RELATIONSHIPS BETWEEN VEGETATION AND SITE FACTORS IN UNCROPPED WILDLIFE STRIPS IN BRECKLAND ENVIRONMENTALLY SENSITIVE AREA

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ABSTRACT

One option for management of arable field margins in Breckland Environmentally Sensitive Area is the creation and maintenance of uncropped, cultivated field boundary strips. The aim is to conserve plant communities containing species adapted to the special conditions of Breckland. From a sample of strips on a typical Breckland farm, the relationship between vegetation and soil variables, field boundary types and cropping history has been investigated by multivariate analysis of plant community data and by analysis of selected species. Soil pH, overhanging trees, broadleaved shelterbelts and previous cropping with sugar beet were the most important factors affecting the plant community composition. Relationships were detected between some individual species and site factors. The results are discussed in the context of the ESA objectives.

INTRODUCTION

The area of Breckland in East Anglia is characterised by its light soils, relatively continental climate and past land use, which comprised extensive grazing of heathland and shifting patterns of short-term cultivation. Land use changes and intensification of agriculture have caused declines in plant communities once typical of the area. These communities contain species adapted to the special conditions of Breckland, which might be defined in an ecological context by soil surface disturbance, summer drought and moderate or low nutrient availability. One aim of the Breckland Environmentally Sensitive Area (ESA) is to re-establish such plant communities by the creation and maintenance of cultivated field boundary strips known as "Uncropped Wildlife Strips" (UWS). Farmers electing to join this part of the scheme are required to cultivate 6m wide strips between August and December. Cultivations must be done 3-5 times in a 5-year period, but only once in any 12-month period. Most other inputs are restricted or prohibited (MAFF, 1988a).

Vegetation data from the environmental monitoring programme of the ESA show considerable variation between UWS sites (MAFF, 1993). To assist farmers and their advisers to target suitable sites for this management, the investigation reported here was carried out to relate UWS vegetation to soil variables, field boundary types and recent cropping history on a Breckland farm.

METHODS

The survey was carried out on a farm which was typical of Breckland in terms of its soils (sands, loamy sands and sandy loams) and cropping, and where management had been consistent between UWS sites. Consistency of management was particularly important because the survey was done in June 1992, at which time the UWS were in their fourth year following establishment. A site is defined as a UWS along one side of a field. From the 192 sites on the farm, a random sample of 32 was selected. One sampling location was randomly selected per site, at which three 25 x 25cm quadrats were positioned 2m, 3m and 4m from the field boundary respectively. Presence of plant species rooted in each quadrat was recorded and local rooted frequencies for each site calculated. Soil samples collected at each sampling location were hand textured and analysed for pH, P, K, Mg and total N. Texture classes were converted to available water estimation values (MAFF, 1988b). Presences of seven field boundary categories (grass/tall herb verge, hedge, broadleaved shelterbelt, coniferous shelterbelt, mixed shelterbelt, unmetalled track, metalled surface) as well as overhanging trees, were recorded separately for the whole site and for the sampling location at each site. Orientation of the site was recorded and a measure of "north-facing" obtained by conversion to absolute degrees from due south. Slope was minimal at all sites and was not recorded. Cropping, fertiliser, herbicide and cultivation data were collected for each site for the three years prior to establishment of UWS, but only previous crop type (spring barley, spring wheat, sugar beet, winter barley, winter wheat) was used in the analysis due to correlations between crop type and crop management factors. Two sites from one field were omitted from the crop analyses to remove the confounding effect of the field, as it was the only one under continuous barley for the three year period. Four separate aspects of cropping were analysed: (i) crop rotation, (ii) crop type in the year prior to establishment, (iii) number of consecutive years the previous crop existed prior to establishment and (iv) an index of occurrence of each crop type in the 3 years prior to establishment. The formula for the index I was

$$I = \sum_{i=1}^{3} (x / y)$$

where y is the number of years prior to establishment of the UWS (1, 2 or 3) for each x occurrence (0 or 1) of the crop type. To investigate the variation between different parts of the farm, sites were allocated to one of 4 blocks of fields. Long-established roads were used to define the block boundaries, as these were most likely to correspond with past management history.

Canonical correspondence analysis (CCA; Ter Braak, 1987) with downweighting of rare species, forward selection of environmental variables and Monte Carlo permutation tests was carried out using field block, soil, field boundary and crop variables separately. Partial canonical correspondence analysis (PCCA; Ter Braak, 1988) using field block as a covariable was carried out on soil variables. Intercorrelations between environmental variables were checked using Spearman rank correlation coefficients, Kruskal-Wallis tests or chi-square tests as appropriate for the measurement scales. To enable interpretation of results in the context of the ESA objectives, a list was compiled from the literature of indicator species which are adapted to some or all of the factors (i) disturbance, (ii) low summer soil moisture and (iii) moderate or low nutrients. In addition, species were allocated to three classes according to their established strategies (Grime *et al*, 1988), (i) species tolerant of disturbance and stress induced by low resource availability (SR or R/SR strategists), (ii) species which tolerate disturbance (R strategists) and (iii) other species. CCA biplots of species and environmental variables were examined for patterns relating to indicator species and established strategies.

To elucidate further the possible relationships identified in the multivariate analyses, individual species were also analysed against selected environmental variables. Species chosen for analysis were the five commonest indicator species (*Anthriscus caucalis*, *Apera spica-venti*, *Arenaria serpyllifolia, Descurainia sophia, Veronica arvensis*), the five commonest serious agricultural weeds (*Bromus sterilis, Cirsium arvense, Elymus repens, Galium aparine, Poa trivialis*) and the five commonest remaining species (*Viola arvensis, Poa annua, Polygonum aviculare,* *Tripleurospermum inodorum, Fallopia convolvulus*). Individual species data (arcsine(square root) transformed) were analysed against ratio scaled and nominal environmental variables using simple linear regression and one-way analysis of variance respectively.

RESULTS AND DISCUSSION

Of 58 species recorded, 20 (34.5%) were indicator species and nine (15.5%) were SR or R/SR strategists (Table 1).

TABLE 1. Indicator species and SR or R/SR strategists (*)

Amsinckia micrantha	*Conyza canadensis*	**Medicago minima*
Anchusa arvensis	*Descurainia sophia*	**Myosotis arvensis*
**Anthemis arvensis*	*Echium vulgare*	*Reseda lutea*
Anthriscus caucalis	**Erodium cicutarium*	*Silene latifolia*
Apera spica-venti	**Geranium pusillum*	*Sisymbrium altissimum*
**Aphanes arvensis*	*Lamium amplexicaule*	**Veronica arvensis*
**Arenaria serpyllifolia*	**Legousia hybrida*	

Multivariate analyses

The CCA analysis showed that (Table 2) one field block (no. 4) had a significant effect on species composition. Of the soil variables, only pH (range 6.8-8.1) had a significant effect on species. However, when the effect of field block was removed using PCCA, the effect of total N and K became significant ($P<0.05$) but pH

TABLE 2. Main relationships between vegetation and site factors from CAA.

Analysis	Total variance in species data	% of total variance explained by all environmental variables	Variables with significant relationship with species (*P*, Monte Carlo test)
Field block	2.027	13.8	block 4 (0.01)
Soil	2.027	21.9	pH (0.03)
Field boundary (sampling point)	2.027	26.7	overhanging trees (0.02) broadleaved shelterbelt (0.04)
Cropping (index of occurrence)	1.919*	17.3	sugar beet (0.03)

* 30 sites only - see text.

was not significant. Soil pH differed significantly between field blocks (Kruskal-Wallis H = 9.14, P<0.05) with pH lowest in block 4. Site maps showed that block 4 was formerly heathland, and that a railway bisected former field boundaries. These results suggest that the effect of field block 4 on species is at least partly due to edaphic factors, and that any effect of management probably pre-dates construction of the railway. Overhanging trees occurred more often at south facing sites (Kruskal-Wallis H = 4.83, *P*<0.05), so orientation was omitted from the analysis. None of the field boundary categories for the whole site showed a significant relationship with species. Of field boundary categories at the sampling point, overhanging trees and broadleaved shelterbelt had a significant effect on species; these variables were positively correlated ($\chi^2 = 4.94$, *P*<0.05). This indicates a localised effect of trees. Crop rotation failed to produce significant results. The other three expressions of previous cropping produced consistent results with only sugar beet having a significant effect on species.

Biplots showed no obvious patterns for either indicator species or established strategies in the analyses of field block, soil or field boundaries. Crop analyses showed that SR or R/SR strategists occurred mainly away from sugar beet, with the exception of *Anthemis arvensis*, which only occurred at one site. No patterns were evident for indicator species.

Analysis of individual species

Of the species showing a significant difference in frequency between field blocks, none were related to soil pH, suggesting that other factors also affected species composition between different parts of the farm (Table 3). Two weed species (*Galium aparine* and *Poa trivialis*) were associated with higher soil K levels, and the latter was also associated with broadleaved shelterbelts. Soil K and Mg were positively related to broadleaved shelterbelt (Kruskal-Wallis H = 4.89, *P*<0.05; H = 3.87, *P*<0.05), and soil P was just outside the limits of significance (*P*=0.05). This suggests a possible causative effect of broadleaved trees on soil nutrients, for example from leaf litter (Rode, 1993) or rainwater throughfall (e.g. Velthorst & Van Breemen, 1989). The fact that the relationship between vegetation and these field boundary types is stronger at individual sampling points than over sites as a whole, lends support to the possibility that trees may have a local effect on soil nutrients. *Anthriscus caucalis*, typically a hedgebank species, showed a positive relationship with overhanging trees.

TABLE 3. Summary of individual species analyses. I - indicator species, W - weed species, C - commonest species. Species/environmental variable combinations not shown are not significant.

Soil (r^2, *P*, +/- association)

Species	K	Mg	Total N	Available water
Veronica arvensis I	n.s.	n.s.	20.6, 0.009,+	18.1, 0.015,+
Galium aparine W	20.0, 0.01,+	n.s.	n.s.	n.s.
Poa trivialis W	19.3, 0.012,+	n.s.	n.s.	n.s.
Viola arvensis C	12.8, 0.045,-	n.s.	n.s.	n.s.
Fallopia convolvulus C	n.s.	12.6, 0.046,+	n.s.	n.s.

TABLE 3 (Continued)

Field block, field boundary and crop (*P*, +/- association for field boundary types)

Species	Field block	*Previous year's crop	Overhanging trees	Broadleaved shelterbelt
Anthriscus caucalis I	n.s.	n.s.	0.045,+	n.s.
Apera spica-venti I	0.003	n.s.	n.s.	n.s.
Veronica arvensis I	n.s.	n.s.	0.012,-	n.s.
Bromus sterilis W	0.033	n.s.	n.s.	n.s.
Cirsium arvense W	0.002	0.004	n.s.	n.s.
Elymus repens W	n.s.	0.001	n.s.	n.s.
Poa trivialis W	n.s.	n.s.	n.s.	0.004,+
Tripleurospermum inodorum C	0.01	n.s.	n.s.	n.s.

*30 sites only - see text

Veronica arvensis showed a negative relationship with overhanging trees, and a positive relationship with total N and available water estimation value. Two weed species (*Cirsium arvense* and *Elymus repens*) were most frequent at sites following sugar beet. It is notable that sugar beet cropping is characterised by applications of Mg, Na and K, although release of mineralised N from ploughed in sugar beet tops is known to have a greater effect on soil nutrients (B. Chambers, pers. comm.). This might also explain the tendency of SR or R/SR species not to occur at sites following sugar beet.

CONCLUSIONS

The results showed significant relationships between species and site factors, and suggested that the effects of field block, trees and previous crop may be operating partly via soil characteristics. As is often the case in ecological studies a large proportion of variance in the species data is unaccounted for, and although the study was confined to one farm, the findings may be of use in helping to decide which sites are likely to most successful in meeting the ESA objectives. The site factors analysed here are readily measured in the field or by standard laboratory techniques. Other major factors affecting species composition of UWS are likely to include chance events such as the introduction of seeds with organic fertiliser. Since the majority of species in UWS have a persistent seed bank, an assessment of the arable weed community at the edge of a cropped field may give further indication of the suitability of a site for this management. Although the lightest soils might be expected to support more indicator species and R/SR strategists on account of lower moisture and nutrient availability, there appears to be no advantage in targeting the lightest soils within the range of soil textures in the sample. Soil pH affected plant community composition but with indicator species and R or R/SR strategists present throughout the range of pH values in the sample. To achieve a diversity of communities therefore, sites with a range of pH values might be selected.

The effect of overhanging or broadleaved trees was localised. Sites with the occasional tree need not be discounted, particularly since the indicator species

Anthriscus caucalis was more frequent where overhanging trees were present. However, sites with an abundance of overhanging or broadleaved trees might be best avoided. Of the four aspects of previous cropping history used, similar results were obtained for all except the most generalised (crop rotation). In practice therefore, there was no advantage in using cropping history data for more than the year prior to establishment of the UWS.

Within the ESA management prescription for UWS, there is some flexibility in how farmers might manage their sites. This study has concentrated on the effects of site variables on species composition under similar management conditions. Variation in management of UWS sites will affect how their vegetation develops after initial establishment. The study also concentrated on sites under typical Breckland conditions. Some rare arable weed species also occur on heavier soils (Wilson, 1991), and this field margin management prescription may have applications elsewhere.

To meet the ESA objectives of encouraging plant communities containing species adapted to the conditions of Breckland therefore, sites with a range of soil pH values and sandy or loamy soils can be equally targeted. Within this range of soil textures, a small advantage might be gained by avoiding sites with overhanging or broadleaved trees and those where sugar beet has been cropped in the previous year. These factors may be related to soil nutrient availability.

ACKNOWLEDGEMENTS

Financial support from the Ministry of Agriculture, Fisheries and Food is gratefully acknowledged for this work, carried out as part of the wider environmental monitoring programme of ESAs. I am also grateful to the farmer for allowing access to sites; Ms A.J. Sherwood for collecting cropping data; Dr B. Davies for advice on soils; Dr J.P. Barkham, Dr S.P. Rushton and Dr R.A. Sanderson for comments on a draft version.

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THE ROLE OF WILD FLOWER SEED MIXTURES IN FIELD MARGIN RESTORATION

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ABSTRACT

Experimental data are used to evaluate the relative benefits to agriculture and conservation of sward re-establishment on boundary strips by natural regeneration and by sowing a wild flower seed mixture. We show that wild flower-seeded swards can be richer in plant and invertebrate species, and produce more rapid and effective weed control for equivalent management effort, than naturally-regenerated swards. These benefits can substantially offset the higher establishment costs of seed mixtures. Benefits to amenity, invertebrates and weed control, however, are likely to depend on only a small number of plant species in the mixture. We suggest that simple seed mixtures, comprising species which confer these benefits and which thrive under the intended management regime, are likely to be most cost-effective. Wild flower seed mixtures are effective in excluding desirable as well as weedy elements in the local flora and should therefore be used only where the flora in the immediate vicinity of the field margin is depauperate and weed control is a problem.

INTRODUCTION

The severe degradation of many arable field margins in post-war years, by close-ploughing, indiscriminate fertiliser application and either deliberate or accidental herbicide application, has resulted in both severe weed management problems and loss of wildlife and amenity interest (Way & Greig-Smith, 1987; Smith *et al.*, 1993). We postulated in 1987 that the conservation interest of boundary strips could be restored, and weed control problems simultaneously combatted, by reversing these deleterious trends. The re-establishment, on expanded-width boundary strips protected from agrochemical drift, of a more diverse flora, dominated by non-aggressive perennial grasses, seemed a likely means of achieving this objective. We tested this idea using a large-scale experiment to examine the re-establishment of swards on fallowed extensions to degraded and weedy boundary strips (Smith & Macdonald, 1989).

We established perennial vegetation on the fallowed extensions to the strips both by allowing natural regeneration and by sowing a wild grass and forb mixture. Considerable prejudice surrounds the use of such seed mixtures in farmland habitat restoration. From the farming perspective they are often viewed as inherently expensive, inferior to conventional agricultural leys and difficult to establish. Many conservationists have reservations about their effects on the genetic integrity of the local flora.

In this paper we use data from the boundary strips experiment to evaluate the role of wild flower seed mixtures as management tools in the restoration of degraded arable field margins. In particular, we compare the performance of seed mixtures with that of naturally regenerating swards in manipulating weed control, plant species richness and butterfly species richness and abundance. We discuss the choice of species for inclusion in mixtures and the situations in which sowing seed mixtures is likely to be both an appropriate and a more cost-effective option than natural regeneration.

METHODS

We created 2 m wide boundary strips around six arable fields at the Oxford University Farm, Wytham, in autumn 1987. The strips comprised the original boundary strip (the 'old' zone), which was usually about 0.5 m wide, and a fallowed extension of about 1.5 m onto cultivated land (the 'new' zone). Ten treatments were each imposed on 50 m lengths of boundary strip in a randomised complete block design with eight blocks. Each block was located around a single field. Eight of the treatments formed a 2x4 factorial structure: four were sown with a mixture of wild grasses and forbs ('sown' plots) and four were allowed to regenerate naturally ('unsown' plots). They then received one of the four following cutting regimes: uncut, or cut (with cuttings removed) in (a) summer only (b) spring and summer or (c) spring and autumn. The plots were first cut in June 1988 and in subsequent years in the last weeks of April, June and September ('spring', 'summer' and 'autumn' respectively). The new margins were rotavated in March 1988 just before the seed mixture was sown. It contained six 'non-aggressive' species of grass and 17 forbs, in a 4:1 ratio, and was sown at 30 kg/ha (Smith *et al.*, 1993).

The relative frequencies of plant species on the old and new zones of the boundary strip and in the crop edge were monitored five times a year until 1990, by recording presence/absence in eight sub-cells in three 50 x 100 cm permanent quadrats in each zone of each plot, in six blocks of the experiment. The frequencies of some key weed species were also monitored in either 1992 or 1993. The relative abundance of butterflies was measured using transect recording methods on eight blocks of the experiment. Counts of all butterfly species on each plot were made at least once a week during the summer months from 1989 to 1991.

In this paper we concentrate on botanical data, collected in June each year from the new zones of the boundary strips, and on annual measures of butterfly abundance and species richness. Data from the eight treatments that allow factorial comparison of sown and unsown plots are analyzed by analysis of variance, following appropriate transformation to achieve homogeneity of variance. We present significance levels for the main effect of sowing together with adjusted means for sown and unsown plots.

RESULTS

Plant species richness

The effect that wild flower seeding has on the development of species richness is at least partly dependent on the species richness of the sown mixture. The numbers of species sown are modified both by the success with which they establish and the numbers of unsown species that are accommodated. Our relatively complex mixture resulted in species richness values that were consistently higher in sown than in unsown plots in 1988, 1989 and 1990 (Table 1).

The numbers of naturally regenerating species colonising the sown and unsown plots did not differ in June 1988, two months after sowing, but the numbers of unsown species that had established by June 1990 were very significantly lower in sown than in unsown plots (Table 2). Sown swards thus effectively excluded natural colonists.

TABLE 1. Mean numbers of species in sown and unsown plots. Numbers in parentheses are mean numbers of sown species in sown plots. Analyses were performed on log-transformed data. Means presented are back-transformed.

Date	Mean no. species /0.5m^2			$F_{[1,35]}$	P
	Sown plots		Unsown plots		
June 1988	18.6	(5.89)	11.97	66.79	<0.001
June 1989	15.8	(10.95)	8.95	97.93	<0.001
June 1990	13.4	(11.06)	10.46	30.89	<0.001

TABLE 2. Mean numbers of unsown species in sown and unsown plots. Analyses were performed on log-transformed data. Means presented are back-transformed.

Date	Mean no. unsown species /0.5m^2		$F_{[1,35]}$	P
	Sown plots	Unsown plots		
June 1988	12.52	12.95	0.34	>0.05
June 1989	6.74	9.74	33.32	<0.001
June 1990	5.12	11.75	213.53	<0.001

Although in both 1989 and 1990, all sown treatments were more species rich than all unsown treatments, species richness could also be substantially modified by mowing (Smith & Macdonald, 1992; Smith *et al.*, 1993). Of the regimes applied, the dominant effect on both sward types was of mowing in spring and autumn, which increased species richness.

Weed control

Sown swards were extremely effective in controlling pernicious weeds. The adjusted mean frequencies of six of the commonest pernicious annual and perennial weed species on the field margins are presented for June 1989, June 1990, and for either 1992 or 1993, for all species except *Elymus repens* (Table 3). In June 1988, two months after the mixture was sown, sown and unsown plots did not differ significantly in the mean frequencies of any common weed species. By the following June, however, frequencies of the three annual grass weeds, and of *E. repens* and *Urtica dioica*, were significantly lower in sown swards. By 1990 differences for all six species were highly significant, with *Avena* species and *A. myosuroides* being virtually eliminated from sown swards. By 1992 both *Avena* species (*A. fatua* and *A. sterilis* subsp. *ludoviciana*) and *Alopecurus myosuroides* had also declined to low frequencies in unsown swards (there were too few data for *A. myosuroides* for formal analysis: Table 3) but the differences for the remaining species remained large and highly significant. The mean frequencies of these species appeared to be relatively stable in both sward types between 1990 and 1992/93.

The effectiveness of weed control in both sward types could be substantially modified by mowing but, in general, even the least successful of the mowing regimes that we applied to sown swards resulted in much more rapid and effective weed control than any mowing regimes applied to unsown swards over this time period (Smith & Macdonald, 1992; Smith *et al.*, 1993).

TABLE 3. Relative frequencies of weed species in sown and unsown plots in June. Analyses were performed on arcsine square-root transformed data. Means presented are back-transformed.

Species	Year	Mean % frequency		$F_{[1,35]}$	P
		Sown	Unsown		
Avena species	1989	1.43	10.75	9.73	<0.01
	1990	0.33	9.96	25.21	<0.001
	1992	0.12	0.42	1.92	>0.05
Alopecurus myosuroides	1989	0.13	5.06	8.75	<0.01
	1990	0.03	4.22	11.94	<0.01
	1992	0.00	0.07	-	-
Bromus sterilis	1989	86.67	20.51	104.18	<0.001
	1990	6.17	85.77	155.88	<0.001
	1992	5.56	58.12	34.21	<0.001
Cirsium arvense	1989	4.03	11.57	3.06	>0.05
	1990	2.32	14.53	12.68	<0.001
	1993	2.67	12.94	11.33	<0.01
Elymus repens	1989	39.91	69.80	8.11	<0.01
	1990	41.80	88.83	20.01	<0.001
Urtica dioica	1989	2.76	16.18	11.56	<0.01
	1990	0.67	14.31	28.35	<0.001
	1993	0.77	14.74	18.91	<0.001

TABLE 4. The mean annual abundance of butterflies in sown and unsown plots

Year	Mean no. per 50m plot		$F_{[1,49]}$	P
	Sown	Unsown		
1989	28.3	25.15	0.70	>0.05
1990	55.0	19.11	45.43	<0.001
1991	33.0	21.20	10.60	<0.01

Butterfly abundance

Sowing resulted in highly significant increases in the abundance of adult butterflies in 1990 and 1991 (Table 4). Species richness was also higher on sown plots but the difference was significant only in 1990 ($F_{[1,35]}=4.55$, $P<0.05$). Summer mowing, however, also had profound effects on butterfly distribution. The removal of important nectar sources, predominantly *Leucanthemum vulgare*, from the half of the sown plots that were mown, resulted in the concentration of butterflies on the remaining sown plots (Feber *et al.*, 1994). Later in the summer, butterflies made more use of unsown plots, feeding particularly on increasingly abundant flowers of *Cirsium* and *Carduus* species (Smith *et al.*, 1993). As a consequence of these changes, sowing had highly significant effects on abundance prior to, but not after, the summer cut in both 1989 and 1990 ($F_{[1,49]}=13.36$, $P<0.001$; $F_{[1,49]}=138.2$,

$P<0.001$ respectively). In 1991, however, the main flight period of the dominant species and the main flowering period of *L. vulgare* were later. Under these circumstances sowing resulted in a significant increase in butterfly numbers after, rather than before, the summer cut ($F_{[1,49]}=12.5$, $P<0.01$).

DISCUSSION

Our results show that wild flower seed mixtures can potentially be powerful tools in field margin restoration. When sown on newly-fallowed boundary strips they can be used to manipulate plant species richness and both annual and perennial weed populations with minimal management. They can also result in increased abundance and species richness of butterflies. However, whilst these assets can offset the high initial outlay on seed mixtures, they are unlikely to be an intrinsic property of such mixtures. Rather, they depend on the careful selection and subsequent establishment of the component species. Species that do not contribute to the attributes required of a mixture, or which do not thrive under the proposed management regimes, reduce its cost-effectiveness as a management option.

Thus, in our experiment, the very rapid and effective control of annual and perennial weeds that was achieved, even with minimum subsequent management, was likely to have depended largely on the dominant grassy components of the mixture, including *Festuca rubra* subspp. *littoralis* and *commutata*, *Phleum pratense* subsp. *bertolonii*, *Poa pratensis* and *Trisetum flavescens*, which rapidly formed a very dense sward base. Most broad-leaved species were sown, and established, at much lower frequencies and had relatively little effect on weed control. Thus, where weed control is the only aim of field margin restoration, grass-only mixtures are the most cost-effective solution. The effectiveness of fine-leaved grasses has not been rigorously tested against that of rye-grass dominated mixtures but the denser sward base that they produce, together with their lower productivity on fertile agricultural soils (Smith *et al.*, 1993), suggests that they may be a superior option.

Inclusion of broad-leaved species, however, has enormous benefits for the amenity value of boundary strips and for nectar-feeding invertebrates. The latter include beneficial species such as hoverflies and bees, as well as attractive and declining species of butterflies (Feber & Smith, in press). Most of these benefits also depended largely on a very few plant species, which together provided an abundant and continuous nectar supply throughout the summer (Feber *et al.*, 1994).

The invertebrate community can be further manipulated by the composition of the seed mixture. For example, we found that the overall abundance of invertebrates, caught by Deitrick-Vacuum suction sampling, was significantly increased by sowing (Smith *et al.*, 1993). Much of this increase was attributable to groups, such as spiders, which benefitted from the structural diversity contributed by species in the seed mixture. Similarly, inclusion of appropriate larval foodplants in mixtures can attract more specialist feeders (Feber & Smith, in press), while that of tussock-forming grasses, such as *Dactylis glomerata* and *Holcus lanatus*, benefits overwintering populations of polyphagous predators (Thomas *et al.*, 1991).

Since only a small number of plant species is likely to contribute to the weed control properties and attractiveness to invertebrates of sown swards, seed mixtures must be restricted to these species to be cost-effective in achieving these objectives. Plant species richness is likely to be sacrificed as a consequence. The relatively few species that were effective in excluding pernicious weeds were also likely to be most effective in excluding other naturally regenerating colonists from the swards. Simple seed mixtures should thus be as effective as more complex mixtures in excluding local colonists, and are therefore likely to remain species poor. However, where sown swards comprise a balance of three to five grass species and include two or more broad-leaved species, they can still be attractive assets. Where objectives and finance permit, inclusion of more broad-leaved species can result in better imitations of semi-natural grassland.

The species composition of cost-effective seed mixtures must also be tailored to suit the management regime intended. For example, in 1990 we found that *Cynosurus cristatus*, which was the most abundant grass species in all sown treatments in 1988, had not changed in abundance in treatments cut twice a year but had declined by 70% in treatments which were left uncut, and by 27% in those cut once annually. By contrast, *Centaurea nigra* increased in frequency during the experiment although the increase was significantly smaller in plots cut in summer than in those left uncut (Smith *et al.*, 1993).

Where a reasonably diverse and attractive flora remains in the immediate vicinity of newly-created boundary strips, sowing wild flower seed mixtures is likely to prevent its successful colonisation. Under these circumstances, and particularly where pernicious weed populations are small, natural regeneration, with mowing management, is likely to be both more cost-effective, and a more desirable option for nature conservation, than sowing. However, in many intensively-farmed areas of lowland England, the potential for natural establishment of swards that are both relatively species rich and acceptable to farmers is low. The enormous potential of carefully designed seed mixtures for creating swards that both control weeds and are attractive to wildlife in these situations should be seen in the light of our long history of sowing wild flower species in agricultural grass leys.

ACKNOWLEDGEMENTS

This work was funded by English Nature, with additional support from the Ernest Cook Trust, the People's Trust for Endangered Species and the Co-Op Bank. We are grateful to Drs. Stephen Baillie and Trudy Watt for helpful comments on the manuscript.

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