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Agriculture, Ecosystems and Environment 113 (2006) 36–44
Agriculture Ecosystems & Environment
www.elsevier.com/locate/agee

Impacts of an agri-environment field margin prescription on the flora and fauna of arable farmland in different landscapes

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Received 13 December 2004; received in revised form 17 August 2005; accepted 29 August 2005
Available online 17 October 2005

Abstract

The hypothesis that sown 6 m grass margins strips at the edges of arable fields have a positive impact on farmland biodiversity was tested using a paired field approach in southern England. A total of 42 fields were investigated, half with at least 3-year-old margin strips created under the UK agri-environment scheme Countryside Stewardship and half nearby control sites. The sites were grouped on the basis of average field size into small, intermediate or open landscape locations to examine landscape structure effects. Assessments of the flora, bird and territory numbers, bees, spiders, Orthoptera and Carabidae were made in early to mid-summer 2003. There were positive impacts on diversity or abundance for the flora, bees and Orthoptera. The herbaceous flora of the pre-existing boundary adjacent to sown 6 m strips was significantly more species-rich than controls, probably reflecting a buffer effect of the strip. Bees and Orthoptera, the latter of which were only found in field boundaries, were more abundant where strips were sited, reflecting added habitat resources. Bee numbers were significantly lower in field centres where there were no 6 m margin strips. There were no significant effects of sown strips on numbers of birds observed or bird territories, spiders or Carabidae, but also no negative impacts. Lycosid spiders were consistently more abundant in boundaries of small fields with 6 m margin strips. Linyphiidae were more abundant within the crop area of smaller fields. Amongst birds, wrens (*Troglodytes troglodytes*) were also more abundant in small fields, while yellowhammers (*Emberiza citrinella*) were more abundant in open landscapes. The results confirm there are benefits to farmland biodiversity from introducing new margin strips at the edges of arable fields. More significantly, the success of agri-environment schemes, which will vary between taxa and species, can be dependent on landscape structure. Scheme administrators may need to address landscape structure and mean field size to achieve significant enhancement of populations of declining farmland species.

Keywords: Biodiversity; Birds; Bees; Carabidae; Flora; Field size; Landscape; Spiders; Orthoptera; Sown margin strips

1. Introduction

Changes in agricultural practices and some intensification of management have occurred in European farmland over the past 50 years (Stoate et al., 2002). As a result, many species of plants and animals associated with farms have shown reductions in population size. Agri-environment schemes have been in operation across much of Europe for over 10 years (Kleijn and Sutherland, 2003), as a means of addressing these effects on the biodiversity of farmed land. Significant amounts of financial support have been given to farmers to enhance biodiversity and to reduce the adverse environmental impacts of agricultural operations by following a range of management prescriptions. Much support has been provided under European Union Regulation 92/2078. Typically, such schemes have been voluntary, often competitive, as funding has been limited. In recent times the efficacy of such schemes has been questioned. Data from the Netherlands indicated only minor positive impacts or even negative impacts on target bird species (Kleijn et al., 2001). Nevertheless, positive indicators of management practices and impact were reported for a number of European schemes by Primdahl et al. (2003).

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doi:10.1016/j.agee.2005.08.036

However, a comprehensive review of schemes suggests that scientific evaluation of the impact of this approach is often poor, with most evaluations concentrated in the United Kingdom and the Netherlands (Kleijn and Sutherland, 2003).

In England, two major agri-environment schemes have been in operation for over 10 years. The Environmentally Sensitive Area (ESA) scheme was initiated in 1987. A total of 22 areas amounting to 10% of the agricultural area of England were designated during the period 1987–1994, selected on the basis of their wildlife, landscape and historic interest. Also in England, the Countryside Stewardship Scheme (CSS) was initiated as a pilot scheme in 1991 and has expanded to cover environmentally valuable agricultural land outside ESAs. The aims of the scheme are set in general rather than specific terms: to sustain diversity and natural beauty, to improve or extend wildlife habitats and to create new habitats and landscapes. By 2003, a total of some 32,000 voluntary 10-year management agreements had been made through these schemes, covering 1.16 million ha or 13% of agricultural land in England. Some assessments of these areas have been published (Defra, 2003a), indicating either no adverse impacts or some generally positive effects. There have been particular successes achieved under CSS. The encouragement of cirl bunting (*Emberiza cirlus*) populations in the county of Devon in southwest England under a special project was reported by Peach et al. (2001). A popular approach to the encouragement of farmland biodiversity has been the creation of field margin strips, particularly in arable land (Marshall et al., 2002; Moonen and Marshall, 2001). A number of different approaches to manipulating the management of arable field edges have been developed, including sown strips, uncropped wildlife strips, flower strips for pollinators and beetle banks (Marshall and Moonen, 2002). The objectives under the UK agri-environment schemes that cover the creation of 6 or 2 m wide grass strips at the edges of arable fields are to (a) recreate field boundaries and other landscape features, (b) to create networks of uncropped grass margins and areas of wildlife seed mixtures and (c) to provide wildlife habitats and corridors to buffer habitats and features from agricultural operations (Defra, 2003b).

The effects of habitat availability, habitat quality, landscape structure and heterogeneity on species occurrence and population size are interrelated. In agricultural landscapes, there is much evidence that landscape heterogeneity affects biodiversity. The effects of habitat loss and landscape change are implicated in the decline of many farmland species. For example, landscape structure was important for the diversity of plants, butterflies and beetles in agricultural ecosystems in southern Sweden (Weibull and Ostman, 2003; Weibull et al., 2003). Heikkinen et al. (2004) noted landscape effects on birds, though the location of important habitat may be more important than heterogeneity, per se. Clearly, the presence of semi-natural habitat is important for biodiversity at the regional scale (Duelli and Obrist, 2003).

In order to test the hypothesis that sown 6 m-wide grass margin strips are having a positive impact on selected taxa of farmland wildlife in England, a paired field approach was initiated in 2003. Arable fields where 6 m grass margins had been sown at least 3 years previously under Countryside Stewardship Scheme contracts were selected and compared with matched non-scheme fields. The flora, birds, bees, spiders and Orthoptera associated with the boundaries and arable crop field centres were assessed and compared. We also hypothesised that surrounding landscape structure would influence the results. In order to test this, the paired fields were grouped into three landscape types, small, intermediate or open, on the basis of field size.

2. Methods

A total of 42 arable field sites were evaluated, comprising 21 field pairs. Each field pair, one being an agri-environment scheme field with a sown 6 m margin (‘‘treatment’’) and the other a control, non-scheme field with no margin, was matched as far as possible for environmental factors. Both fields were located in similar landscapes, with a similar field boundary structure and arable crop on the same soil type. Field pairs were located from 1 to 5 km apart, reflecting the range of farm size from 150 to 3500 ha. The 21 pairs were grouped a priori into three landscapes based on field size, each landscape with seven pairs of fields. The three landscapes comprised: (a) areas dominated by small fields (average = 4 ha) with much semi-natural habitat, (b) areas dominated by intermediate field sizes (8–10 ha) and (c) areas with large fields (>10 ha) in open prairie-type landscapes, subsequently termed small, intermediate and open landscapes. There were no significant differences in mean boundary height (typically hedges) between areas or between margin types. Land-use within a circle of radius 500 m, based on each field site, was ascribed to arable, grassland, woodland, water, hard standing and nature reserve. Principal component analysis of these data, together with average arable and grass field size, separated the small and open sites, with intermediate landscapes lying between in ordination space. Data on cropping practices, crop yield and fertiliser and pesticide use were derived from interviews with the farmers, Analysis of variance of land cover, mean field size, study field size, total nitrogen (kg ha^{-1}) applied in the season and number of pesticide applications showed no differences between treatment and control areas. There were significant differences in mean field size and farm size between the landscapes (field sizes: 5.4, 9.1 and 13.0 ha (S.E.D. = 0.99; d.f. = 18) and farm sizes: 335, 626 and 1109 ha (S.E.D. = 234; d.f. = 18) in small, intermediate and open landscapes, respectively. There was significantly more arable land (88%) and less grassland (4%) in open areas, compared with the small and intermediate landscapes (62% arable; 26% grass). There were no significant differences in pesticide use (mean = six active ingredient applications) or fertiliser usage between the areas (mean = 188 kg N ha^{-1}). Where the 6 m margin had been introduced, a variety of seed mixtures had been employed. Often a grass-only mixture had been sown, commonly based on *Dactylis glomerata* L. and *Festuca rubra* L. Occasionally, more diverse seed mixtures had been used, including a number of common flowers, such as *Leucanthemum vulgare* L. and *Achillea millefolium* L., but still with a preponderance of grasses in the seed mix.

A series of sampling locations for fauna and flora were established at each field site (Fig. 1). Terminology applied to the field margin follows that of Greaves and Marshall, (1987). Flora were assessed in quadrats in the pre-existing boundary, usually beside hedges, in the crop edge and the crop centre. Where 6 m margin strips had been established, these were also assessed. Different arthropod groups were also assessed in the boundary and the crop centre, using sweeps and pitfall traps.

The plant communities present in the field boundary and the crop were assessed in 1 m × 5 m long quadrats. Percentage ground cover of higher plant species was assessed by eye in June and July in ten 5 m^2 quadrats from the two locations. Quadrats were located within the field boundary (*sensu* Greaves and Marshall (1987)) where the natural vegetation persisted from before the introduction of a 6 m margin (where this was present) and in the crop centre at least 50 m from the field edge (Fig. 1). In addition, the flora was assessed in three quadrats in the centre of the 6 m margin (where present) and three quadrats in the crop edge located at random and placed parallel to the edge. The crop edge quadrats were located inside the outermost seed drill line and might be expected to contain both typical arable weed species and species that may originate from the field boundary (Marshall, 1989).

Bird observations were made using a standard territory mapping approach (Bibby et al., 1992) to assess numbers of nesting birds. Bird occurrence and activity were recorded during morning visits within a 12.5 ha area based on the boundary of the field under study. All sites were visited four times during the breeding season starting in May and all observations by sight or sound were charted on sketch maps of the fields. Paired fields were visited by the same observer, with visits made at least 5 days apart and during good weather. Territories were then based on clusters of complementary observations of singing or displaying males or actual nest sites made during the four visits. The data were expressed as the total number of observations over the four visits and numbers of territories per species, as well as numbers of species observed and Red List species observed and nesting.

The bee fauna (Apididae) were assessed using two survey methods on three occasions from June up to before crop harvest in mid-July. Flying bees were caught using a butterfly net in transects of 15 min total catching time along the field boundary and in the crop centre (transects) (Fig. 1). In addition, the vegetation was swept with a cloth sweep net (Bioquip Products Inc., Rancho Dominguez, CA, USA) from the two locations (sweeps). Samples were bulked from three sets of 20 contiguous sweeps taken walking through the vegetation. Insects were killed with ethyl acetate in plastic sample containers; these were kept cool before sorting and identification.

Spiders were collected in pitfall traps located within the field boundary and the crop centre. Traps comprised plastic

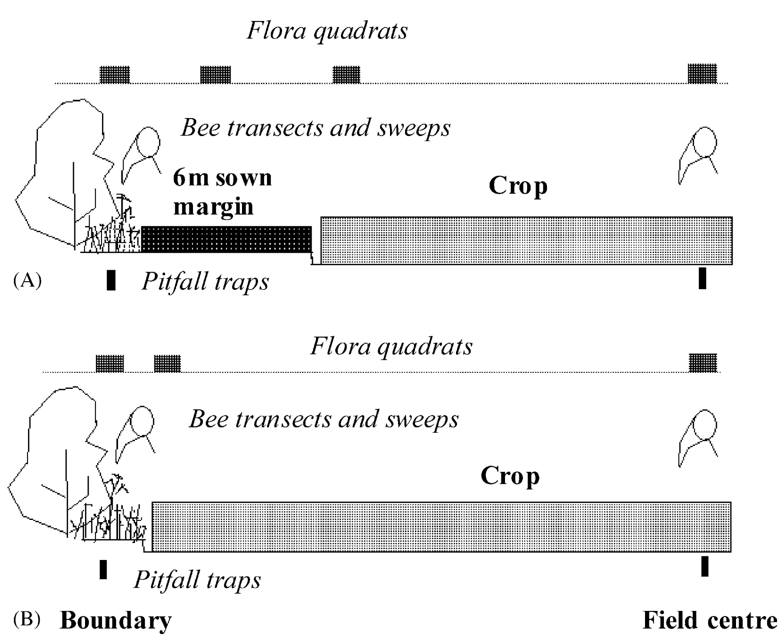

Fig. 1. Location of sampling points for the flora and fauna in the boundary and crop of field sites (A) with and (B) without sown 6 m grass margin strips: quadrats for the flora, transects and sweeps for bees and Orthoptera (net symbol) and pitfall traps for spiders and beetles (not to scale).

tubing of 12 cm diameter dug flush with the soil surface with a plastic powder funnel inside. Arthropods falling into the funnel were collected in a plastic jar below containing a preservative solution of 70% industrial methylated spirits and 1% glycerol. Traps were covered with plastic rain covers to reduce water entering the collecting jars. Traps were open for three 2-week periods; the first two consecutive periods began in early June 2003, followed by a 2-week break and the final trapping period in early July. Pitfall traps were set in pairs, to offset trap losses caused by badgers, rainfall, etc. A single sample from each location and time, a surviving sample or one selected at random, was sorted by hand under a binocular microscope. Spiders were identified to species using standard keys. Carabidae were sorted, counted, weighed fresh, dried at 80 °C for 48 h and re-weighed to give total dry weights.

Grasshoppers were assessed in catches from the 100 m field boundary and crop transects taken shortly before harvest. Hoppers were located by sight and sound and caught using a sweepnet. Identification was made after Marshall and Haes (1990). In addition, a simple five-point score of grasshopper activity based on sound (0 = no hopper activity seen or heard; 1 = only a few hoppers seen or heard along boundary; 2 = some activity at various places; 3 = activity at several places; 4 = activity at many places; 5 = activity detected all along the 100 m transect), was used to support the catch data. No Orthoptera were recorded within the arable crops, only from the boundary.

Data were analysed formally using analysis of variance as a split-split plot design. Landscape type was taken as the main plot, with field pairs nested within landscapes. The effects of landscape type, treatment (with and without 6 m margins) and, where necessary, location (boundary versus field centre) were analysed and interactions between these factors tested. Residuals were examined for under dispersion and where necessary data were square root transformed ($\sqrt{x + 0.05}$) to achieve normality. All analyses were performed using the Genstat8 program (Payne et al., 2002). Where significant, differences between means were tested using the standard error of the differences between means (S.E.D.) to calculate least significant differences ($P = 0.05$).

3. Results

A total of 275 different plant species were identified from the four sampled locations in the boundary, 6 m strip, the crop edge and the crop centre across the 42 field sites. Analysis of the species richness of the flora of field boundaries and crop centres indicated significantly greater biodiversity in the boundary of margins adjacent to sown 6 m margin strips (33.2 versus 27.7 species; S.E.D. = 2.058; $P = 0.029$), but no difference between landscapes.

Total non-crop plant cover (i.e. excluding crops), showed the expected significant difference between the boundary and field (142.4 and 10.6%, respectively). Crop weed cover was highest in small arable fields, but species richness did not differ across treatments or landscapes.

Weed diversity in the crop close to the field edge averaged 13.8 species (7.0 in the field centre) and did not differ between margin types (6 m margin versus control) or landscapes. Analysis indicated that weed cover was statistically significantly lower in the field centre, compared with the crop edge (32 versus 11%). There was also a trend ($P = 0.061$) for weed cover to be less adjacent to sown 6 m margins (18%), compared with field edges with arable crops close to the boundary hedge (26%).

Plant diversity in the sown 6 m margins averaged 17.8 species per 50 m^2. Species richness and cover were unaffected by landscape type.

Analysis of the number of bird territories in each 12.5 ha area showed that there were no significant impacts of the sown 6 m margins. However, there was a significant trend in territory numbers across landscape types, with most in small (13.7) and intermediate fields (12.1) and least in large field landscapes (8.2; S.E.D. = 2.038; d.f. = 18). Numbers of species nesting mirrored these results, with no margin effect, but more species nesting in small fields. Analyses of the total number of bird observations from the four visits also showed no impact of 6 m margins, but significantly more birds seen in small and intermediate compared with open landscapes (118, 100, 59; S.E.D. = 13.88; d.f. = 18). Numbers of species observed were also highest in small fields, but a significant interaction between margin management and landscape was the result of the highest species richness in small fields with 6 m margins (Table 1).

Numbers of observations were also divided into numbers of seed- and insect-eating passerines, following Henderson et al. (2004). There were no significant differences in numbers of seed-eating birds across treatments, but insectivore numbers were significantly lower in open landscapes, compared with intermediate and small landscapes (means = 11, 19 and 20, respectively).

More detailed analyses were made for seven of the most abundant bird species: *Turdus merula* blackbird, *Fringilla coelebs* chaffinch, *Prunella modularis* dunnock, *Alauda arvensis* skylark, *Sylvia communis* whitethroat, *Troglodytes troglodytes* wren and *Emberiza citrinella* yellowhammer. There were no effects of the margin treatment (6 m margin versus control) on any of the species. However, for the last three and *T. merula*, there was evidence for differences in

Table 1
Numbers of bird species observed per site recorded over four visits in 12.5 ha areas with or without 6 m sown margin strips

Landscape type	Small	Intermediate	Open
With 6 m margin	18.3 c	12.7 ab	11.3 a
Control (no margin)	15.3 bc	15.0 b	10.7 a

Data from paired sites in three landscape types: small, intermediate and open. Figures with the same letter are statistically similar. (S.E.D. = 1.566, d.f. = 31).

Table 2
Numbers of nesting territories per 12.5 ha and numbers of birds observed in three landscape types

Species	Landscape type					
	Small		Intermediate		Open landscapes	
	Territories	No. of birds observed	Territories	No. of birds observed	Territories	No. of birds observed
Turdus merula	2.07	13.7 x	1.93	11.3 x	1.07	6.8 y
Sylvia communis	1.79 b	9.4	0.50 a	4.9	1.21 b	5.3
Troglodytes troglodytes	2.36 b	10.0 x	3.14 b	12.6 x	0.71 a	2.6 y
Emberiza citrinella	0.64 a	4.4 x	2.00 b	10.6 y	2.07 b	9.9 y

Numbers of territories (a, b, c) or observations (x, y, z) with different letters in each row are significantly different after analysis of variance of transformed data ($\sqrt{n+0.05}$).

numbers of birds observed and territory number associated with landscape (Table 2).

For *T. merula*, there was no statistical difference in territory number between landscapes, but there were significantly fewer birds observed in open landscapes with large fields. *S. communis* had fewest territories in fields with intermediate size, but highest numbers observed in small field landscapes. *T. troglodytes* had most territories and observations in the intermediate and small sized fields and fewest in the open landscape. *E. citrinella*, in contrast, was least abundant in the small landscapes, with higher densities in intermediate and open landscapes.

Very few bees were caught in sweep samples, with records from only five occasions. More bees were caught in timed transects with a butterfly net, but catches were low, averaging only two bees per location per visit. Analyses of total bees caught showed a highly significant positive effect of 6 m margins and boundary sampling location. More bees were found adjacent to sown 6 m margins compared with controls (7.3 versus 4.6; $\sqrt{}$data $P = 0.01$) and fewer in the centre of arable crop fields compared with the boundary (7.6 versus 4.4; $\sqrt{}$data $P < 0.001$). Overall, bee numbers were lowest in field centres where 6 m margins were absent. Species richness of bees followed the trends noted for bee numbers, with greater diversity in fields with 6 m margins and in boundaries (mean = 3.7 species) compared with field centres (mean = 1.1).

The most abundant species was the bumblebee *Bombus lapidarius* L., which averaged 40% of the catch. Analyses of this species indicated significant effects of margin type on bee numbers and an interaction between location and landscape type. *B. lapidarius* numbers were enhanced by sown 6 m margins (mean = 4.0), compared with control fields (mean = 1.7). Interestingly, numbers of this species were higher in the adjacent arable crop in intermediate and open landscapes, but lower in small fields (Fig. 2).

A total of 83 spider species were identified, with the Linyphiidae (money spiders) being the most diverse family with 46 species. Four species of Linyphiidae found are nationally uncommon: *Gongylidiellum murcidum* Simon, *Mioxena blanda* Simon, *Syedra gracilis* Menge and *Troxochrus scabriculus* Westring. The remaining 37 species of mainly ground-active hunting spiders were grouped together for initial analyses. These included 14 species of Lycosidae, the second most diverse family. Spider species richness showed some increase over the three trapping periods, but was unaffected by margin treatment, trap location or landscape.

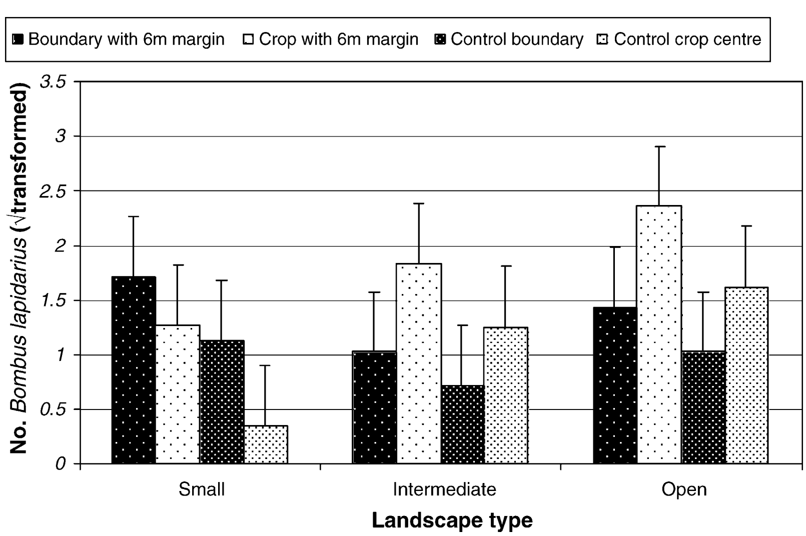

Fig. 2. Mean total number ($\sqrt{}$-transformed) of *Bombus lapidarius* caught in transects along boundaries with and without sown 6 m margins and in adjacent arable crops from three landscape types (small, intermediate and open). Error bars: S.E.D. = 0.554; d.f. = 36.

Analysis of total spider numbers per location from three trapping periods showed no overall effect of the 6 m margin, but significant differences between the boundary and crop trap sites. Overall, more spiders were caught in field centres compared with the boundary (50 versus 36 per location). There were also significant interactions between margin treatment and landscape area and interactions between margin treatment and location. Highest numbers of spiders (67) were found in small landscapes with 6 m margin strips; all other combinations were statistically similar, but with lower numbers (38). Analyses of the two groups of spiders, the Linyphiidae and the wolf spiders, indicated that after square root or log *e* transformation there were significant differences between the field locations. As might be expected for highly dispersive Linyphiidae, more were caught in the crop (18 versus 42; $P < 0.001$), whereas the more sedentary wolf spiders were more abundant in the field boundary (18 versus 8; $P = 0.006$).

For numbers of wolf spiders, three were significant interactions between margin treatment and landscape type and also between margin treatment and location. The data indicate that non-Linyphiid spider numbers were highest in boundaries with 6 m sown margins, with lower numbers in field centres and boundaries without 6 m margins (Table 3). This was particularly the case in small field landscapes. An examination of the spider densities of the two groups indicates some effects of landscape structure (Fig. 3). Irrespective of field margin strips, numbers of Linyphiidae were highest in crop centres of small fields. Wolf spiders, in contrast were able to respond to the presence of 6 m margin strips with increased numbers in field boundaries. However, the response only occurred in landscapes dominated by small fields.

Analysis showed no significant impact of the 6 m margins or landscape types, but much higher numbers of Carabidae trapped within the arable crops, compared with the boundaries (Table 4). Whilst beetle numbers stabilised in the crop between the second and third trapping periods, dry weight continued to increase, indicating larger beetles were caught in the final sample period.

A total of 11 species of grasshoppers and crickets were recorded in the study, with one uncommon species, *Metrioptera roeselii* (f. *diluta*) Hagenbach, Roesel's bush-cricket, found in one site.

Presence of the 6 m sown margin strip had a highly significant ($P < 0.001$) positive effect on the presence of Orthoptera. While Orthoptera were absent from the centre of arable crops, significantly higher numbers of individuals (5.2 versus 0.9; S.E.D. = 1.021) and species (1.8 versus 0.6; S.E.D. = 0.37) were found in the boundaries of sites with wide grass margins compared with controls. The Orthoptera were also significantly more abundant in small and intermediate landscapes, compared with open landscapes with large mean field size (3.3, 4.4 and 1.4, respectively; $\sqrt{\text{data}}$ $P = 0.011$).

4. Discussion

4.1. The impact of sown 6 m margin strips

There were no significant effects of 6 m margin strips on bird territory numbers, Linyphiid spiders or carabid beetles. However, there were clear positive effects of sown 6 m margins on plant species diversity in pre-existing boundaries and on bee and grasshopper numbers in boundaries.

A significant positive effect on plant species richness in the field boundary adjacent to sown grass strips has been reported previously from a single farm in southern England (Moonen and Marshall, 2001). Fertiliser and herbicide can reach field boundaries (de Snoo and de Wit, 1998; Tsiouris and Marshall, 1998) with adverse effects on the flora (Kleijn and Snoeijing, 1997). However, with arable field operations at least a further 6 m away, margin strips are likely to provide a buffer against such disturbance effects.

Positive impacts on numbers of Orthoptera are likely to be a result of increased habitat size and availability. Most boundaries with no sown grass strip have a tall herb plant community that is less suited to hoppers; where sown strips have been introduced, the flora includes typical grassland flower and grass species.

Pollinators have been suggested as good indicators of the impacts of agri-environment schemes (Sepp et al., 2004). This is supported by the present study, in which numbers of bees caught in transects were higher along boundaries with 6 m margin strips. There was also evidence that bee numbers caught in the field centres were also higher in fields with boundary strips, compared with fields without. The response is likely to reflect better floral resources in locations with margins (Backman and Tiainen, 2002; Carvell et al., 2004; Dramstad and Fry, 1995). Bumblebees, the commonest component of the catches, are known to forage over

Table 3
Total numbers of non-Linyphiid spiders per trap (untransformed) in the boundary and centre of fields with and without sown 6 m margins in three landscapes

Area	Boundary			Crop centre		
	Small	Intermediate	Open landscapes	Small	Intermediate	Open landscapes
With 6 m margin	45.7 c	21.3 b	8.1 ab	11.0 ab	2.3 a	4.0 ab
Control fields	6.7 ab	8.4 ab	19.7 b	6.1 ab	16.7 b	6.6 ab

Letters indicate statistically similar mean values, after analysis of transformed data ($\sqrt{n+0.05}$). See Fig. 4B for transformed means and S.E.D.

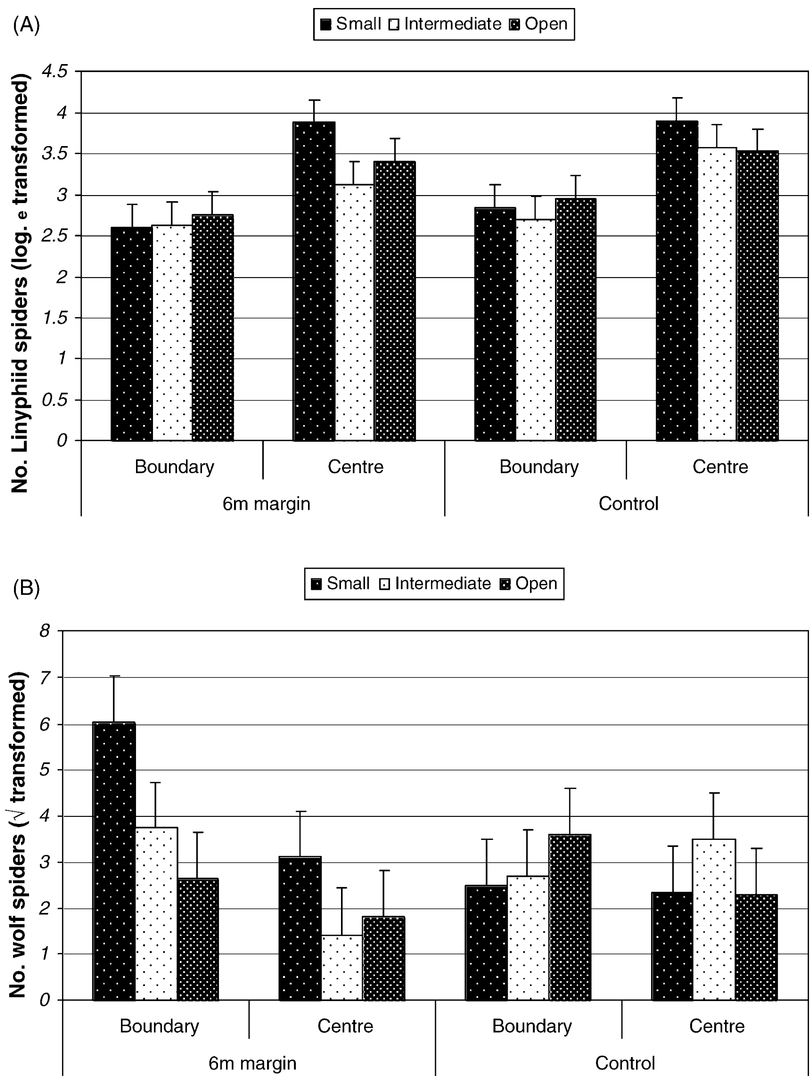

Fig. 3. Numbers of spiders caught in pitfall traps from field boundaries and crop centres with and without 6 m margin strips in three landscape types (small, intermediate and open): (A) Linyphiidae (transformed data — log e $n + 0.05$) and B) wolf spiders (transformed data — $\sqrt{n} + 0.05$). Error bars = S.E.D.

considerable distances (Dramstad et al., 2003; Walther-Hellwig and Frankl, 2000). The enhancement of bee numbers caught at least 50 m into arable crops adjacent to sown margins, indicates an influence of the boundary beyond its physical location, for this taxon.

Table 4
Mean numbers and total dry weight (g) of carabid beetles caught in pitfall traps at different locations over three trapping periods in June and July 2003, with square root transformed ($\sqrt{n} + 0.05$) total numbers and dry weights with appropriate S.E.D.s

Trap period	Numbers of carabidae		Total dry weight (g)	
	Boundary	Crop	Boundary	Crop
1	16.7	68.6	0.55	1.76
2	52.1	156.9	1.65	5.02
3	30.4	161.0	1.50	8.56
Totals (transformed)	8.68	18.35	1.65	3.63
S.E.D.	1.109		0.215	

Whilst margins are important for some bird species (Vickery et al., 2002), for others that forage over considerable areas the introduction of 6 m margin strips appears to be of little significance. Of the seven species analysed in detail, none nest within grass margins and only *E. citrinella* nests in hedge bases. The value of sown margins to most birds will be to enhance foraging. The data for spiders and Carabidae, groups that birds may feed on, indicated no major differences associated with the 6 m margins. In contrast, Orthoptera, key prey items for buntings like *E. citrinella*, were enhanced. A variety of approaches that address different quantitative and qualitative aspects of habitat are required for the conservation of farmland birds (Vickery et al., 2004).

The highly dispersive Linyphiid spiders (Halley et al., 1996) were also unaffected by margin treatment. Numbers were much higher in the centre of arable fields, reflecting their dispersal behaviour of ballooning on air currents over several kilometres. Whilst pitfall trapping gives only a representation of the fauna of particular habitats (Thomas and Marshall, 1999; Topping and Sunderland, 1992), the prevalence of Linyphiidae in the arable crops and Lycosidae in field margins has been reported elsewhere (Huusela-Veistola, 1998). The Lycosidae and other non-Linyphiid spiders appeared to be affected by both field size and sown margin strips. The interaction indicated that abundances were enhanced by sown strips in small-scale landscapes (Table 2), but not in large fields. Whilst there is considerable site-to-site variability in the data, this effect may reflect low dispersal and lack of source habitat for population responses to new habitat creation in open landscapes.

Carabidae did not respond to the presence of 6 m margin strips. Most species of Carabidae are relatively mobile (Thomas et al., 1998), but many species show affinities for either the crop area or field margins during the summer, with relatively few found in both habitats at this time of year (Thomas et al., 2001). Beetles from the crop centre are unlikely to be influenced by margin structure; the lack of response in boundary samples probably reflects a lack of influence of the habitat structure or size on activity–density.

4.2. Landscape structure

There were a number of statistically significant influences of field size and thus landscape structure on the taxa examined, as well as interactions between boundary structure and landscape type. Whilst some of the former influences may reflect habitat preferences, these with the latter interactions may have important implications for the success of agri-environment schemes. Amongst landscape responses, *E. citrinella* were more abundant in open landscapes (Table 2). This bird species is associated with short hedges and wide uncultivated grassy margins around fields and avoids pastures and grass leys for nesting (Bradbury et al., 2000; Stoate and Szczur, 2001). *E. citrinella* also prefer cereal crops for foraging in, as the summer progresses (Stoate et al., 1998). Arable crops predominated in open landscapes, while grassland fields were more abundant in small-scale landscapes typical of mixed farming. Wrens *T. troglodytes* were more abundant in small and intermediate landscapes, reflecting their use of hedges and woodland (e.g. Hinsley et al. (1996)). Blackbirds, *T. merula*, were also significantly less abundant in open landscapes and whitethroats, *S. communis*, tended to be more abundant in small landscapes. These common farmland bird species are likely to be more abundant in areas where average field sizes are less than 9 ha. The trend for hedge removal and field size increase seen over the last century are likely to have been detrimental to populations of these species. Agri-environment schemes may need to address landscape structure, as well as habitat creation. A balance between small and open landscapes might be achieved in areas with an average field size of 8 ha.

Amongst the spiders and Orthoptera, there was evidence of differential responses to the presence of 6 m margins between landscapes. The wolf spiders, dominated by the Lycosidae, were significantly enhanced in abundance only in field boundaries in areas dominated by small fields averaging 5 ha (Table 3). The response was not found in areas with larger fields. The abundance of grasshoppers was significantly enhanced by 6 m margins in small and intermediate landscapes. Introduction of 6 m margins into open landscapes gave a lower response, perhaps reflecting lower dispersal and/or small source populations.

The data indicate that a specific field boundary prescription, a sown 6 m grass strip introduced under an agri-environment scheme, has positive effects on the diversity of plants, bee pollinators and grasshoppers. These data also indicate that a case-by-case approach is needed for evaluating the influences of habitat manipulation on different farmland biota, supporting work by Jeanneret et al. (2003). The principle of targeted prescriptions as part of agri-environment schemes is confirmed as worthwhile for the maintenance and enhancement of farmland biodiversity. Nevertheless, agri-environment schemes may need to address landscape structure, as well as habitat creation, as these results indicate that, in general, smaller scale farmland landscapes may be more responsive to biodiversity initiatives.

Acknowledgements

We thank the editor and two reviewers for improvements to this paper. We also thank the UK Department for Environment, Food and Rural Affairs, especially Sally Mousley, and the Farming and Wildlife Advisory Group for help in finding sites. Bird assessments were made by Dr. Jeff Kirby and staff of Just Ecology Ltd. Bees, spiders and Carabidae were sorted and identified by Dr. David Kendall and Naomi Teague. Gareth Marshall assisted with field sampling and Philip Brain with statistics. We acknowledge with thanks the assistance and support of all the landowners and managers on whose land we worked. The study formed part of the EU Project QLK5-CT-2002-01495 Evaluating Current European Agri-environment Schemes to Quantify and Improve Nature Conservation Efforts in Agricultural Landscapes (EASY).

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