\pm$ 3	13 $\pm$ 4	21 $\pm$ 7	19 $\pm$ 3	31 $\pm$ 10
<i>Bembidion mannerheimi</i> Sahlberg	8 $\pm$ 4	7 $\pm$ 5	5 $\pm$ 3	3 $\pm$ 2	0 $\pm$ 0
<i>Pterostichus niger</i> (Schaller)	7 $\pm$ 3	7 $\pm$ 3	4 $\pm$ 2	10 $\pm$ 5	7 $\pm$ 5
<i>Bembidion lampros</i> (Herbst)	3 $\pm$ 3	2 $\pm$ 1	10 $\pm$ 4	1 $\pm$ 1	4 $\pm$ 1
<i>Agonum muelleri</i> (Herbst)	2 $\pm$ 1	1 $\pm$ 7	6 $\pm$ 3	1 $\pm$ 0.4	9 $\pm$ 5
<i>Bembidion aeneum</i> (Germar)	1 $\pm$ 1	1 $\pm$ 1	9 $\pm$ 4	1 $\pm$ 1	9 $\pm$ 5
<i>Leistus rufescens</i> (Fabricius)	1 $\pm$ 1	6 $\pm$ 4	0 $\pm$ 0.4	6 $\pm$ 4	0 $\pm$ 0

Information is provided only on dominant species (i.e. plants with an average cover over 20% and carabids with a mean relative abundance over 5% in at least one treatment). The species are listed on the basis of decreasing order of mean occurrence in the Conservation Headland treatment. Cons = conservation, Conv = conventional, E = edge, HL = headland.

DCA analysis of the ground beetle data found eigenvalues of 0.520, 0.284, 0.217 and 0.128 for axes one to four, respectively, and the variation accounted by these axes were 15.3, 8.3, 7.4 and 3.8%, respectively. The first two axes therefore described most of the observed variation in ground beetle assemblage structure. The separation of sites in the ordination space could be attributed to geographical location and treatment (Figs. 2 and 3). The two Fife fields

(House Park and Ladies Park) tended to have lower axis one scores than the remaining three farms (Fig. 2). Influences of treatment were also apparent with the grassland conventional headlands and the open fields having lower axis two scores than the conservation headlands and field edges (Fig. 3). The newly established headlands (i.e. House Park and Ladies Park) had low axis one scores (<100) thus indicating that the ground beetle assemblage structure of

Table 3

Results of REML analyses on the activity abundance of key invertebrates, the abundance of weeds, the activity density (Carabidae N) and richness of carabids (Carabidae S) and the density of the vegetation as measured by the visual obstruction method (Robel et al., 1970)

	Cons E	Cons HL	Conv E	Conv HL	Field	S.E. of differences	Wald statistic (4 d.f.); χ^2 prob	Location of significant differences
Limacidae	2.73	2.80	2.33	1.86	1.14	0.330	34.97, $P < 0.001$	ConsE, ConsHL > Field, ConvHL; ConvE, ConvHL > Field
Arionidae	2.40	2.26	2.10	0.73	0.33	0.348	61.32, $P < 0.001$	ConsE, ConsHL, ConvE > ConvHL, Field
Homoptera	1.85	2.08	1.95	0.77	0.57	0.260	60.61, $P < 0.001$	ConsE, ConsHL, ConvE > ConvHL, Field
Lepidoptera	2.14	0.82	1.72	0.51	0.40	0.321	56.97, $P < 0.001$	ConsE, ConvE > ConsHL, ConvHL, Field
Symphyta	1.74	1.10	1.81	0.77	0.78	0.233	37.91, $P < 0.001$	ConsE, ConvE > ConsHL, ConvHL, Field
Heteropteran	1.21	0.66	1.10	0.39	0.19	0.230	29.69, $P < 0.001$	ConsE, ConvE > ConvHL, Field; ConsHL > Field; ConsE > ConsHL
Carabidae N	3.21	3.50	3.77	3.60	4.00	0.240	12.23, $P < 0.001$	Field > ConsHL, ConsE; ConvE > ConsE
<i>Cirsium</i> spp.	1.19	1.51	0.38	0.08	0.01	0.240	16.03, $P < 0.001$	ConsE&ConsHL > ConvE, ConvHL, Field
<i>Rumex</i> spp.	0.45	0.44	0.52	0.59	0.62	0.169	0.44, $P = \text{NS}$	–
Carabidae S	2.15	2.17	2.26	2.22	2.26	0.106	1.87, $P = \text{NS}$	–
Vegetation density cm	3.24	3.43	2.677	2.154	2.14	0.165	105.7, $P < 0.001$	ConsE, ConsHL > ConvE > ConvHL, Field

Mean values (log transformed) are given for each of the five treatments. Cons = conservation, Conv = conventional, E = edge, HL = headland.

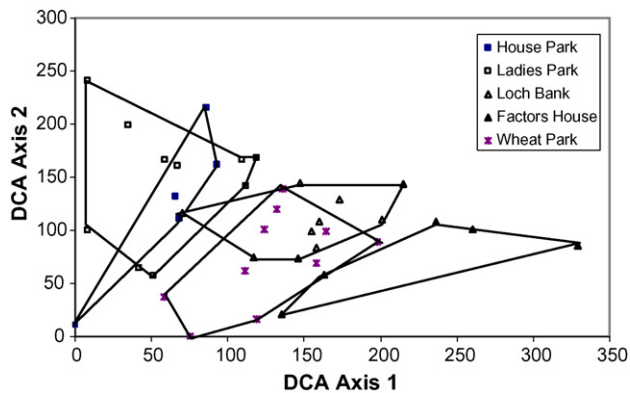


Fig. 2. DCA ordination of the ground beetle relative abundance data for all geographical locations, treatments and years highlighting geographical differences. Prior to analyses both spring and summer uplifts were combined to obtain an overall indication of the ground beetle assemblage structure for each study year.

these headlands was more similar to the open fields than to the mature headlands (i.e. Ayrshire and Dumfries and Galloway). This is in agreement with the vegetation findings.

The conventional headlands and open fields had higher relative abundances of species typical of intensively managed agricultural land (e.g. *Bembidion lampros*, *Bembidion aeneum* and *Agonum muelleri*; Table 2). The grassland conservation headlands and field edges had higher relative abundances of *Pterostichus strenuus* and *Leistus refescens*, both of which tend to be associated with field margins and more extensive habitats. REML analyses found headland management did not significantly influence ground beetle species richness, but did influence ground beetle activity density (Table 3). The activity density in the open field was significantly higher than that of the grassland conservation headland, the conventional field edge and the conservation field edge.

Headland management significantly influenced all invertebrates studied (Table 3). Arionidae slugs and

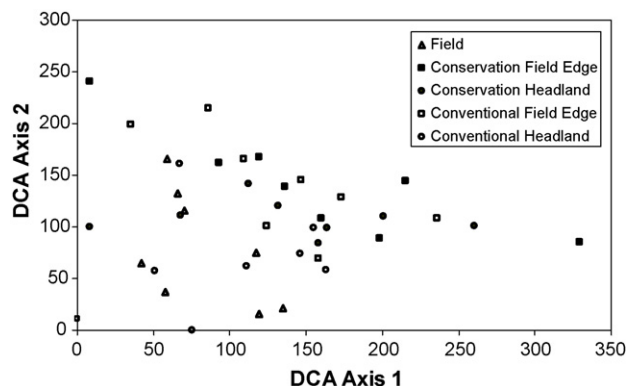


Fig. 3. DCA ordination of the ground beetle relative abundance data for all geographical locations, treatments and years highlighting differences between headland treatments. Prior to analyses both spring and summer uplifts were combined to obtain an overall indication of the ground beetle assemblage structure for each study year.

homopteran bugs had higher activity densities in the field edges (both conventional and conservation) and the conservation headlands than in the conventional headlands and open fields. The activity density of heteropteran bugs was greater in grassland conservation headlands and field edges than in open field sites. The activity density of lepidopteran and sawfly larvae was greater in the field edges (conventional and conservation) than headlands (conventional and conservation) or open fields. The activity density of Limacidae slugs was greater in the field edges and headlands (both conventional and conservation) than the open fields.

Sixteen bird species were recorded across the study sites, however, too few individuals of any one species occurred to allow statistical analyses. There was little difference in utilisation between the grassland conservation headlands (five species recorded), the conventional headlands (four species recorded) or the conventional headlands' backing habitats. There was a tendency for more bird species to be recorded in the backing habitat of the conservation headlands. This was unlikely a result of differences in backing habitat structure as the same backing habitats ran continuously between the conventional and conservation headlands and were subjected to the same management practices.

4. Discussion

Adapting the arable conservation headland approach to intensive grassland could provide farmers with an intermediate means of promoting invertebrate assemblage diversity in intensively managed grassland without changing the management of the remainder of the field. Conservation management in grassland headlands favoured Arionidae slugs, homopteran bugs and heteropteran bugs. Haysom et al. (1999, 2004) found that lepidopteran and sawfly caterpillars were adversely influenced by intensive cutting regimes and in this study the activity density of these two groups of invertebrates was greatest in the field edges (rather than the headlands or the fields) where disturbance by livestock and machinery was reduced. While the activity density of caterpillars in the grassland conservation headlands was slightly higher than that of the conventional headlands and open fields, this difference was not significant. It is possible that the vegetation in the conservation headlands was too dense to allow the colonisation of plant species such as charlock (*Sinapis arvensis*) and fat hen (*Chenopodium album*) which are attractive to sawfly and lepidopteran caterpillars (Sotherton, 1991).

Despite the higher activity density of some prey invertebrates in grassland conservation headlands, no evidence was found that they were used more than conventional headlands by farmland birds. As many birds identify prey visually, dense vegetation (typical of that found in our grassland conservation headlands) can greatly

decrease the detectability of prey (Atkinson et al., 2004) and can impede the mobility of the forager (Brodman et al., 1997). On the other hand, frequent grazing or cutting (typical of the conventional headlands), while enhancing the accessibility of prey items, tends to reduce their abundance (Haysom et al., 2004; Vickery et al., 2001). Our results therefore appear to support the suggestion that management practices in grasslands that favour the abundance of invertebrate prey species conflict with those that favour prey accessibility (McCracken and Tallowin, 2004; Plan-tureux et al., 2005).

While the economic impact of weed and pest encroachment in grassland is likely to be less severe than in arable land, farmers will be more likely to adopt the grassland conservation headland approach if they can be reassured that encroachment is limited (Deschênes et al., 2002; De Snoo, 1997). In this study several weed species were found in the field edges and this is in agreement with Boutin and Jobin (1998) who found 32% of plants present in hedgerows were weeds. Creeping thistle occurred at its highest abundance in grassland conservation headlands and their adjacent field edges indicating the headlands' potential to harbour weeds. Marshall and Arnold (1995), however, found that the weed flora of the crop is largely unrelated to that of the field margin. In agreement with this, multivariate analyses indicated that the vegetation assemblage structure of the grassland conservation headlands and field edges was distinct from that of the conventional headlands and open fields. Hence, at least over the period in which the headlands were established, there was no evidence that the conservation headlands influenced the occurrence of weeds in the adjacent fields.

Frank (1998) found that some species of slugs migrated from the field margins into the surrounding crop causing significant damage to arable field edges. In this study the activity density of slugs was greater in the grassland conservation headlands than the conventional headlands indicating their potential to harbour pests. The higher activity density was most likely due to the deeper litter layer in the conservation headlands resulting in a more humid and thus favourable microclimate for slugs. From the current study, the lower abundance of pests and weeds in the open field indicates that the movement of these pests and weeds is largely restricted to the headland area.

Grassy headlands are important aestivating sites for *Nebria brevicollis* during summer (Thomas et al., 2001) and the higher relative abundance of this species in conservation headlands and field edges may be related to its dispersal into these habitats to aestivate. The tussocky nature of the vegetation in grassy field margins also provides an aerated and temperature-buffered microclimate for overwintering predators (Pfiffner and Luka, 2000). Previous studies have found that ground beetle populations in field margins tend to be denser (Desender et al., 1989) and richer (Haysom et al., 1999; Kromp and Steinberger, 1992) than the adjacent field. In this study headland management did not influence ground beetle species richness and, contrary to the findings of other

studies, the activity density of ground beetles in the grassland conservation headlands was lower than that of open fields. As the vegetation was denser in the conservation headlands than the open fields, it is possible that differences in sampling efficiency resulted in the higher activity density in the open fields.

Differences in vegetation densities between the treatments do not, however, account fully for the observed differences in the ground beetle assemblage structure. Ground beetle assemblages in the field edges and conservation headlands differed considerably from those in conventional headlands and open fields indicating that some species were reluctant to move between the two habitats. Field margin species such as *Leistus* spp. and *P. strenuus* were more common in the conservation headland than the conventional headland and while the conservation headland provided additional habitat for these species, it is likely they would be restricted to the outer margins of the field.

The current study illustrated that the adaptation of the arable conservation headland approach to the grassland situation increased the occurrence of some groups of invertebrates in intensively managed agricultural land. Grassland conservation headlands have the potential to facilitate intermediate forms of biodiversity conservation within intensively managed grassland landscapes while enabling the landowners to maintain their profit margins. However, the grassland conservation headlands established using the draft agri-environment prescription being tested were found to have extremely dense vegetation that can impede the movement of some invertebrates and potentially discourage foraging farmland birds. It is therefore essential that additional management practices (e.g. opening up the vegetation structure annually) be considered to enable grassland conservation headlands to achieve their full potential.

Acknowledgements

We would first like to thank the many farmers and landowners who provided access to their land for this study. We are also extremely grateful to Ruth Morton, Shona Blake, Sarah Brocklehurst and Susan Bone for their help and advice, and to Billy Harrison, Elaine McEwan and Catherine Blake for their technical assistance. SAC receives financial support from the Scottish Executive Environment and Rural Affairs Department (SEERAD). We are grateful to two anonymous referees for helpful comments on an earlier draft of the manuscript.

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