BOTANICAL REJUVENATION OF FIELD MARGINS AND BENEFITS FOR INVERTEBRATE FAUNA ON A DRYSTOCK FARM IN COUNTY LONGFORD

H. Sheridan, J.A. Finn and G. O'Donovan

ABSTRACT

This study investigates methods to rejuvenate the flora of previously degraded field margins on a pastoral farm in County Longford. We also assess the effects of individual treatments on the abundance of various orders of invertebrates recorded within the experimental plots. Field margin treatments were 1.5m-wide unfenced control margins, 1.5m-wide fenced margins or 3.5m-wide fenced margins. Nutrient inputs were excluded from all of the experimental plots. The botanical composition of the plots was examined on four occasions between 2002 and 2004 using permanent, nested quadrats. Emergence traps were used to measure invertebrate abundance within treatment plots and the main sward. Results indicated that 1) exclusion of nutrient inputs had a positive effect on plant species richness within the field margins; 2) plant species richness decreased with increased distance from the hedgerow; 3) herb species richness was greatest in the 1.5m closest to the hedgerow; 4) greater abundance of invertebrates occurred within the 3.5m-wide margins; 5) successful control of *Pteridium aquilinum* was achieved through spot treatment with the selective herbicide 'Asulox'; and 6) a combination of management techniques such as cutting and grazing is likely to enhance plant species richness and facilitate the structural diversity of vegetation that is necessary for many invertebrate taxa.

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INTRODUCTION

The role of field margins in providing refuges for biodiversity within arable farming systems has been clearly demonstrated for numerous taxa, e.g. flora and invertebrates (Marshall *et al.* 2006), birds (Vickery *et al.* 2002) and mammals (Tew *et al.* 1994). However, modern agricultural practices such as sward reseeding, fertilisation and silage cutting are known to have deleterious effects on the botanical (Frame 2000) and invertebrate faunal communities (Rushton *et al.* 1989) associated with grasslands. To date the conservation value of field margins within grasslands has largely been overlooked by policy makers, despite the fact that grassland accounts for a large proportion of agricultural land in many European countries, e.g. 79% in Ireland (DAF 2006) and 67% in the UK (Defra 2002).

A principal factor in the degradation of field margin flora within grass-based systems is elevated nutrient status, usually arising from either fertiliser and slurry misplacement or the dunging of grazing animals. This may promote the growth of 'problematic' species that are undesirable from an agricultural point of view and are of low conservation value. Examples include nitrophilous species such as *Urtica dioica* and *Galium aparine* (Boatman *et al.* 1994; Tsiouris and Marshall 1998). Another undesirable species is the rhizomatous *Pteridium aquilinum*, which frequently occurs in field margins and may become invasive in the sward if left unmanaged (Pakeman *et al.* 1998). Grazing of this species may increase the incidence of poisonings and cancers in animals, while its luxuriant growth can reduce the conservation value of the habitat where it occurs (Pakeman and Marrs 1992). Coupled with high nutrient status, soil poaching caused by grazing animals is likely to magnify the deterioration of the field margin flora (Theaker *et al.* 1995).

The principal objectives of this research are to identify appropriate management options focusing on width and nutrient exclusion, which lead to the rejuvenation of botanically degraded grassland field margins. This information may be used to inform agri-environmental policy and consequently lead to improvement of measures relating to field margin protection and management within the Rural Environment Protection

Scheme (REPS). We investigate whether nutrient exclusion alone can produce significant benefits for the botanical and invertebrate faunal communities of these habitats. We also investigate whether additional benefits arise from coupling nutrient exclusion together with the exclusion of grazing animals and/or extending field margin width. We report the effects of spot treatment of *P. aquilinum* with a selective herbicide on the botanical composition of the field margin habitat.

METHODS

The experimental site was located on a commercial drystock farm in County Longford, Ireland. The farm had been a participant in the REPS for five years prior to the establishment of the experiment. This required the exclusion of nutrient inputs from a 1.5m-wide strip adjacent to all farm field boundaries. Fields in which the experiment was undertaken had not been reseeded for at least 40 years, and while still dominated by *Lolium perenne* were also observed to contain numerous other grass and herb species such as *Agrostis* spp, *Holcus lanatus*, *Phleum pratense*, *Poa trivialis*, *Alopecurus pratensis*, *Taraxacum officinale* agg., *Cerastium fontanum*, *Bellis perennis*, *Rumex acetosa*, *Ranunculus repens* and *Trifolium pratense*. Swards were mown twice annually for silage production, i.e. early June and late July–August, and were grazed at stocking levels of about one livestock unit ha^{-1} by sheep in the spring and by suckler cows and their calves in the autumn. Inorganic nitrogen fertiliser was applied to the swards annually at a rate of between 140 kg N ha^{-1} and 170 kg N ha^{-1}. Fields were separated by hedgerows that dated back to at least the 1920s and principally consisted of *Crataegus monogyna*, *Prunus spinosa* and *Fraxinus excelsior*. The herbaceous flora of the associated field margin habitats had become badly impoverished, with an abundance of *U. dioica*, *G. aparine* and *P. aquilinum*. In addition, many of the wild flower species, e.g. *Primula vulgaris*, *P. veris* and *Hyacinthoides non-scripta*, which had been present up to approximately 20 years ago, had since disappeared from the margin habitats (pers. obs.).

A randomised paired block experiment was established in February 2002 to investigate the effects of increased width and the exclusion of nutrient input and grazing animals on the botanical and invertebrate faunal composition of the previously degraded field margins. Blocks were located parallel to, and paired on alternate sides

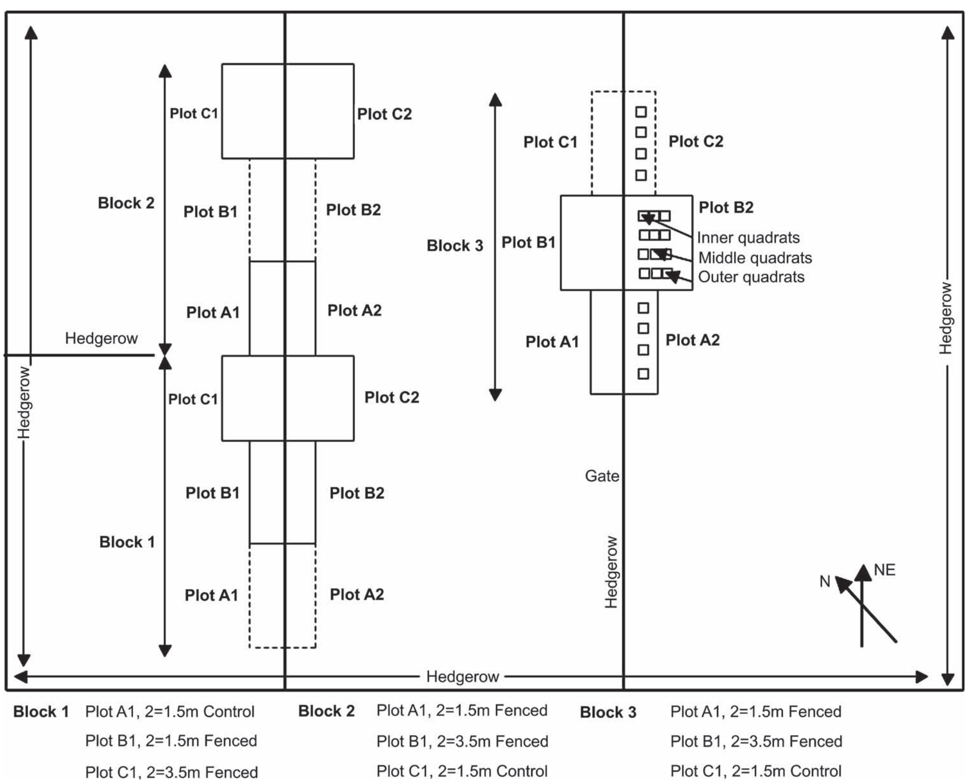

Fig. 1—Layout of experimental plots and quadrats, adjacent and parallel to internal farm hedgerows at the County Longford farm.

of internal farm hedgerows running north-east to south-west (Fig. 1). Blocks consisted of three 30m-long treatment plots randomly arranged along the length of the hedge. Treatments included controls, i.e. the existing 1.5m-wide margins, which were grazed and cut for silage in a similar manner to the remainder of the field. The second and third treatments were 1.5m- and 3.5m-wide margins from which domestic grazing animals were excluded through a combination of sheep wire and barbed wire. Nutrient inputs were excluded from all control and experimental plots. Three replicates of each paired block were established (see Fig. 1). To allow seed to set within plots, vegetation was not cut from the experimental plots until August 2002 and August 2003. Cutting of vegetation was undertaken using a lawn mower and strimmers. Clippings were gathered and removed to further reduce the nutrient input load in the plots.

SAMPLING

Botanical data were collected using permanent, nested quadrats. Four 3m × 1m quadrats were systematically placed at 3m intervals along the long axis of each plot 0.5–1.5m ('inner' quadrats) away from the base of the woody vegetation at that particular point along the hedgerow. To exclude edge effects between treatments, a 4.5m-long section at the end of each plot was not sampled. Additional parallel quadrats were placed at 1.5–2.5m ('middle' quadrats) and 2.5–3.5m ('outer' quadrats) from the hedgerow, in the 3.5m-wide margins (see Fig. 1). Presence/absence data were collected from the 3m × 1m quadrats. Abundance values using the Braun-Blanquet scale were assigned to vascular plants rooted within the central $1m^2$ of each quadrat. Data were collected from 120 quadrats on each of four sampling occasions, i.e. August 2002 (base year) and August 2003, June 2003 and June 2004. With the exception of *Agrostis* and *Salix*, all vegetation was identified to species level according to Stace (1997). While the majority of *Agrostis* appeared to be *A. stolonifera*, it was impossible to separate this species from *A. capillaris* in some plots as the two appeared to be hybridising. Hybridisation of these species has also been reported by Hubbard (1984). Individual species of *Salix* were impossible to distinguish as they were only present in seedling form.

Following the first sampling period in August 2002, vegetation was mown and *P. aquilinum* (which was abundant within some treatment plots) was spot-treated with the selective, systemic herbicide Asulam (methyl 4-aminobenzene sulphonyl carbamate, trade-name 'Asulox') at the recommended treatment level of 4.4 kg ha^{-1} of active ingredient (Keary *et al.* 2000). Contamination of surrounding vegetation with the herbicide was avoided through the use of a hand-controlled knapsack sprayer.

Emergence traps were used to investigate differences in invertebrate abundance between the main sward of the field and the field margins and also among the individual field margin treatments. Details of trap design are provided in Sheridan *et al.* (2008). Six emergence traps were randomly placed within each of the three field margin treatments. An additional ten traps were randomly located within the main sward of the adjacent fields. Trap heads were changed at 28-day intervals on five collection dates, i.e. 5 June 2003, 2 July 2003, 29 July 2003, 27 August 2003 and 29 September 2003. Seven trap catches were lost over the sampling period due to damage caused by farm machinery and grazing animals. As low numbers of invertebrates were present within the collection heads by the end of the first collection period, a 12V hand-held suction sampler was used to suction the ground area contained within each trap for a period of 90 seconds. Suction samples were added to the normal sample to provide a pooled catch for each trap. Following suctioning, traps were moved to another random location within the treatment plots and fields, and a collecting head was attached.

Invertebrate samples were sorted and specimens identified to order. Within the order Coleoptera, members of the Chrysomelidae, Staphylinidae, Coccinellidae and Curculionidae families were recorded separately. All other beetle families were recorded under the general title of Coleoptera. Aphids were recorded separately from the remainder of the Homopterans as the super family Aphidoidea. The Collembola were separated into the Anthropleona and the Symphyleona.

STATISTICAL ANALYSIS

To illustrate plant species richness, relative abundance and examine how this changed over time, species were ranked in descending order of abundance in terms of their mean cover value (Braun-Blanquet) (Table 1). Generalised linear model (GLM) with *post hoc* Tukey analysis was undertaken using SPSS Version 12, to investigate the effect of treatment (control, 1.5m fenced, 3.5m fenced) aspect (north-westerly vs south-easterly) and time (four sampling periods) on mean plant species richness within the quadrats located 0.5–1.5m from the hedgerow (see Fig. 1).

Table 1—Species recorded in control, 1.5m fenced and 3.5m fenced plots in 2002 and 2004 ranked in order of mean abundance, to allow assessment of vegetation change within experimental plots. Species cover recorded according to the Braun-Blanquet Scale, i.e. 1 = < 1%; 2 = 1–5%; 3 = 6–25%; 4 = 26–50%; 5 = 51–75%; 6 > 75% ground cover.

Species	*2002*					*2004*				
			3.5m fenced					*3.5m fenced*		
	Control	*1.5m fenced*	*Inner*	*Middle*	*Outer*	*Control*	*1.5m fenced*	*Inner*	*Middle*	*Outer*
Agrostis spp	4	4	4	5	5	5	5	5	6	6
Galium aparine	4	3	4	3	2	2	3	4	3	2
Bare ground	3	3	4	2	2	2	3	3	1	1
Dactylis glomerata	3	3	3	3	3	3	3	3	2	3
Holcus lanatus	3	2	1	2	3	2	2	2	2	2
Ranunculus repens	3	3	3	3	3	4	3	3	4	3
Rubus fruticosus agg.	3	1	2	1	1	2	2	1	1	1
Alopecurus pratensis	2	2	1	2	2	2	2	2	2	2
Arrhenatherum elatius	2	2	1	1	1	1	2	1	2	1
Cirsium arvense	2	2	2	2	2	2	2	2	2	2
Dryopteris filix-mas	2	1	1	–	–	1	–	1	–	–
Elytrigia repens	2	1	1	1	1	3	2	2	2	2
Festuca rubra	2	2	1	1	1	2	2	1	1	1
Hedera helix	2	2	2	1	1	2	2	2	1	1
Heracleum sphondylium	2	1	1	3	3	2	2	1	2	2
Holcus mollis	2	2	2	2	2	2	2	2	2	2
Lolium perenne	2	2	2	3	3	4	3	3	3	4
Poa trivialis	2	2	2	2	2	2	2	2	2	2
Urtica dioica	2	3	5	4	3	2	3	4	4	3
Veronica persica	2	2	2	1	1	–	–	–	–	–
Vicia cracca	2	2	–	–	–	1	2	–	1	2
Cardamine flexuosa	1	1	1	1	1	–	–	1	1	1
Conopodium majus	1	1	1	–	–	1	2	1	–	1
Cynosurus cristatus	1	1	–	–	–	1	1	–	–	–
Filipendula ulmaria	1	1	–	–	–	1	1	1	–	1
Fragaria vesca	1	1	–	–	–	–	–	–	–	–
Fraxinus excelsior	1	–	–	–	–	–	–	–	–	–
Geranium robertianum	1	1	1	–	–	2	2	1	–	–
Geum urbanum	1	1	1	–	1	2	1	1	–	–
Ligustrum vulgare	1	–	–	–	–	1	–	–	–	–
Lythrum salicara	1	–	–	1	1	1	–	1	1	1
Plantago lanceolata	1	–	–	–	1	–	–	–	–	–
Rumex acetosa	1	1	1	1	2	1	1	1	1	1
Rumex obtusifolius	1	1	–	1	1	–	1	–	1	–
Taraxacum off. agg.	1	–	1	1	1	1	1	1	1	1
Trifolium repens	1	2	–	–	1	1	1	–	–	–
Viola riviniana	1	1	–	–	–	1	1	1	–	1

GLM was also used to explore the effect of distance from hedgerow, i.e. 'inner', 'middle' and 'outer' quadrats (see Fig. 1), and time and aspect on mean plant species richness recorded within the 3.5m-wide plots. We also investigated changes in mean cover of *P. aquilinum* (Braun-Blanquet) in response to treatment and time.

Classification of vegetation data was undertaken using two-way indicator species analysis (TWINSPAN) using PC-ord (McCune and

Mefford 1999). This is a polythetic divisive classification process, i.e. the classification is based on the progressive refinement of a single axis ordination through reciprocal averaging. This produces a dichotomy of smaller vegetation groups, with each of the groups characterised by differential species (Kent and Coker 1992). TWINSPAN classification was undertaken using vegetation abundance data collected from the experimental plots in 2002 and 2004. In addition to botanical species, abundance of dung and bare ground were also included within the data set for this analysis.

GLM with *post hoc* Tukey analysis was used to investigate the effect of treatment, i.e. field margin vs main sward and control vs 1.5m fenced vs 3.5m fenced plots and time of sampling on mean abundance of invertebrates recorded.

RESULTS

A total of 62 higher plant species, including 13 grasses, 41 herbs and 6 woody species were recorded within treatment plots over the four sampling periods. Two species of fern were also recorded. Plant species and changes in their mean abundance (Braun-Blanquet) within the individual treatments between the first and last sampling periods are presented in Table 1.

GLM analysis of the 2002 data (base year) showed that mean plant species richness recorded within quadrats located 0.5–1.5m (control, 1.5m fenced and 'inner' quadrats of 3.5m–wide plots) from the hedgerow was not affected by either treatment or aspect, nor was there a significant interaction between these factors ($P > 0.05$) (Table 2). Mean plant species richness recorded during the 2002 sampling period was 14.21 ± 1.17 SEM within 1.5m control plots, 13.79 ± 1.23 SE within 1.5m fenced plots and 14.04 ± 1.01 SEM in the 'inner' quadrats of the 3.5m-wide plots.

Comparison of mean plant species richness within quadrats located 0.5–1.5m from the hedgerow, over the four sampling periods indicated that treatment had a significant effect, while aspect and time did not (Table 2). *Post hoc* Tukey analysis of treatment revealed significantly lower mean species-richness within the 'inner' area of

Table 2—Results of GLM comparison of mean plant species richness and mean grass species richness within plots located 0.5–1.5m from the hedgerow ('inner' section of 3.5m-wide margins) sampled using 3m × 1m quadrats over four sampling periods.

Quadrats 0.5–1.5m from hedgerow in 2002 (base year) $n = 6$					
		d.f.	*F-value*	*P-value*	*Sig.*
Mean plant species richness	Treatment	2, 12	0.055	0.947	ns
	Aspect	1, 12	0.814	0.385	ns
	Treatment × Aspect	2, 12	0.158	0.855	ns

Quadrats 0.5–1.5m from hedgerow over four sampling periods ($n = 24$)					
		d.f.	*F-value*	*P-value*	*Sig.*
Mean plant species richness	Treatment	2, 48	4.963	0.011	*
	Time	3, 48	1.030	0.388	ns
	Aspect	1, 48	4.001	0.051	ns
	Time × Treatment	6, 48	0.079	0.998	ns
	Time × Aspect	3, 48	0.018	0.997	ns
	Treatment × Aspect	2, 48	0.566	0.571	ns
	Time × Treatment × Aspect	6, 48	0.270	0.948	ns
Mean grass species richness	Treatment	2, 48	10.155	0.000	***
	Time	3, 48	1.617	0.198	ns
	Aspect	1, 48	3.165	0.082	ns
	Time × Treatment	6, 48	0.394	0.879	ns
	Time × Aspect	3, 48	0.173	0.914	ns
	Treatment × Aspect	2, 48	0.753	0.476	ns
	Time × Treatment × Aspect	6, 48	0.220	0.969	ns

* = $P < 0.05$; *** = $P < 0.001$.

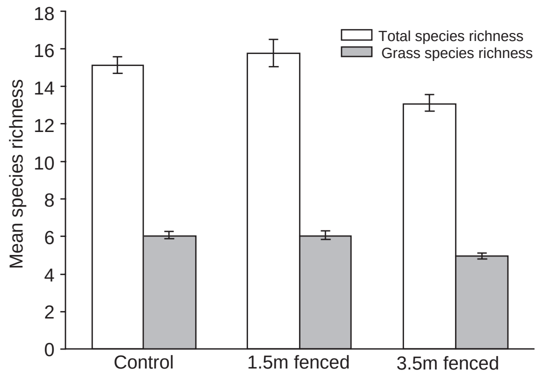

Fig. 2—Mean total species richness and mean grass species richness recorded within quadrats located 0.5–1.5m from the hedgerow in control, 1.5m fenced and 3.5m fenced plots ± SEM.

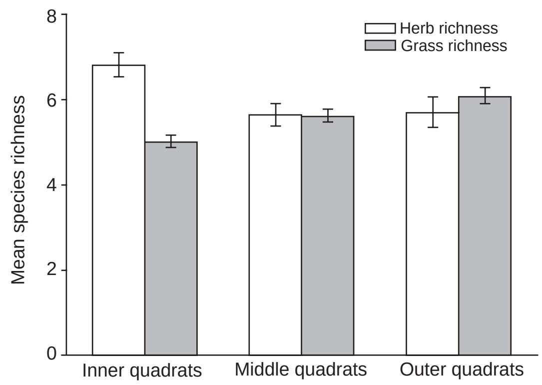

Fig. 3—Mean grass and herb species richness recorded within 'inner', 'middle' and 'outer' quadrats of the 3.5m-wide experimental field margin plots ± SEM.

the 3.5m-wide plots than was recorded within the 1.5m control (P = 0.013) and 1.5m fenced plots (P = 0.006) (Fig. 2). Mean plant species richness recorded was 15.15 ± 0.44 SEM within the 1.5m-control plots, 15.79 ± 0.71 SEM within the 1.5m fenced plots and 3.13 ± 0.44 SEM within the 3.5m fenced plots.

Comparison of grass species richness within these quadrats indicated a significant response to treatment (P < 0.001) (Table 2). *Post hoc* Tukey analysis revealed significantly higher mean grass species richness within the 1.5m control (Mean = 6.08 ± 0.19 SEM; P < 0.001) and 1.5m fenced plots (Mean = 6.08 ± 0.22 SEM; P < 0.001) than was recorded within the 'inner' section of the 3.5m-wide plots (Mean = 5.02 ± 0.15 SEM). No difference in grass species richness was found between the 1.5m control and 1.5m fenced plots (P = 0.758) (Fig. 2). Neither time nor aspect were found to have significantly influenced mean grass species richness within these plots (Table 2). The effect of time (n = 18; $F_{3, 48}$ = 0.717; P = 0.547), treatment (n = 24; $F_{2, 48}$ = 2.121; P = 0.131) and aspect (n = 36; $F_{1, 48}$ = 1.731, P = 0.195) on mean herb species richness recorded within these quadrats, was not significant.

The effects of treatment, i.e. location within plot, time and aspect on mean overall plant species richness within 'inner', 'middle' and 'outer' sections of the 3.5m-wide margins, were not significant ($F_{3, 48}$ = 1.350, P = 0.269; $F_{2, 48}$ = 1.959, P = 0.152; $F_{1, 48}$ = 1.898, P = 0.175, respectively). Mean plant species richness recorded within the 'inner' sections was 13.13 ± 0.45 SEM, within the 'middle' sections was 11.91 ± 0.38 SEM, and within the 'outer' sections was 12.14 ± 0.49 SEM. However, the effect of quadrat location within the 3.5m plots had a highly significant influence on mean grass species richness (Fig. 3; Table 3). *Post hoc* Tukey analysis revealed significantly higher grass species richness within 'middle' (Mean = 5.63 ± 0.14 SEM) and 'outer' quadrats (Mean = 6.09 ± 0.18 SEM) than was recorded within the 'inner' quadrats (Mean = 5.02 ± 0.15 SEM; P < 0.01). The difference between 'middle' and 'outer' quadrats was not significant (P = 0.082) (Fig. 3). The influence of time and aspect on mean grass species richness at the 'inner', 'middle' and 'outer' locations of these plots was not significant (P > 0.05) (Table 3). Location of quadrats within the 3.5m plots also had a significant influence on mean herb species richness (Fig. 3; Table 3) with significantly higher species richness recorded from 'inner' quadrats (Mean = 6.81 ± 0.28) than from 'middle' (Mean = 5.65 ± 0.26) (P = 0.017) and 'outer' quadrats (Mean = 5.70 ± 0.35) (P = 0.009). The difference between 'middle' and 'outer' quadrats was not significant (P = 0.791) (Fig. 3).

Analysis of mean cover (Braun-Blanquet) of *P. aquilinum* within plots, in response to treatment, time and aspect revealed that time had a significant effect ($F_{3,80}$ = 4.025, P = 0.010). Treatment (control, 1.5m fenced and 3.5m fenced) and aspect effects were non-significant ($F_{4, 80}$ = 1.409, P = 0.238 and $F_{1, 80}$ = 0.662, P = 0.418, respectively). *Post hoc* analysis showed a significant decrease in *P. aquilinum* cover between August 2002 and all other sampling periods (P < 0.05). Although a further decrease was recorded during June 2004, this was not significantly different from either June or August 2003 (P > 0.05) (Fig. 4).

The dichotomy of vegetation groups produced from TWINSPAN analysis of the 2002 abundance data is presented in Fig. 5. The initial split of the 57 species recorded within the 120 quadrats produced a positive group (n = 16), the indicator

Table 3—Results of GLM comparison of mean grass and herb species richness and mean grass species richness within 'inner', 'middle' and 'outer' sections of the 3.5m-wide field margin plots, sampled using 3m × 1m quadrats over four sampling periods.

'Inner', 'middle' and 'outer' sections of 3.5m margins, *n* = 24					
		d.f.	*F-value*	*P-value*	*Sig.*
Mean grass species richness	Treatment	2, 48	10.125	0.000	***
	Time	3, 48	0.960	0.419	ns
	Aspect	1, 48	0.153	0.697	ns
	Time × Treatment	6, 48	0.603	0.727	ns
	Time × Aspect	3, 48	0.761	0.522	ns
	Treatment × Aspect	2, 48	1.414	0.253	ns
	Time × Treatment × Aspect	6, 48	0.513	0.796	ns
Mean herb species richness	Treatment	2, 48	4.512	0.016	*
	Time	3, 48	2.218	0.098	ns
	Aspect	1, 48	3.639	0.062	ns
	Time × Treatment	6, 48	0.501	0.805	ns
	Time × Aspect	3, 48	0.110	0.954	ns
	Treatment × Aspect	2, 48	0.211	0.811	ns
	Time × Treatment × Aspect	6, 48	0.580	0.745	ns

* = $P < 0.05$; *** = $P < 0.001$.

species of which all occur at relatively low soil fertility levels. Further division produced a second positive group (*n* = 4, 'Group A') whose indicator species again occur frequently under conditions of relatively low soil fertility. In addition, this group of indicators represent species that tend to prefer short sward conditions. No indicator species were identified for the negative group (*n* = 16, 'Group B') arising from this split (Fig. 5). The initial division also gave rise to a negative group (*n* = 100), for which no indicator species were identified. The indicator species for the positive group produced at the next level of division (*n* = 68,

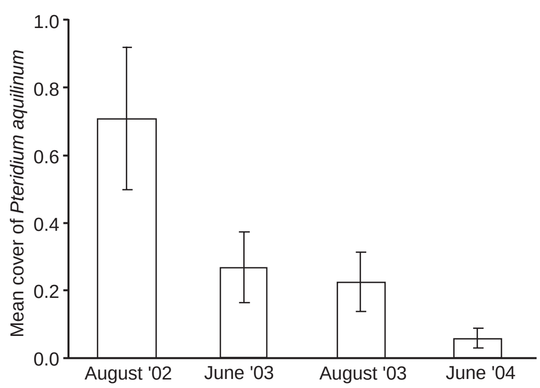

Fig. 4—Mean cover of *Pteridium aquilinum* (Braun-Blanquet i.e. < 1% = 1; 1%–5% = 2; 6%–25% = 3; 26%–50% = 4; 51%–75% = 5; > 6% = 6) recorded within experimental plots during August 2002, June 2003, August 2003 and June 2004 ± SEM.

'Group C') are not desirable from an agricultural perspective and tend to be difficult to control due to their ability to spread via rhizomes or stolons. The indicator species identified for the negative group produced at this level of division (*n* = 32, 'Group D') all represent areas of ground that were under heavy shade conditions (Fig. 5).

TWINSPAN analysis of the botanical data collected in 2004 revealed the same indicator species for 'Group A' and an increase in the number of quadrats that were classified into this group, i.e. *n* = 12 (Fig. 6). *Rubus idaeus* was identified as the single indicator species for 'Group B' (*n* = 4). This species also occurs under relatively low levels of soil fertility but is also likely to be indicative of woody hedgerow species that can spread into adjacent grassland. No indicator species were produced for 'Group C', although quadrat numbers within this group were found to have increased (*n* = 82). Indicator species produced for 'Group D' (*n* = 22) represent a group of shade tolerant species that would typically be associated with hedgerow bottoms or open woodlands (Fig. 6).

Individuals from the orders Collembola (Anthropleona and Symphypleona), Diptera, Opilones, Unirama, Hemiptera (Homoptera and Heteroptera), Coleoptera, Dermaptera, Neuroptera, Hymenoptera together with Araneae and Acari were recorded within emergence trap samples. GLM analysis revealed a significant influence of both time (i.e. five collection periods) and treatment (i.e. location of traps

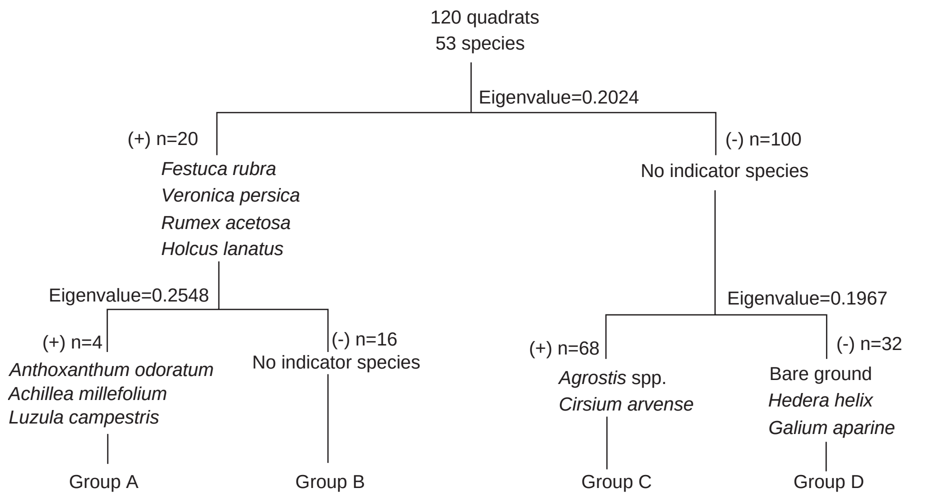

Fig. 5—TWINSPAN dichotomy of vegetation groups produced from abundance data collected within experimental field margin plots in 2002.

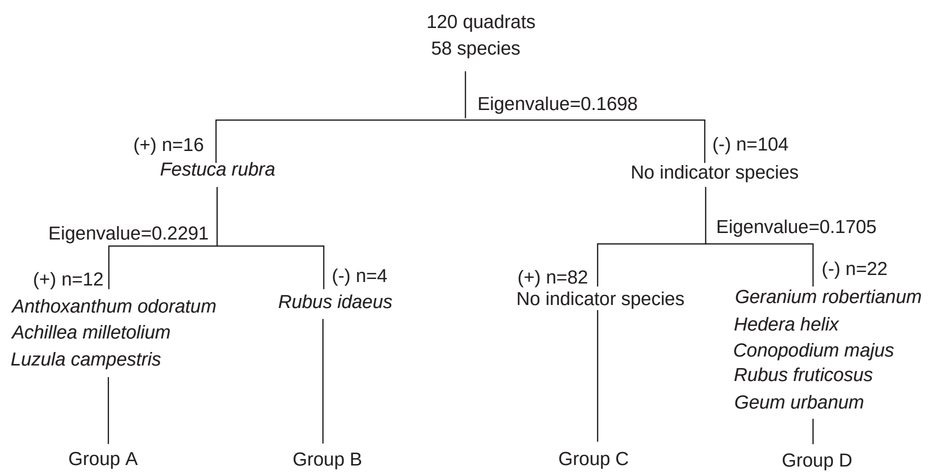

Fig. 6—TWINSPAN dichotomy of vegetation groups produced from abundance data collected within experimental field margin plots in 2004.

in field or field margin) on mean invertebrate abundance recorded (Table 4). *Post hoc* Tukey analysis indicated that overall density of invertebrates recorded was significantly greater within the 3.5m-wide margins (Mean = 97.11 ± 9.95 SEM) than was recorded within the main sward of the field (Mean = 71.67 ± 5.45 SEM; $P < 0.01$) (Fig. 7). Density of invertebrates within the 3.5m-wide margins did not differ significantly from that recorded within either control (Mean = 81.44 ± 7.50) or 1.5m-wide plots (Mean = 72.67 ± 5.12; $P > 0.05$) (Fig. 7).

Both time of sampling and trap location had significant effects on the abundance of Collembola recorded (Table 4). Significantly greater abundance of Collembola was recorded within the 3.5m-wide margin plots (Mean = 48.18 ± 6.21 SEM) than within the main sward (Mean = 41.20 ± 4.49 SEM) ($P < 0.01$). The difference in abundance between the three field margin treatment plots was not significant ($P > 0.05$). *Post hoc* Tukey analysis showed that the abundance of Collembola recorded during collecting period 3 (29 July 2003 to 27 August 2003 inclusive; Mean = 53.32 ± 5.89 SEM) was significantly greater than during collecting period 4 (27 August 2003 to 29 September 2003 inclusive; Mean = 25.29 ± 4.21 SEM) ($P < 0.05$). No other differences between collecting periods were observed.

The location of the traps had a highly significant influence on the abundance of spiders recorded, with greater numbers recorded within each of the field margin treatments than within the main sward of the field ($P < 0.001$). Mean abundance of Araneae within the main sward

Table 4—Results of GLM comparison of mean abundance of all invertebrates, mean abundance of Collembola only and mean abundance of Araneae only, recorded from emergence traps located within Control, 1.5m fenced and 3.5m fenced field margins and within the main sward of the field.

Mean abundance of invertebrates $n = 28$				
	d.f.	*F-value*	*P-value*	*Sig.*
Time (5 collections)	4, 123	2.967	0.022	*
Treatment (Field vs field margin)	3, 123	7.040	0.009	*
Time × Treatment	12, 123	0.907	0.462	ns

Mean abundance of Collembola				
	d.f.	*F-value*	*P-value*	*Sig.*
Time	4, 113	3.46	0.01	**
Treatment	3, 113	5.21	0.002	**
Time × Treatment	12, 113	1.76	0.063	ns

Mean abundance of Araneae				
	d.f.	*F-value*	*P-value*	*Sig.*
Time	4, 113	2.22	0.071	ns
Treatment	3, 113	28.13	<0.001	**
Time × Treatment	12, 113	1.17	0.312	ns

* = $P < 0.05$; ** = $P < 0.01$.

was 2.61 ± 0.42 SEM, within the 1.5m control was 8.11 ± 0.82 SEM, within 1.5m fenced plots was 7.17 ± 0.74 SEM and within 3.5m plots was 9.41 ± 0.71. The difference between the individual field margin treatments was not significant ($P > 0.05$) nor was time of sampling (Table 4).

Plot treatment had a significant influence on the abundance of Coleoptera ($F_{3,\ 113} = 3.00$; $P = 0.033$), with significantly greater numbers recorded within those traps located in the 1.5m fenced field margins than within those from any other location ($P < 0.05$). Time was not a significant factor in the analysis ($F_{4,\ 113} = 1.326$; $P = 0.265$). Mean abundance of Coleoptera was 0.59 ± 0.15 SEM within the main sward, 1.56 ± 0.42 SEM within the 1.5m control, 1.63 ± 0.36 within the 1.5m fenced margin and 1.11 ± 0.23 SEM within the 3.5m fenced margins. The effect of plot treatment on mean abundance of aphidae and diptera was not significant ($F_{3,\ 113} = 0.68$; $P = 0.566$ and $F_{3,\ 113} = 1.99$; $P = 0.119$, respectively).

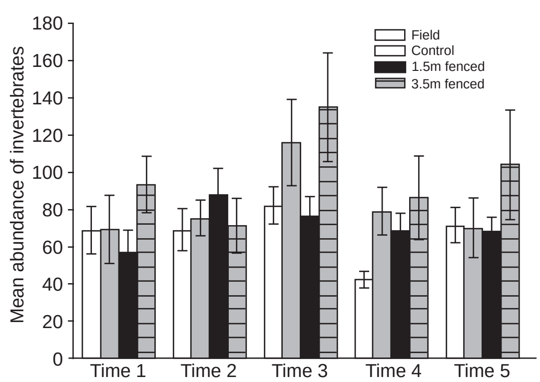

Fig. 7—Mean invertebrate abundance recorded on five collection dates within emergence traps located within the main field sward and the field margin plots ± SEM (collection times: 1 = 5 June 2003; 2 = 2 July 2003; 3 = 29 July 2003; 4 = 27 August 2003; 5 = 29 September 2003).

DISCUSSION

Natural regeneration of field margins is the only method of habitat establishment and rejuvenation that preserves the local flora (Baines *et al.* 1996; Asteraki *et al.* 2004). However, it can be an unreliable process as some 'undesirable' species may produce large quantities of long-lived seed (Radosevich and Holt 1984). Lewis (1973) found that seeds of dicotyledonous weeds generally remained more viable in the seed bank than did grass seed. Therefore, the success of this method is dependent on the availability of 'desirable' seed sources and a corresponding lack of 'undesirable' seed in the vicinity of the margin habitats (Baines *et al.* 1996). Where suitable seed sources do not exist in the vicinity, species-rich seed mixtures may be introduced to establish a diverse field margin flora (e.g. Sheridan *et al.* 2008). However, results indicated that while some 'undesirable' species were abundant at this site, a reasonably diverse field margin flora also persisted and, therefore, the use of expensive, non-native seed mixtures could not be justified.

However, even where diverse seed sources are available, successful regeneration of the field margin flora is unlikely where there is continued nutrient input into the habitat (Hopkins *et al.* 1999; Thomas *et al.* 2002). Our results indicate that under these experimental conditions plant species diversity was higher in the control and 1.5m-wide fenced margins than within the inner sections of the 3.5m-wide margins. The increased botanical species richness within the 1.5m and control plots over the duration of the experiment may possibly be explained by the distance maintained between nutrient spreading operations and the experimental plots. While farmers may be required to exclude nutrient inputs from field margin habitats, the machinery used for land-spreading slurry often have a spreading distance of 12m to 15m (Lenehan 1991; Huijsmans 2003), while single disk fertiliser spreaders, which are the most commonly used spreaders on dry stock farms, generally have widths less than 12m (Fortune 1995). Therefore an actual operating distance of between 7.5m and 9m from the boundary feature should be maintained to avoid accidental spreading of nutrient inputs on field margins.

The lower plant species richness recorded in the inner sections of the 3.5m plots when compared with the control and 1.5m fenced plots may have been due to increased levels of shade caused by the dense grass growth in the outer sections of these plots where grass species richness and abundance were higher. This was not an issue in the 1.5m margins where the adjacent sward was grazed in the spring and autumn and cut for silage in the summer. Analysis of herb species richness within the 3.5m-wide margins indicated that under these experimental conditions, the ecotone effect only extended approximately 1.5m into the sward, with reduced herb and increased grass species richness at distances greater than 1.5m from the hedgerow.

Cutting of vegetation can benefit low-growing plant species, particularly due to reduced competition for light and space (Bokenstrand *et al.* 2004). The removal of the cuttings also has the desirable effect of reducing soil fertility (Bakker 1989; Berendse *et al.* 1992). However, heterogeneity in field margin structure is known to be important for mobility, foraging ability, etc., for numerous taxa, for example invertebrates (Anderson *et al.* 2005) and birds (Atkinson *et al.* 2004). Management practices such as cutting may have conflicting results favouring the abundance of one taxa while apparently having no impacts or negative impacts on the abundance of other taxa (Cole *et al.* 2007). Therefore, application of generic management techniques to field margins could prove detrimental to particular taxa.

Nutrient enrichment often leads to the perception held by some farmers and policy makers that field margins may act as sources of weeds and pests (Milsom *et al.* 1994; Marshall and Arnold 1995). Nevertheless difficulties with weed ingress into the main sward within pastoral systems are really only likely where there is a reduction in sward density, e.g. caused by silage cutting, poaching or overgrazing (Hagger *et al.* 1985; Lewis and Hopkins 2000). However, *P. aquilinum* can invade the pasture sward if left unmanaged (Pakeman *et al.* 1998). Our results indicate that Asulox herbicide may be used for its successful control. Due to its selective, systemic nature and the very low levels of mammalian and fish toxicity associated with its use (Pakeman *et al.* 1998), it may be applied with minimal environmental impact.

Many of the management practices associated with pasture improvement, particularly soil cultivation, pesticide use and resultant changes in vegetation composition, are deleterious to arthropod diversity (Rushton *et al.* 1989; Asher *et al.* 2001). Despite relatively high plant species richness within the main sward and the absence of soil cultivation over a prolonged period, mean abundance of invertebrates was greater in the field margins. This may, in part at least, be explained by the lack of structural diversity that is occurs under silage production regimes (Andrews and Rebane 1994; Anderson and Purvis 2008). In addition, the spreading of organic manure can reduce the number of refuge and hibernation sites available to invertebrates (Desender 1982).

While results indicate that plant species richness was lowest within the 3.5m-wide margins, increasing the width of the margins is likely to provide a buffer effect for the inner area of the margin against agricultural practices in the adjacent field area (Marshall *et al.* 2006). In addition, enlargement of field margins may facilitate an increase in species population size and therefore aid persistence of diversity. The wider margins were found to support greater abundance of Collembola and Araneae than was recorded within the main sward. This may be due to grassland management practices that preclude the development of a litter layer (Rushton *et al*. 1989), which may in turn result in a lack of small litter-inhabiting spiders, e.g. *Ceratinella brevipes* and *Tiso scopigera*, and the linyphiine species, e.g. *Allomengea scopigera* and *Meioneta saxatilis*. Lack of a litter layer is also known to affect other invertebrate orders, for example the Anthropleona (Collembola) (Chinery 1993). Greatest abundance of the Coleoptera was recorded within the 1.5m fenced margins when compared to all other trap locations. However, increased resolution of identification of the Coleoptera, Aphidoidea and Diptera to species level might have detected increased invertebrate diversity in field margin samples when compared with field samples.

CONCLUSIONS

While this study was geographically and temporally limited, results indicate that nutrient exclusion from field margins does benefit the botanical diversity within these habitats. However, the success of such a measure is dependent on the availability of desirable species within the surrounding area. In order to facilitate such improvements it may be necessary to specify actual operating distances that should be maintained from field boundary habitats when undertaking nutrient spreading operations. Exclusion of grazing animals may be necessary to facilitate recovery of the vegetation where field margins have become badly degraded with extensive areas of bare ground. However, for long-term management, prescription grazing is likely to be the most appropriate form of management as it gives rise to the architectural diversity required by many taxa, which is not formed under cutting regimes. Extension of field margin widths showed positive results for invertebrate abundance; however, its effect on botanical diversity was not so obvious. This is likely due to the limited time span of this experiment. Further research regarding the impact of grazing and extension of width on both botanical and invertebrate faunal diversity is required and is currently underway at Teagasc, Johnstown Castle.

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