REPORT TO THE DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS

Project no. MA01017

Monitoring of Cereal Field Margin Options in Agri-environment Schemes

Phase II Part 2:

Re-assessment of Uncropped Wildlife Strips in Breckland Environmentally Sensitive Area

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Final Report

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Summary

1. Intensive agricultural practices in the UK have caused major changes to the arable flora, including a marked decline in annual dicotyledonous species. The Breckland area of East Anglia is notable for arable plant communities of sandy soils. In 1988, Uncropped Wildlife Strips (UWSs) were introduced as a management option for arable field margins in the Breckland Environmentally Sensitive Area (ESA) agri-environment scheme, with the aim of conserving annual, arable plant communities.

2. UWSs are 6 m or 12 m wide field boundary strips that are cultivated regularly (usually every year or every other year) during 31 July to 31 March but only once in a twelve-month period. No other inputs are allowed apart from cutting and selective weed control.

3. Previous studies in Breckland and elsewhere showed that annuals and dicotyledons, including nationally rare or declining species, established in the first few years. However, perennials and grasses tended to increase over time, often to the detriment of the target species. Variation between sites was attributable to soil type, cultivation regime and field boundary characteristics.

4. In Breckland ESA, 125 sites had been surveyed in 1996 as part of the ESA monitoring programme. The objectives of the current study were (1) to assess change in the plant species composition of UWSs between 1996 and 2004 and (2) to assess the effect of management on species composition.

5. A random sub-sample of 32 sites was re-surveyed during late June – July 2004 using the same botanical recording method as previously. Plant species were recorded from two transects per site, each comprising twenty 10 cm^2 quadrats, and soil samples, management and other site information collected. Data were analysed using Analysis of Variance, ordination methods and variation partitioning by Partial Redundancy Analysis. Sites were also searched systematically for rare species and soil and plant community data collected from rare species loci.

6. In total, 108 taxa were recorded from transects. This was similar to the total number in 1996 although only 66 were recorded in both years. The most widespread species were annuals and dicotyledons. At the site level, species richness and numbers of annuals, dicotyledons and perennials increased by *circa*. 40% compared to 1996. Foodplants of farmland birds, butterfly larvae and bumblebees also increased. No changes were detected in Ellenberg nutrient or moisture values, an index of species' changing national range size or pernicious weeds. Most trends were consistent among farms.

7. Two thirds of sites were cultivated annually and the season and depth of cultivation varied amongst sites. About half of the sites were cut in at least some years but only five had selective weed control applied. The soil was loamy sand in almost all cases.

8. Species composition and numbers varied amongst sites. Farm, management, habitat variables and soil properties together accounted for 63% of variation in species composition. Cultivation regime tended to be confounded by farm. Despite this, farm uniquely explained 22% of variation and cultivation frequency, timing, depth and mechanical method uniquely explained 19%.

9. Species composition was most strongly related to intensity of disturbance. Perennial species were associated with sites not cultivated in the twelve months prior to the survey. Annuals were more strongly associated with deep cultivation than cultivation by disc. Species composition was also related to the season of cultivation.
10. Variation explained by habitat context or soil properties and not shared with other variables was less than 5% in both cases. The only significant variables were field boundaries with broadleaved trees, adjacent woodland and soil extractable P.
11. Pernicious weeds were more prevalent at sites with soil pH >7 and higher Ellenberg fertility values.
12. Change in species composition between 1996 and 2004 was related to farm, management and habitat context but not soil properties. However, the relationships were relatively weak and not very informative.
13. Rare species were found at almost half of the sites (15). In total there were 18 records but of only four species, *viz*. *Apera spica-venti* (loose silky-bent), *Silene noctiflora* (night-flowering catchfly), *Papaver argemone* (prickly poppy) and *Polygonum rurivagum* (cornfield knotgrass). Some large populations (>100 individuals) were found of *Apera spica-venti* and *Silene noctiflora*. Rare species occurred at sites with more annuals and dicotyledons and where Ellenberg moisture values were lower. The species relative change index showed the same pattern.
14. Rare species were found in five National Vegetation Classification communities or sub-communities, all of which are associated with light, well-drained soils. Most records were from the OV3 *Papaver rhoeas – Viola arvensis* (common poppy – field pansy) community.
15. Concerns about long-term replacement of annuals and dicotyledons by perennials and grasses in UWSs were not fully upheld in this study, although the results might not apply to sites elsewhere on heavier soils.
16. Recommendations for management of UWSs in Breckland are made. These include annual cultivation, spatial and temporal variation of the cultivation timing, depth and mechanical method and targeting of the drier sites. If followed, UWSs can be maintained successfully *in situ* in Breckland and possibly other areas on sandy soils.

Introduction

In the second half of the 20th century, intensive agricultural practices caused major changes to the arable flora in the UK. Annual dicotyledonous species declined, often to be replaced by a small number of nitrophilous species, particularly autumn-germinating grass weeds (Chancellor, 1975; Chancellor & Froud-Williams, 1984). Species associated with light or chalky soils showed particularly marked declines (Rodwell, 2000; Wilson & King, 2000). Many formerly common plant species are now nationally scarce.

The Breckland area of East Anglia is characterised by light, sandy soils and a relatively continental climate including low summer rainfall (Trist, 1979). Some of the most notable arable plant communities of sandy soils are found in Breckland but are also particularly threatened (Wilson, 1994). The Breckland Environmentally Sensitive Area (ESA) scheme was launched in 1988 and included the uncropped wildlife strip (UWS) as an option for arable field margin management. The aim of this option was to conserve arable plant species. UWSs were 6 m wide, uncropped field boundary strips, cultivated 3-5 times during a five-year period between 31 July and 1 January, but only once in any twelve-month period. In 1993, the management prescriptions were amended to allow cultivation during either autumn or spring (31 July to 31 March) and with cultivation frequency increased to at least every other year. Strips could now be 6 m or 12 m wide. No other inputs were permitted except for cutting and a requirement to control certain weeds (ADAS, 1997). Subsequently, the Habitat Action Plan for Cereal Field Margins (Anon., 1995) also recommended UWSs for wider application in the UK.

Monitoring studies showed that by 1996 approximately half of the UWS sites in Breckland ESA contained the target vegetation (ADAS, 1997). Variation between sites was attributable to differences in soil type, cultivation regime and field boundary features such as the presence of overhanging trees (Critchley, 1994; 2000). Subsequently, field experiments demonstrated a strong effect of cultivation timing and depth on species composition. In addition, there was a tendency for monocotyledonous species (grasses) to increase in abundance, especially after shallow cultivations, whereas perennials tended to increase irrespective of the cultivation regime (Critchley *et al*., 2001). In the Arable Stewardship Pilot Scheme, UWSs were found to contain a high proportion of annual species in the first year of establishment (Critchley e*t al*., 2004b) but became increasingly dominated by perennials after five years (Critchley *et al*., 2004a). Nationally scarce and declining annual species have been recorded from many UWSs in agri-environment schemes and in experimental plots but their long-term co-existence with competitive grasses or perennials is unlikely.

The previous monitoring programme in Breckland ESA comprised detailed recording from 1989-1996 of 15 UWSs paired with normally cropped control sites, plus a survey of a representative sample of 125 UWS sites in 1996. The aim of this study was to re-survey sites from the main sample. Specific objectives were:

1. To assess change in the plant species composition of UWSs between 1996 and 2004 and
2. To assess the effect of management on species composition.

Methods

Field survey

In 1996, a proportionate random sample of 125 sites had been selected for survey from fourteen farms, the number of sites on each farm depending on the total length of UWS available there (ADAS, 1997). This provided a representative sample of the sites under ESA agreement at that time. For the 2004 re-survey, a proportionate random sub-sample of the original 32 sites was selected, but with a minimum of one site from each of the eleven farms that still had sites under ESA agreement. By 2004, the age of sites ranged from 10 to 16 years.

In 1996, the vegetation recording method was designed to be comparable with the more detailed monitoring programme (of 15 UWSs and 15 control sites) in place at that time (ADAS, 1997). The same method was therefore used in 2004 to ensure comparability with the 1996 survey. Two transects were established at each site, respectively at $\frac{1}{3}$ and $\frac{2}{3}$ distance from one end. Each transect was 4 m long, positioned at right angles to the field boundary in the centre of 6 m wide UWSs. In 12 m wide UWSs, they were placed in the centre of the outer 6 m. Each transect comprised 20 quadrats of size 10 x 10 cm at 10 cm spacing. Rooted frequency of all plant species was recorded for each transect. Occasionally, vascular plants could not be identified reliably and were recorded to genus level. Plant names follow Stace (1997). Bryophytes and seedlings were recorded collectively. Frequency of bare ground and plant litter was also recorded.

Each site was searched systematically for rare annual arable plant species on a target list compiled from a range of data sources (Wilson, 1999; Preston *et al*., 2002; Wilson & King, 2003) (Appendix 1), by walking in a zigzag pattern at a slow to moderate pace. The number of individuals per site of any rare species found was estimated in the field on a log scale. Casual observations of rare species elsewhere on the selected farms were also made. At the main locus of the rare species in a site, three 2 x 2 m quadrats were positioned 2 m apart and parallel to the field boundary. Plant species present in each quadrat were recorded and their percentage cover estimated. The grid reference of each rare species locus was recorded for future reference.

Soil samples were collected from all transects and rare species loci. Ten evenly distributed cores of depth 0-15 cm were collected per transect, and bulked to provide one sample. At rare species loci, ten cores were collected from the central quadrat (avoiding damage to the rare plants) and bulked. Soil samples were analysed at Direct Laboratory Services Ltd., Wolverhampton using standard techniques (MAFF, 1986) for pH, extractable phosphorus (P), potassium (K) and magnesium (Mg) and a hand texture assessment done.

Management information was collected for each site. The frequency (annual, every other year or less often), month, depth and mechanical method (plough, rotavate, tine or disc) of cultivation most often applied were recorded, as well as the season, depth and method of the most recent cultivation. Details of any weed control and cutting frequency were also recorded.

The habitat context of each site was recorded in terms of the presence of adjacent field boundary categories (grass/tall herb verge, hedge, broadleaved trees, coniferous trees, overhanging trees, unmetalled surface, metalled surface, arable land or other), adjacent land cover beyond the field boundary (arable, grassland, woodland, scrub, wetland, heathland, open water, urban or other), site width and aspect. Altitude was not recorded because variation between sites was negligible.

Sites were surveyed during the period 23 June to 29 July 2004.

Data analysis

All data were input from field forms to the Defra AEMA database. All data were validated by comparing hardcopy outputs from AEMA with the original field forms.

Vegetation change from 1996-2004

Species data for 2004 were fitted as supplementary (passive) variables to a Principal Components Analysis (PCA) of the 1996 data to assess general trends in species composition between 1996 and 2004. A preliminary Detrended Correspondence Analysis (DCA) of 1996 data showed a linear response of species along the first axis, confirming that PCA was the appropriate method to use (ter Braak & Šmilauer, 1998). Analysis was carried out on log-transformed mean species frequencies for each site, but excluding unidentified seedlings and bryophytes. This and subsequent multivariate analyses were carried out using Canoco V.4.02 software (ter Braak & Šmilauer, 1998).

Vegetation change was also determined using Analysis of Variance (ANOVA) on a range of plant community variables. Farm was included as a factor in the model and year as a repeated-measure. Analyses were done on untransformed data using Statistica V6.0 (Statsoft, Inc., 2001). Mean values from the two transects were calculated for each site. Total species richness and numbers of dicotyledons, monocotyledons, obligate annuals and perennials, and frequency of food plants of farmland birds, butterfly larvae and bumblebees and pernicious weeds were analysed. Bird and butterfly larva food plants were as listed in Smart *et al*. (2000). Bumblebee food plants were those identified previously during surveys of the Arable Stewardship Pilot Scheme (Pywell *et al*., 2005; Appendix 2). Eight pernicious weeds were specified, namely *Alopecurus myosuroides* (black-grass), *Anisantha sterilis* (sterile brome), *Avena fatua* (wild oat), *Cirsium arvense* (creeping thistle), *Elytrigia repens* (couch-grass), *Galium aparine* (cleavers), *Rumex crispus* (curled dock) and *R. obtusifolius* (broad-leaved dock). Ellenberg scores for fertility and moisture (Hill *et al*., 1999) and species change index (Preston *et al*., 2002) were also analysed. Ellenberg scores for plant species were sourced from Hill *et al*. (1999) and the mean score calculated of all species present in the transect. The change index indicates the relative change in range size of a species in Britain and Ireland from 1930-69 to 1987-99. A negative value for a site signifies a high proportion of species that have shown a relative decline, and therefore a potentially valuable contribution to their conservation.

Relationship of species composition with management and other site factors

Variation partitioning (Borcard *et al*., 1992; Økland & Eilertsen, 1994) was applied to site species frequencies and environmental data from 2004 to determine the relative importance of farm, management, habitat context and soil properties. One site with no available management data was omitted. Soil, site width and aspect data were averaged for each site. Aspect was expressed as absolute degrees from due south to give a measure of 'north facing'. Field boundary and land cover categories were allocated values of 0.5 or 1 if they were adjacent to one or two transects respectively per site.

Variation partitioning was performed using Redundancy Analysis (RDA) and Partial Redundancy Analysis (PRDA) because a preliminary DCA of log-transformed 2004 species data indicated a linear response. Environmental variables were grouped into subsets (farm, management, context and soil), and for each in turn an RDA was carried out to select those variables that contributed significantly to the model (at $P < 0.05$) and to eliminate highly correlated environmental variables. Each variable was tested in turn using forward selection and Monte Carlo tests with 999 permutations.

For each environmental variable subset, the variation explained only by the subset was calculated from a PRDA in which the subset of interest was specified as environmental variables, and the remaining subsets as covariables. Variation shared by the subset with other variables was calculated as the total variation explained (TVE) by the subset of interest (from the RDA) minus the variation explained only by the subset. The relationship between species and farm, management, context and soil was assessed by carrying out an RDA using the reduced (significant) sets of environmental variables.

The relationship between change in species frequencies from 1996 to 2004 and the environmental variables was also analysed using the same variation partitioning procedure. This was done to assess whether vegetation change was related to farm, management, context or soil properties. Frequency data for a species was expressed as $\log(b - a + 100.1)$ where a and b were the percentage frequency of the species in 1996 and 2004 respectively.

One-way ANOVA was also used to explore differences between groups of sites according to their management or soil properties.

Phytosociological associations of rare species

Data from the three quadrats at each rare species locus were used to identify the National Vegetation Classification (NVC) (Rodwell, 2000) plant community in which the rare species was located. Similarity coefficients with NVC communities were calculated using both MATCH v2.16 (Malloch, 1999) and TABLEFIT v1.0 (Hill, 1996) software. Coefficients were used along with NVC floristic tables (Rodwell, 2000) to determine which community or sub-community the vegetation resembled most closely.

To examine differences in species composition between sites with and without rare species, a PCA of log-transformed transect data from 2004 was done, but excluding any records in transects of the rare species themselves. Differences between sites with and without rare species were also explored using one-way ANOVA.

Results

In total, 108 taxa (hereafter referred to as species) were recorded from transects at the 32 sites in the 2004 survey. The majority (88) were dicotyledons whereas twenty monocotyledons, including two crop volunteers, were recorded. The most widespread species were *Arenaria serpyllifolia* (thyme-leaved sandwort) and *Tripleurospermum inodorum* (scentless mayweed) recorded from 78% of sites, followed by *Silene latifolia* (white campion) and *Veronica persica* (common field speedwell) (75%), *Polygonum aviculare* (common knotgrass) (72%), *Chenopodium album* (fat-hen) (66%) and *Papaver rhoeas* (common poppy) (63%) (Appendix 3). By contrast, the most widespread monocotyledons were *Elytrigia repens* (59%) and *Poa trivialis* (rough meadow-grass) (56%). Apart from *Elytrigia repens*, the most widespread pernicious weeds were *Cirsium arvense* (56%) and *Anisantha sterilis* (47%). The number of species was virtually identical to the number recorded in the same sub-sample of sites in 1996 (109). The combined total for the two surveys was 151 species but only 66 species were recorded in both years.

Vegetation change from 1996-2004

The PCA ordination showed only a weak separation of 1996 and 2004 data (Figure 1a). Sites in 2004 tended to have higher values along axis 2 of the ordination compared to 1996 but there was considerable overlap. Many species with highest weights in the analysis (i.e. those having most influence and therefore being the most important) also tended to occupy that part of the ordination space (Figure 1b). This suggests a general increase in species abundance in 2004. The trajectories of individual sites from 1996 to 2004 in the ordination were variable. However, several had higher scores along axis 2 in 2004, which also indicates an increase in abundance of many species at these sites. Generally, sites on the same farm tended to occupy the same part of the ordination space in 2004, although there were exceptions. This indicates that variation in species composition was often lower within than between farms.

There was a significant increase in total species richness and the numbers of annuals, perennials and dicotyledons between 1996 and 2004 (Table 1). These were relatively large increases, all being approximately 40% higher in 2004. No increase in monocotyledons was detected although there was an increasing trend. Mean species richness in 2004 was 17.9 species per 0.2 m^2 transect. The majority of species were dicotyledons (12.9) and annuals (10.0), the incidence of perennials (4.6) and monocotyledons (3.5) being much lower. No change was detected in Ellenberg values, indicating that the type of species and the prevailing environmental conditions (nutrient and moisture availability) had not changed. No changes were detected in the species change index or frequency of pernicious weeds. These trends were consistent among farms except for total species richness, which showed a significant farm x year interaction. Species richness tended to increase at all but two farms. At one farm, with only two sites, it tended to decline. These sites had shallow autumn cultivations every other year (and not since 2002). At the second, there appeared to be no overall change in species richness.

(a)

(b)

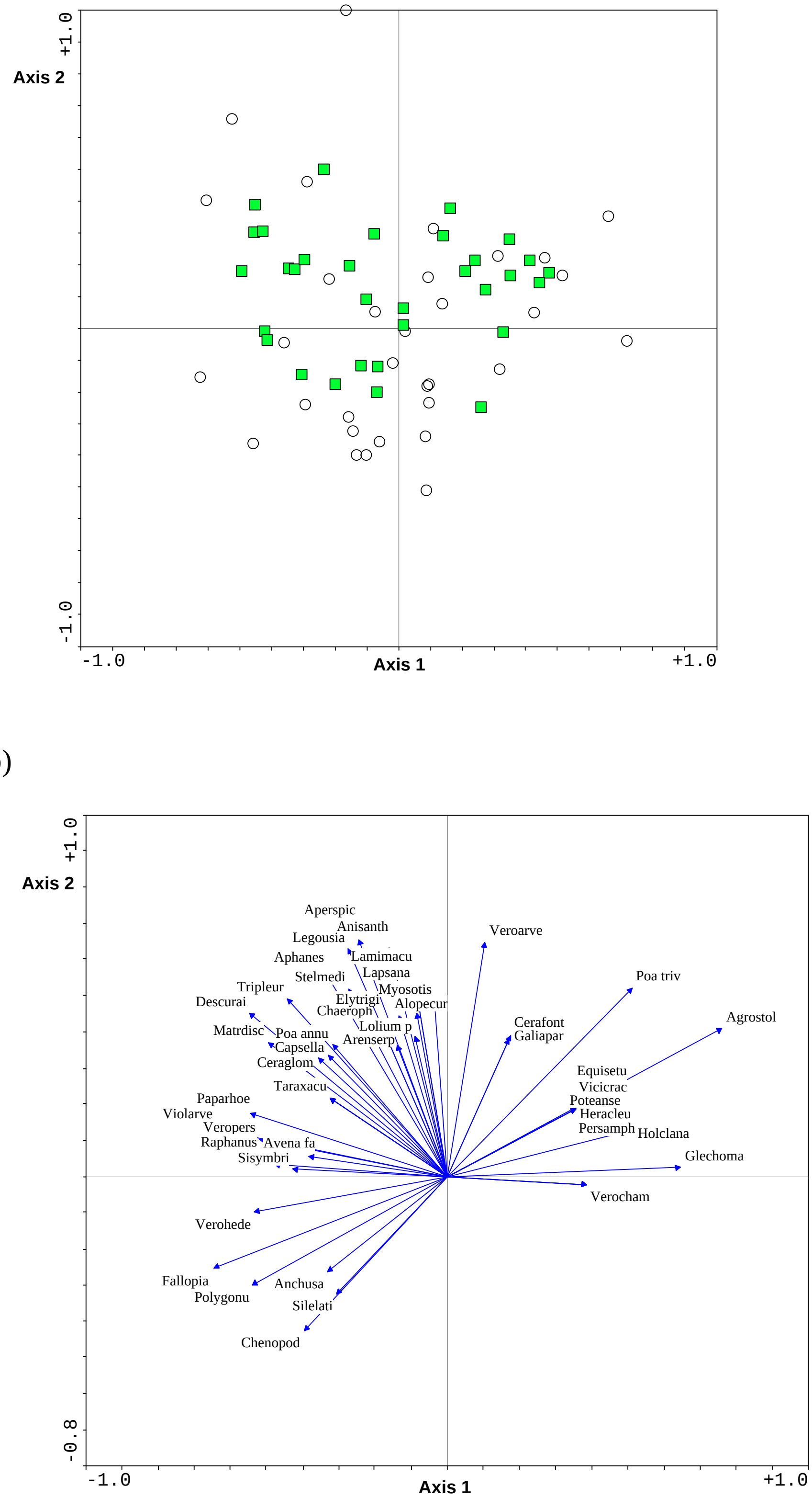


Figure 1. PCA ordination of 1996 data with 2004 added as supplementary variables. (a) sites (open circles 1996, filled squares 2004); (b) species (only those with minimum weight 15, i.e. the most influential species, shown for clarity). For full species names see Appendix 4.

Differences between farms were detected in many of the vegetation variables. Numbers of annuals, perennials and monocotyledons, Ellenberg moisture, species change index and pernicious weeds frequency all varied significantly.

Table 1. Mean numbers of species, Ellenberg values, change index and frequency of pernicious weeds and food plants (standard errors in parentheses) in 1996 and 2004 with ANOVA results (*n* = 32 sites). * *P* < 0.05; ** *P* < 0.01;* *P* < 0.001.**

Variable	**1996**	**2004**	**Year**		**Farm**		**Year x Farm**	
			$F_{1,21}$		$F_{10,21}$		$F_{10,21}$	
Species richness	12.3 (0.14)	17.9 (0.16)	38.80	***	1.06		2.45	*
No. of annuals	7.2 (0.65)	10.0 (0.77)	11.16	**	2.82	*	1.80	
No. of perennials	3.2 (0.44)	4.6 (0.39)	10.49	**	2.74	*	1.04	
No. of dicots	9.4 (0.66)	12.9 (0.77)	21.05	***	1.83		1.57	
No. of monocots	2.8 (0.33)	3.5 (0.31)	2.57		2.48	*	1.24	
Ellenberg fertility	6.1 (0.06)	6.0 (0.06)	1.22		2.21		1.30	
Ellenberg moisture	4.9 (0.06)	4.8 (0.05)	3.23		0.40	***	0.61	
Change index	-0.01 (0.067)	-0.01 (0.038)	1.56		6.00	***	1.76	
Weeds	8.8 (1.60)	7.8 (1.24)	0.05		2.61	*	1.60	
Bird food	18.8 (1.61)	22.3 (2.05)	6.34	*	1.86		2.00	
Butterfly larva food	12.7 (1.72)	15.2 (1.67)	7.88	*	3.44	**	3.39	**
Bumblebee food	10.7 (1.35)	14.6 (2.02)	13.61	**	1.52		5.25	***

There were also significant increases in the frequency of farmland bird, butterfly larva and bumblebee foodplants. Changes in farmland bird foodplants were consistent among farms. Significant interactions showed that butterfly larva and bumblebee foodplant frequency tended not to change, or showed slight downward trends, at some farms.

Relationship of species composition with management and other site factors

Most sites were cultivated annually, although almost one third were cultivated every other year or less often (Table 2). Sites normally cultivated in autumn, winter or spring were well represented in the sample, but more than half (17) were not cultivated in the same season every year. Ploughing and/or discing were the most commonly applied methods and the normal cultivation depth ranged from 8 to 30 cm. About one third of sites had not been cultivated during the 12 months prior to the 2004 survey. Slightly more sites had been shallow cultivated than deep ploughed. Ten sites were cut annually, seven less often and the remainder were never cut. Only five sites had weed control measures applied. Target species included *Cirsium* spp. (thistles), *Urtica* spp. (nettles), *Senecio jacobaea* (common ragwort) and, surprisingly, *Artemisia vulgaris* (mugwort).

Arable land and woodland were the most common adjacent land cover categories (Table 3). Most sites had a grass/tall herb verge and two thirds had broadleaved trees in the permanent field boundary. Ten sites had trees overhanging the transect locations. Ten sites were 12 m margins and several of the remainder were less than 6 m in width (overall mean width 7.7 m $\pm$ 3.09 st.dev.). Average aspect was 112^0 from due south ($\pm$ 48.7 st.dev.).

Table 2. Cultivations most often applied to sites (normal) and most recently (last). Data are numbers of sites (*n* = 31). Some sites might be allocated to more than one category (e.g. a site might be cultivated by tine and disc).

	Normal		Last				Normal	Last	
Frequency	annual	22	-		**Timing**	autumn	22	spring 04	13
	biennial	7	-			winter	11	winter 03/04	7
	less often	2	-			spring	15	earlier	11
Depth (cm)	3-5	0	3-5	4	**Method**	rotavate	1	harrow	1
	8-10	10	8-10	13		tine	4	tine	4
	20-23	9	20-23	8		disc	14	disc	18
	23-30	7	23-30	4		plough	22	plough	12
	variable	5	variable	2					

Table 3. Incidence of land cover and field boundary categories adjacent to UWS sites (*n* = 32). Sites can have more than one category present. Grassland includes set-aside, grass heath and derelict land; grass/tall herb verge includes *Pteridium aquilinum* (bracken).

Adjacent land cover	No. of sites	Field boundary	No. of sites
Woodland	12	Grass/tall herb verge	22
Arable	13	Broadleaved trees	20
Grassland	7	Coniferous trees	13
Metalled road	2	Overhanging trees	10
		Hedge	12
		Ditch	2
		Unmetalled track	5

The soil was loamy sand at all but two sites, one being sandy loam and the other clay loam. Soil extractable P was relatively high, being an average of ADAS index 3, although this is expected in sandy soils (Table 4). Soil extractable Mg was low, being Index 1 or 0 at all but two farms.

Table 4. Soil properties in UWSs (*n* = 64 transects).

Variable	Mean (st. dev.)	ADAS Index
pH	7.9 (0.63)	-
Extractable P (mg l^{-1})	28.8 (13.33)	3
Extractable K (mg l^{-1})	128.5 (43.73)	2
Extractable Mg (mg l^{-1})	34.0 (14.04)	1

Collectively, the significant variables from the RDAs of farm, management, context and soil properties explained 62.7% of the total variation in the species data, which is relatively high for this type of analysis. Six of the eleven farms had a significant effect on species composition (Table 5). The strongest management effect was where the most recent cultivation had been done more than twelve months before the survey. Normal season of cultivation (spring or winter), normal cultivation depth and normal cultivation by disc also had an effect on species composition. The only habitat context variables that were associated with species composition were related to nearby trees, *viz.* broadleaved trees in the field boundary and woodland adjacent to the site. Soil extractable P was the only significant soil property.

Table 5. Variation partitioning between subsets of explanatory variables on 2004 species data. Variation is % of total variation in species data except for % of TVE (total variation explained). Data to the left of the line are from individual RDAs of each subset. Variables in each subset are ordered according to their descending importance in the models. Data to right of line are from PRDAs of each subset. Codes refer to previous tables: LC last cultivation, NC normal cultivation, FBblt field boundary broadleaved trees. ** *P*<0.01, * *P*<0.05.

Subset	Significant variables	Variation explained	RDA Axis 1 (*F*)	RDA Trace (*F*)	Variation explained only by subset	Variation shared with other sets	Variation explained by covariables	% of TVE attributed only to subset	PRDA Axis 1 (*F*)	PRDA Trace (*F*)
Farm	Farm 8 Farm 5 Farm 7 Farm 9 Farm 4 Farm 3	32.9	2.75**	1.96**	21.5	11.4	41.2	34.3	1.78	1.54**
Management	LC earlier NC spring NC winter NC depth NC disc	29.7	3.60**	2.11**	19.1	10.6	43.6	30.5	1.89	1.64**
Context	FBblt Woodland	12.0	2.20**	1.90**	4.9	7.1	57.8	7.8	1.16	1.04
Soil	P	6.1	-	1.87*	3.4	2.7	59.2	5.4	-	1.46
All sig. vars.	as above	62.7	2.52**	1.92**	-	-	-	-	-	-

Farm and management explained the most variation in species composition (*c.* 30% each – see column 3 in Table 5). The variation shared with other subsets was high (*c.* 10% each – column 7 in Table 5), indicating some confounding of environmental variables, i.e. management and other site factors were linked to particular farms. Axis 1 was not significant in any of the PRDAs. Habitat context and soil each uniquely explained less than 5% of the total variation (column 6 in Table 5), and these were not statistically significant in the PRDAs. Again, this illustrates the overlapping effects of the different subsets.

The RDA biplot of all significant environmental variables showed a gradient along the first axis related to intensity and season of disturbance (Figure 2). At one end of the gradient were the effects of more than twelve months since the last cultivation and cultivation by disc, i.e. low levels of disturbance. Perennial species were clearly related to this, for example *Holcus lanatus* (Yorkshire-fog) and *Urtica dioica* (stinging nettle). At the opposite end were deep cultivation and spring cultivation, with which many annuals were strongly related. The second main gradient separated sites normally cultivated in winter and next to woodland from those with high soil P. The scarce *Apera spica-venti* (loose silky-bent) was associated with high soil P.

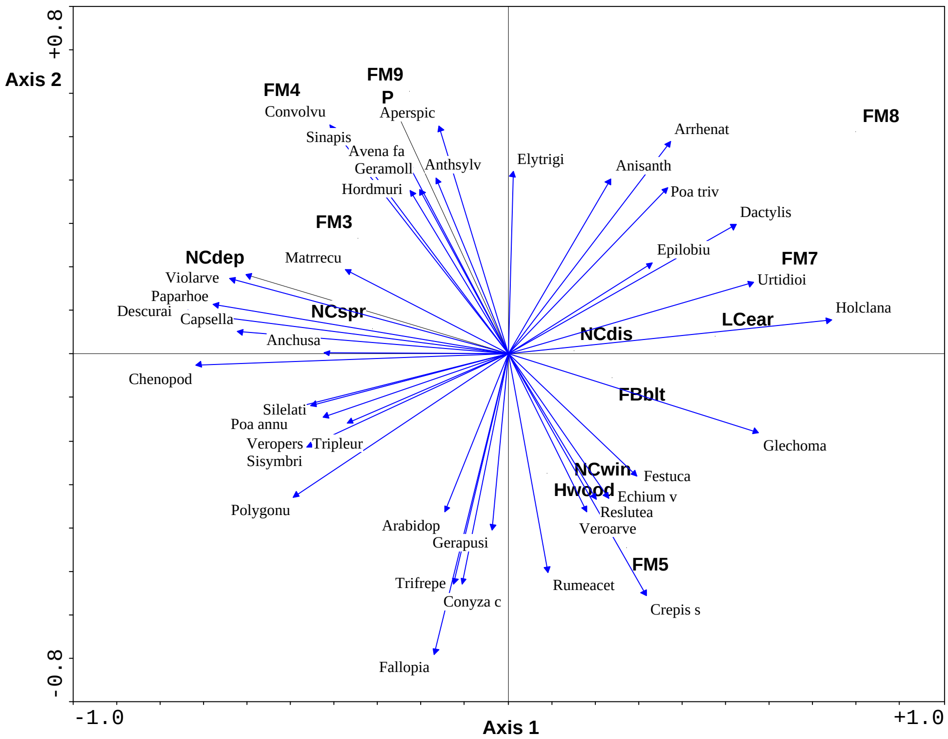


Figure 2. RDA ordination of 2004 species data and environmental variables. Only species with minimum weight 15, i.e. the most influential species, shown for clarity. For full species names see Appendix 4. FBblt = field boundary broadleaved trees; FM = farm; Hwood = woodland; LCear = last cultivation more than 12 months ago; NCdep, NCspr, NCwin, NCdis = normal cultivation (depth, spring, winter, disc); P = soil P.

The elapsed time since the last cultivation had a strong effect on the vegetation. One-way ANOVA showed that the ratio of annuals to perennials was significantly higher at sites cultivated in 2004 than those last cultivated in 2002 or 2003 ($F_{2,28}$ = 5.77, $P < 0.01$) (Figure 3; see also Plate 1 and Plate 2). This had an impact on nationally declining species, as shown by the strong negative correlation between the change index and ratio of annuals to perennials (r = -0.76, $P < 0.001$) (Figure 4). The change index was also correlated with Ellenberg moisture values (r = 0.65, $P < 0.001$), indicating that nationally declining species were more prevalent at drier sites.

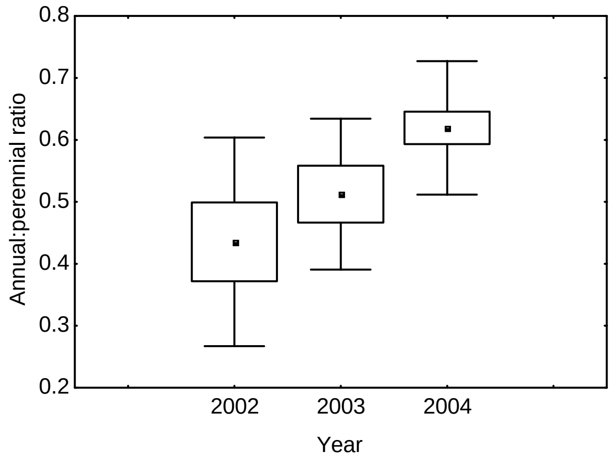


Figure 3. Annual:perennial ratio and year of last cultivation. Means (points), standard errors (boxes) and standard deviations (bars) shown. *n* = 7, 7 and 17 sites respectively for 2002, 2003 and 2004.

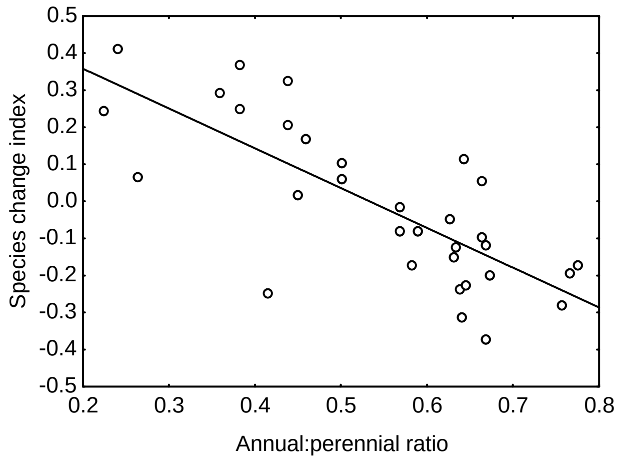


Figure 4. Relationship between species change index and ratio of annuals to perennials. Indices are negative where there is a high incidence of nationally declining species. *n* = 32 sites.

Plate 1. Uncropped wildlife strip with annuals and dicotyledons. Ploughed annually; approx. 12 years old.

Plate 2. Uncropped wildlife strip dominated by perennial grasses. Not cultivated for 2 years.

Pernicious weeds were related to soil pH and fertility. Although there were only four sites with soil pH < 7, they had significantly fewer weed species than those with higher soil pH values ($F_{2,29} = 4.34$, $P < 0.05$) (Figure 5). Total frequency of weed species was also positively correlated with the Ellenberg fertility index ($r = 0.43$, $P < 0.01$) (Figure 6).

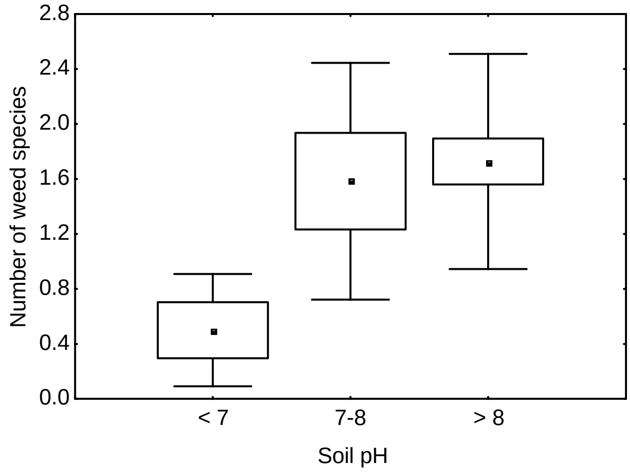


Figure 5. Number of pernicious weed species per site in relation to soil pH categories. Means (points), standard errors (boxes) and standard deviations (bars) shown. *n* = 4, 7 and 21 sites for pH < 7, 7-8 and >8 respectively.

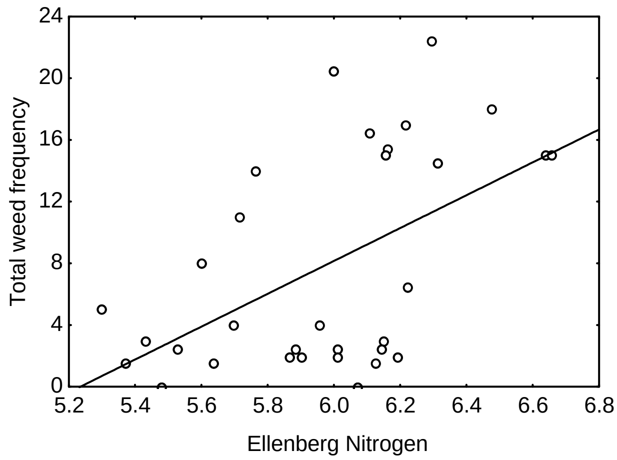


Figure 6. Relationship between total weed frequency and Ellenberg fertility index. *n* = 32 sites.

Farm, management and habitat context had a significant relationship with change in species composition between 1996 and 2004, together explaining 38.4% of the variation (Table 6). However, vegetation change was not related to any soil properties. Farm and management explained similar amounts of variation, about half of which were not shared with other subsets. The variation explained only by habitat context was similar to farm and management. However, only the PRDAs for farm and context were significant (axis 1 for farm was not significant) and the relationships with change in species frequencies were not very clear. Of the two farms that had a significant effect, one (farm 8) was associated with increased frequency of tall perennials such as *Arrhenatherum elatius* (false oat-grass), *Urtica dioica* and *Dactylis glomerata* (cock's-foot) (Figure 7). Biennial cultivation by disc or tine was done at this farm, although there were only two sites. Several species tended to decline at the second farm despite annual cultivation by disc and plough. It was not clear why these trends occurred, although cultivations were normally done in January. Several species tended to increase at sites with an adjacent track, but there was no consistent pattern to suggest any causative effect. It is possible that spatial separation of the site from the field boundary by a track might reduce its impact in some way, for example if trees were present.

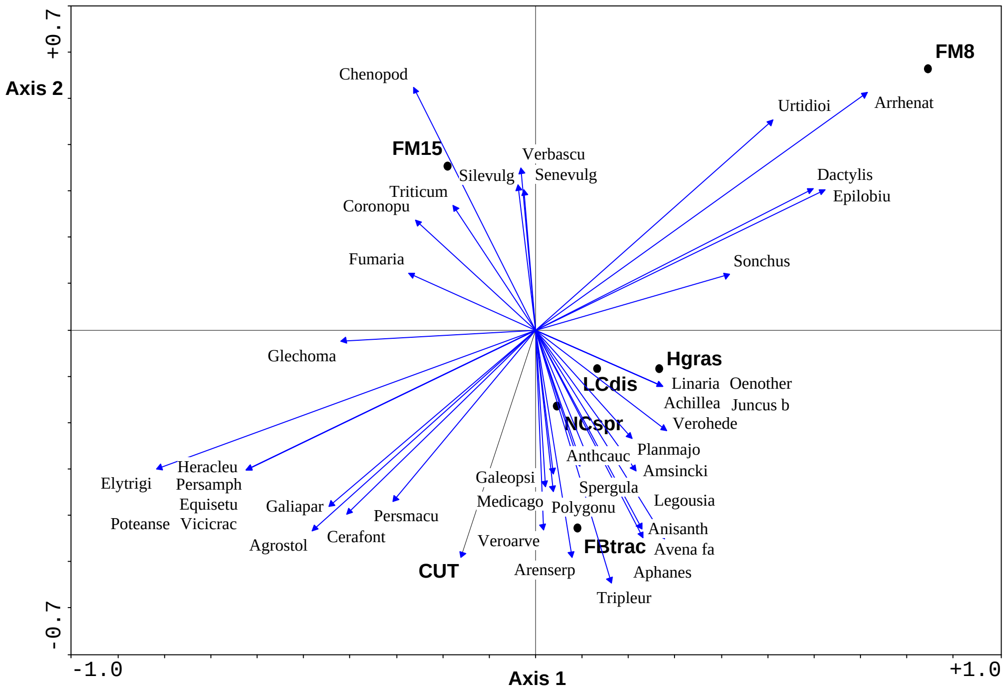


Figure 7. RDA ordination of change in species data 1996-2004 and environmental variables. Only species with minimum weight 9, i.e. the most influential species, shown for clarity. For full species names see Appendix 4. CUT = cutting frequency; FBtrac = field boundary track; FM = farm; Hgras = grassland; LCdis = last cultivation by disc; NCspr = normal cultivation in spring.

Table 6. Variation partitioning between subsets of explanatory variables on change in species' frequencies from 1996 to 2004 data. For explanation see Table 5.

Subset	Significant variables	Variation explained	RDA Axis 1 (*F*)	RDA Trace (*F*)	Variation explained only by subset	Variation shared with other sets	Variation explained by covariables	% of TVE attributed only to subset	PRDA Axis 1 (*F*)	PRDA Trace (*F*)
Farm	Farm 8 Farm 15	18.0	3.52	3.07**	9.3	8.7	29.1	24.2	1.94	1.73*
Management	LC disc cutting NC spring	18.4	2.73*	2.03**	9.2	9.2	29.2	24.0	1.79	1.14
Context	FB track Grassland	12.7	2.37	2.03**	10.1	2.6	28.3	26.3	2.75*	1.88*
Soil	none	-	-	-	-	-	-	-	-	-
All sig. vars.	as above	38.4	3.51*	2.04**	-	-	-	-	-	-

Rare or declining species

There were eighteen records of four rare or declining species, distributed amongst almost half (15) of the sites (Table 7). *Apera spica-venti* was found most often, followed by *Silene noctiflora* (night-flowering catchfly), *Papaver argemone* (prickly poppy) and *Polygonum rurivagum* (cornfield knotgrass). Three sites had two rare species present. Most populations were of 2 – 10 or 11 – 100 individuals. *P. argemone* populations were all small (10 individuals or fewer), whereas *A. spica-venti* and *S. noctiflora* both had some substantial populations of > 100 individuals (and one of > 1000 of the former). Two further records of *A. spica-venti* and one of *P. argemone* were noted on land adjacent to UWSs.

Table 7. No. of rare species records by population size.

	No. of individuals					
Species	**1**	**2 – 10**	**11 – 100**	**101 – 1000**	**>1000**	**Total**
Apera spica-venti	-	3	2	2	1	8
Silene noctiflora	-	2	2	2	-	6
Papaver argemone	1	2	-	-	-	3
Polygonum rurivagum	-	-	1	-	-	1
Total	1	7	5	4	1	18

Sites with rare species were separated from those with none along axis 1 of the PCA of 2004 transect data (Figure 8a). The species plot shows that sites with rare species were strongly associated with annuals, most of which were dicotyledons (Figure 8b; see also Plate 3). In contrast, those with no rare species had a greater tendency to be associated with perennials, including perennial grasses (e.g. *Holcus lanatus*, *Dactylis glomerata*, *Poa trivialis*). There was some overlap between the two categories of sites in the ordination but otherwise the pattern was clear.

These patterns were confirmed by ANOVA, which showed there were significantly more annuals ($F_{1,30} = 19.5$, $P < 0.001$) and dicotyledons ($F_{1,30} = 8.4$, $P < 0.01$) in sites with rare species than those without. Rare species also occurred at sites with lower Ellenberg moisture values ($F_{1,30} = 4.3$, $P < 0.05$). Variation in moisture values amongst sites with no rare species was high, suggesting that even if prevailing levels of moisture availability are generally suitable, rare species are often still absent. However, there was no significant difference in any soil properties between sites with and without rare species.

Rare species were found in five NVC communities or sub-communities (Table 8). All communities are normally associated with light, well-drained soils. Some samples had elements of trampled or ruderal communities even although they were most closely aligned with arable plant communities. All rare species and more than half of the records (11) were from the OV3 community. This community is found on light, 'not too calcareous' soils in the warmer and drier lowlands (Rodwell, 2000). The OV17 community is most typical of Breckland, being associated with dry, sandy soils and a continental climate. *Apera spica-venti* and *Papaver argemone* were recorded there. OV7 and OV9d are associated with more fertile soils, and OV16 with calcareous soils.

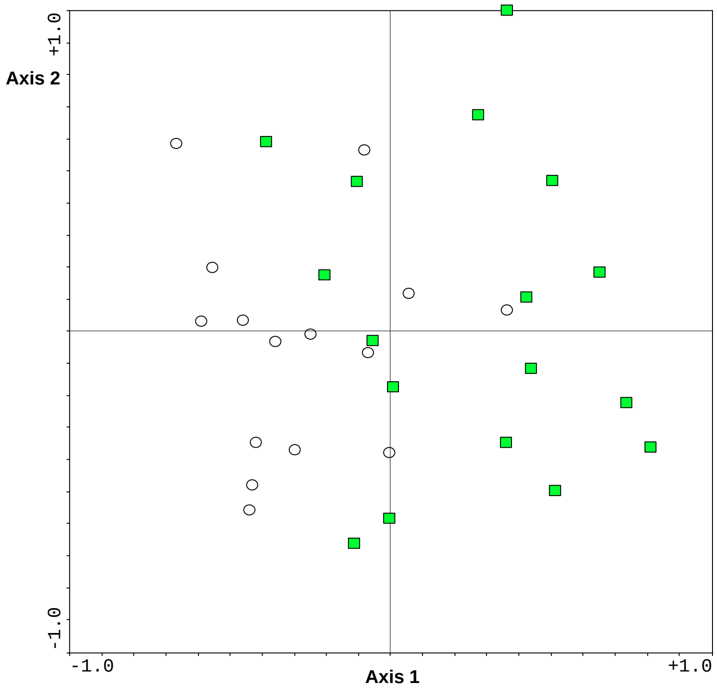
Summary data for each species recorded in UWSs are presented in Appendix 5, including information on soils and plant communities.

Table 8. Occurrence of rare species in NVC communities or sub-communities. No. = number of records.

Species	NVC		No.
Apera spica-venti	OV3	*Papaver rhoeas – Viola arvensis*	5
	OV9d	*Tripleurospermum inodorum – Stellaria media Fallopia convolvulus – Veronica persica* sub-community	1
	OV16	*Papaver rhoeas – Silene noctiflora*	1
	OV17	*Reseda lutea – Polygonum aviculare*	1
Papaver argemone	OV3	*Papaver rhoeas – Viola arvensis*	2
	OV17	*Reseda lutea – Polygonum aviculare*	1
Polygonum rurivagum	OV3	*Papaver rhoeas – Viola arvensis*	1
Silene noctiflora	OV3	*Papaver rhoeas – Viola arvensis*	3
	OV7	*Veronica persica – Veronica polita*	1
	OV9d	*Tripleurospermum inodorum – Stellaria media Fallopia convolvulus – Veronica persica* sub-community	1
	OV16	*Papaver rhoeas – Silene noctiflora*	1

Plate 3. Uncropped wildlife strip containing *Silene noctiflora* population. Cultivated annually by disc.

(a)



(b)

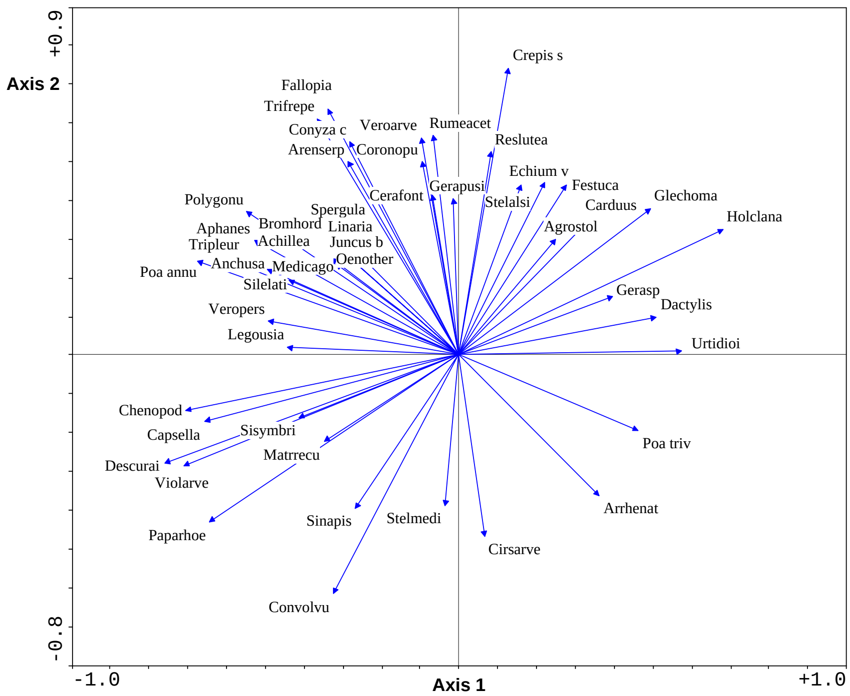


Figure 8. PCA ordination of 2004 transect data. (a) sites (open circles with rare species, filled squares without rare species); (b) species (only those with minimum weight 15, i.e. the most influential species, shown for clarity). For full species names see Appendix 4.

Discussion

Vegetation of UWSs

Concerns about long-term increases in perennials and monocotyledons and their detrimental impact on the target annual dicotyledons in UWSs were not fully upheld in this study. The soils were predominantly sandy, where the problem might be less acute than on heavier, more fertile soils. Overall, annuals and dicotyledons were still abundant at many sites and numbers increased substantially since 1996, despite the sites having been established for up to sixteen years. Although perennial numbers also increased during that period, they were relatively low across the whole sample. There were also potential benefits for farmland birds, butterfly larvae and bumblebees, as their foodplants also increased. Pernicious weeds, although present, were not a major issue and weed control had been deemed necessary at only a few sites. With only two sampling periods, it is not certain whether the changes reflected long-term trends or simply annual fluctuations. However, there was no evidence of a major shift in the type of species present. At the ESA scale, annual arable plant communities had been maintained at many sites.

Although the total number of species recorded in the two surveys was similar, a large proportion of these were only recorded in either 1996 or 2004. This might be due to species turnover during the intervening period, or alternatively simply to sampling error. The spatial scale of sampling was small (0.4 m^2 per site) because the 1996 survey had to be compatible with the other, more detailed, study being done at that time (ADAS, 1997). Sampling error is normally higher at small spatial scales.

Variation between sites

Species composition varied considerably between sites, although arable plant communities were common across the whole sample. Cultivation regime had a clear relationship with the vegetation of UWSs, and in particular the elapsed time since the last cultivation. Sites not cultivated recently had a high proportion of perennial species, especially perennial grasses. Annual cultivation was therefore important for ensuring maintenance of annual arable plant communities. With longer undisturbed periods, perennials are more likely to build up over time, even if they are reduced in years following cultivation. The season, depth and mechanical method of cultivation were also related to species composition, confirming results of previous research (Critchley *et al.*, 2001). Disturbance intensity affects the relative abundance of annuals and perennials in vegetation (Schippers, *et al.*, 2001). In this study, annuals and perennials were associated with the relative intensity of disturbance, i.e. the frequency, depth and method of cultivation. Sites on the same farm tended to be subject to the same cultivation regime, so opportunities for maximising spatial variation in UWS vegetation within farms were not being realised. Cultivation regimes did however vary between farms, and accounted for much of the variation across the ESA. In some, but not all cases the cultivation timing varied from year to year. This would be expected to maintain more diverse communities in the longer term (Crawley, 2004). Cultivation depth and method tended to be more consistent over time at individual sites. If these were also varied, temporal variation in species composition can also be expected to increase (Critchley *et al.*, 2001).

UWS vegetation can also be influenced by adjacent habitats, particularly overhanging trees as a result of altered microclimate, shading, leaf litter and rainwater throughfall (Critchley, 1994). In this study, there was some relationship between species composition and the proximity of trees, although it was relatively minor. No effect of aspect was detected, suggesting that shelter or shading might not have been important. However, casual observation of heavily shaded sites outside the sample did reveal that in extreme cases grasses and rank vegetation could be dominant. With a relatively small sample and only a few farms available, there are limitations on the number of associations that can be isolated, particularly since the management practices were often confounded by farm. Site management and other environmental factors were more closely associated with the vegetation in 2004 than with the change in species composition between the two surveys.

Results of this study contrast with those from UWSs in the Arable Stewardship Pilot Scheme, in which there was a substantial increase in perennials four years after establishment, primarily because of infrequent cultivations (Critchley *et al*., 2004a). However, the Breckland ESA sample was from a restricted geographic area, in which there was relatively little variation in soil properties or climate. On loamy or clayey soils, it might be more difficult to maintain annual communities in the longer term. The results from this study might only be applicable to sites on light, sandy soils.

Rare or declining species

Several populations of rare or declining species were found. In the Arable Stewardship Pilot Scheme, populations of rare species declined markedly in the first four years following establishment of UWSs, and this was thought to be related to increasing competition from perennial species (Critchley *et al*., 2004a). In the Breckland ESA, rare species were clearly associated with annual communities, which supports the earlier conclusions from the Arable Stewardship Pilot Scheme. Since rare species have survived in the Breckland sites after up to sixteen years, it seems likely that they will be maintained as long as sites are cultivated annually. Many of the most rapidly declining species in Britain are annual arable plants (Preston *et al*., 2002). The benefits to them of maintaining annual communities in the Breckland sites were shown by the relative change indices, which were much lower when annuals predominated.

Some sites appeared to be suitable for rare species but had none. This probably reflects the fact that most are intrinsically rare, despite the availability of apparently suitable habitat. Rarity might be a consequence of poor reproductive, dispersal or competitive ability, combined with the lasting impact of unsuitable management practices in the past. Although there were several rare species records from UWSs, only four different species were found. These particular species might be less restricted in their habitat requirements and have greater potential for recovery when suitable habitat is restored. These species might benefit most from well-managed UWSs but others might require more specific site targeting and management. Some species typical of the Breckland environment such as *Veronica praecox* (Breckland speedwell) and the early flowering *V. verna* (spring speedwell) and *V. triphyllos* (fingered speedwell) are thought to be extinct outside a handful of known sites and are unlikely to colonise naturally elsewhere.

Recommendations

1. Annual cultivation is recommended for maintenance of the target plant communities and should be encouraged at all sites.

2. Spatial and temporal variation in cultivation regime (season, depth and mechanical method) should be encouraged. Maximising disturbance by deep ploughing (15 – 30 cm) at least occasionally will also be beneficial.
3. In Breckland and possibly on sandy soils elsewhere, it is feasible to maintain UWSs *in situ* in the long term, as long as the appropriate cultivation regime is applied.
4. Even on suitable soil types, the drier sites should be given priority and those with many overhanging trees avoided.
5. Cutting and selective weed control should continue to be permitted where necessary.
6. Regular checks should be carried out to ensure adherence to the management prescriptions, including maintenance of the required width of strip.
7. Where rare species are present, site-specific advice should be given on management, including cultivation timing.

Acknowledgements

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Appendices

Appendix 1. Target List of Rare Arable Species

Species are those known to occur in the 1km squares in which Breckland ESA is located.

Adonis annua
Agrostemma githago
Ajuga chamaepitys
Alyssum alyssoides
Anagallis arvensis subsp. *foemina*
Anthemis arvensis
Apera interrupta
Apera spica-venti
Briza minor
Bromus arvensis
Bromus secalinus
Bunium bulbocastanum
Centaurea cyanus
Chrysanthemum segetum
Echium plantagineum
Erodium moschatum
Euphorbia exigua
Euphorbia platyphyllos
Filago lutescens
Filago pyramidata
Fumaria densiflora
Fumaria parviflora
Fumaria vaillantii
Galeopsis angustifolia
Galium tricornutum
Gastridium ventricosum
Hypochaeris glabra
Iberis amara
Lathyrus aphaca
Lavatera cretica
Lithospermum arvense
Lythrum hyssopifolium
Misopates orontium
Myosurus minimus
Papaver argemone
Papaver dubium subsp. *lecoqii*
Papaver hybridum
Petroselinum segetum
Polycarpon tetraphyllum
Polygonum rurivagum
Ranunculus arvensis
Ranunculus parviflorus
Scandix pecten-veneris
Silene gallica
Silene noctiflora
Torilis arvensis
Valerianella dentata
Valerianella rimosa
Veronica praecox
Veronica triphyllos
Veronica verna
Vicia parviflora

Appendix 2. Plant taxa classified as farmland bird, butterfly larva or bumblebee food plants.

Bird and butterfly plants from Smart *et al*. (2000), bumblebee plants from observations during surveys of Arable Stewardship Pilot Scheme sites (Pywell *et al*., 2005).

Taxon	Farmland Bird	Butterfly Larva	Bumblebee
Agrostis capillaris		✓	
Alliaria petiolata		✓	
Anchusa arvensis			✓
Anthoxanthum odoratum		✓	
Arctium agg.	✓		
Arctium lappa	✓		
Arctium minus	✓		✓
Arrhenatherum elatius		✓	
Artemisia vulgaris	✓		
Avena fatua	✓		
Avena sativa	✓		
Avena sp.	✓		
Ballota nigra			✓
Barbarea vulgaris		✓	
Beta sp.	✓		
Beta vulgaris ssp. *vulgaris*	✓		
Borago officinalis			✓
Brachypodium sylvaticum		✓	
Brassica napus	✓		✓
Brassica napus ssp. *oleifera*	✓		✓
Brassica nigra	✓		
Brassica oleracea	✓		
Brassica oleracea var. *capitata*	✓		
Brassica oleracea var. *viridis*	✓		
Brassica rapa	✓		
Brassica rapa ssp. *rapa*	✓		
Brassica sp.	✓		
Calystegia sepium			✓
Capsella bursa-pastoris	✓	✓	
Carduus nutans			✓
Centaurea nigra			✓
Centaurea scabiosa			✓
Cerastium fontanum	✓		
Cerastium glomeratum	✓		
Chamerion angustifolium			✓
Chenopodium album	✓		
Chenopodium ficifolium	✓		
Cirsium arvense	✓		✓
Cirsium palustre	✓		✓
Cirsium sp.			✓
Cirsium vulgare	✓		✓
Convolvulus arvensis			✓
Crataegus monogyna	✓		
Cynosurus cristatus		✓	
Dactylis glomerata		✓	
Deschampsia cespitosa		✓	
Dipsacus fullonum			✓

Taxon	Farmland Bird	Butterfly Larva	Bumblebee
Elytrigia repens		✓	
Epilobium hirsutum			✓
Festuca arundinacea	✓		
Festuca pratensis	✓	✓	
Festuca rubra	✓		
Festuca sp.	✓		
Galeopsis tetrahit			✓
Hedera helix	✓		
Helianthus annuus	✓		✓
Holcus lanatus	✓	✓	
Holcus mollis	✓	✓	
Hordeum vulgare/distichon	✓		
Kickxia spuria			✓
Knautia arvensis		✓*	✓
Lamium purpureum			✓
Lathyrus pratensis		✓	
Linaria vulgaris			✓
Lolium multiflorum/perenne	✓	✓	
Lotus corniculatus		✓	✓
Lotus pedunculatus		✓	
Malva sylvestris			✓
Medicago lupulina		✓	✓
Medicago sativa			✓
Melilotus officinalis			✓
Melilotus sp.			✓
Onobrychis viciifolia			✓
Papaver rhoeas			✓
Persicaria hydropiper	✓		
Persicaria lapathifolia	✓		✓
Persicaria maculosa	✓		✓
Phacelia tanacetifolia			✓
Picris echioides			✓
Poa annua	✓	✓	
Poa pratensis	✓		
Poa trivialis	✓		
Polygonum aviculare	✓		
Polygonum rurivagum	✓		
Potentilla anserina		✓	
Potentilla reptans		✓	
Prunus spinosa	✓		
Raphanus raphanistrum		✓	
Reseda lutea		✓	✓
Reseda luteola			✓
Rosa sp.	✓		
Rubus fruticosus	✓		✓
Rumex acetosa	✓	✓	
Rumex acetosella	✓	✓	
Rumex conglomeratus	✓		
Rumex crispus	✓		
Rumex obtusifolius	✓		
Rumex sanguineus	✓		
Rumex sp.	✓		
Senecio erucifolius	✓		
Senecio jacobaea	✓		✓
Senecio vulgaris	✓		✓
Sinapis alba	✓		
Sinapis arvensis	✓		

Taxon	Farmland Bird	Butterfly Larva	Bumblebee
Sisymbrium officinale		✓	
Sonchus arvensis	✓		✓
Sonchus asper	✓		
Sonchus oleraceus	✓		
Sonchus sp.	✓		
Spergula arvensis	✓		
Stachys sylvatica			✓
Stellaria holostea	✓		
Stellaria media	✓		
Taraxacum officinale agg.	✓		
Trifolium arvense	✓		
Trifolium dubium	✓	✓	
Trifolium pratense	✓	✓	✓
Trifolium repens	✓	✓	✓
Tripleurospermum inodorum			✓
Triticum sp.	✓		
Urtica dioica	✓	✓	
Urtica urens		✓	
Vicia hirsuta	✓		
Vicia sativa	✓		
Vicia sp.	✓		
Vicia tetrasperma	✓		
Viola arvensis			✓
Zea mays	✓		

* additional species not listed in Smart *et al*. (2000).

Appendix 3. Taxa recorded from transects in UWS sites in 2004.

Name	Number of margins	% of margins
Bare ground	32	100
Seedlings	29	91
Bryophyte sp.	27	84
Litter	16	50
Hordeum vulgare/distichon	4	13
Triticum sp.	2	6
Elytrigia repens	19	59
Poa trivialis	18	56
Poa annua	17	53
Anisantha sterilis	15	47
Agrostis stolonifera	15	47
Holcus lanatus	12	38
Dactylis glomerata	8	25
Apera spica-venti	6	19
Bromus hordeaceus	6	19
Lolium perenne	6	19
Arrhenatherum elatius	5	16
Avena fatua	4	13
Holcus mollis	4	13
Agrostis capillaris	2	6
Festuca rubra	2	6
Hordeum murinum	2	6
Agrostis stolonifera/capillaris	1	2
Bromus sp.	1	2
Arenaria serpyllifolia	25	78
Tripleurospermum inodorum	25	78
Silene latifolia	24	75
Veronica persica	24	75
Polygonum aviculare	23	72
Chenopodium album	21	66
Papaver rhoeas	20	63
Capsella bursa-pastoris	19	59
Cirsium arvense	18	56
Myosotis arvensis	18	56
Descurainia sophia	17	53
Anchusa arvensis	16	50
Viola arvensis	16	50
Fallopia convolvulus	15	47
Stellaria media	15	47
Veronica arvensis	15	47
Sonchus asper	11	34
Aphanes arvensis	10	31
Conyza canadensis	10	31
Crepis capillaris	10	31
Geranium pusillum	10	31
Medicago lupulina	10	31

Name	**Number of margins**	**% of margins**
Sisymbrium officinale	10	31
Convolvulus arvensis	9	28
Legousia hybrida	9	28
Reseda lutea	9	28
Trifolium repens	8	25
Urtica dioica	8	25
Cerastium fontanum	7	22
Echium vulgare	7	22
Anthriscus caucalis	6	19
Plantago major	6	19
Anagallis arvensis	5	16
Artemisia vulgaris	5	16
Ballota nigra	5	16
Geranium molle	5	16
Glechoma hederacea	5	16
Spergula arvensis	5	16
Cirsium vulgare	4	13
Erodium cicutarium	4	13
Plantago lanceolata	4	13
Rumex acetosella	4	13
Rumex crispus	4	13
Sinapis arvensis	4	13
Urtica urens	4	13
Amsinckia micrantha	3	9
Anthriscus sylvestris	3	9
Crataegus monogyna	3	9
Galium aparine	3	9
Geranium sp.	3	9
Matricaria discoidea	3	9
Matricaria recutita	3	9
Rumex obtusifolius	3	9
Senecio vulgaris	3	9
Arabidopsis thaliana	2	6
Carduus nutans	2	6
Coronopus didymus	2	6
Lamium sp.	2	6
Papaver dubium	2	6
Silene noctiflora	2	6
Lamium amplexicaule	2	6
Acer pseudoplatanus	1	2
Achillea millefolium	1	2
Aethusa cynapium	1	2
Arctium minus	1	2
Arctium agg.	1	2
Cynoglossum officinale	1	2
Crepis vesicaria	1	2
Epilobium sp.	1	2
Euphorbia sp.	1	2
Filago vulgaris	1	2
Galeopsis tetrahit	1	2

Name	**Number of margins**	**% of margins**
Galium verum	1	2
Juncus bufonius	1	2
Kickxia elatine	1	2
Koeleria macrantha	1	2
Lapsana communis	1	2
Linaria vulgaris	1	2
Odontites vernus	1	2
Oenothera biennis	1	2
Ranunculus repens	1	2
Senecio jacobaea	1	2
Stachys sylvatica	1	2
Stellaria alsine	1	2
Trifolium dubium	1	2
Verbascum thapsus	1	2
Vicia sepium	1	2
Vicia sp.	1	2

Appendix 4. Abbreviated species names used in ordination figures.

Abbreviation	Species	Abbreviation	Species
Achillea	*Achillea millefolium*	Hordmuri	*Hordeum murinum*
Agrostol	*Agrostis stolonifera*	Juncusb	*Juncus bufonius*
Alopecur	*Alopecurus myosuriodes*	Lamimacu	*Lamium maculatum*
Amsincki	*Amsinckia micrantha*	Lapsana	*Lapsana communis*
Anchusa	*Anchusa arvensis*	Legousia	*Legousia hybrida*
Anisanth	*Anisantha sterilis*	Linaria	*Linaria vulgaris*
Anthcauc	*Anthriscus caucalis*	Loliump	*Lolium perenne*
Anthsylv	*Anthriscus sylvestris*	Matrdisc	*Matricaria discoidea*
Aperspic	*Apera spica-venti*	Matrrecu	*Matricaria recutita*
Aphanes	*Aphanes arvensis*	Medicago	*Medicago lupulina*
Arabidop	*Arabidopsis thaliana*	Myosotis	*Myosotis arvensis*
Arenserp	*Arenaria serpyllifolia*	Oenother	*Oenanthera biennis*
Arrhenat	*Arrhenatherum elatius*	Paparhoe	*Papaver rhoeas*
Avenafa	*Avena fatua*	Persamph	*Persicaria amphibia*
Bromhord	*Bromus hordeaceus*	Persmacu	*Persicaria maculosa*
Capsella	*Capsella bursa-pastoris*	Planmajo	*Plantago major*
Carduus	*Carduus nutans*	Poaannu	*Poa annua*
Cerafont	*Cerastium fontanum*	Poatriv	*Poa trivialis*
Ceraglom	*Cerastium glomeratum*	Polygonu	*Polygonum aviculare*
Chaeroph	*Chaerophylum temulentum*	Poteanse	*Potentilla anserine*
Chenopod	*Chenopodium album*	Raphanus	*Raphanus raphanistrum*
Cirsarve	*Cirsium arvense*	Reslutea	*Reseda lutea*
Convolvu	*Convolvulus arvensis*	Rumeacet	*Rumex acetosella*
Conyzac	*Conyza Canadensis*	Senevulg	*Senecio vulgaris*
Coronopu	*Coronopus* sp.	Silelati	*Silene latifolia*
Crepiss	*Crepis* sp.	Silevulg	*Silene vulgaris*
Dactylis	*Dactylis glomerata*	Sinapis	*Sinapis arvensis*
Descurai	*Descurainia sophia*	Sisymbri	*Sisymbrium officinale*
Echiumv	*Echium vulgare*	Sonchus	*Sonchus asper*
Elytrigi	*Elytrigia repens*	Spergula	*Spergula arvensis*
Epilobiu	*Epilobium* sp.	Stelalsi	*Stellaria alsine*
Equisetu	*Equisetum palustre*	Stelmedi	*Stellaria media*
Fallopia	*Fallopia convolvulus*	Taraxacu	*Taraxacum officinale*
Festuca	*Festuca rubra*	Trifrepe	*Trifolium repens*
Fumaria	*Fumaria officinalis*	Tripleur	*Tripleurospermum inodorum*
Galeopsi	*Galeopsis tetrahit*	Triticum	*Triticum aestivum*
Galiapar	*Galium aparine*	Urtidioi	*Urtica dioica*
Geramoll	*Geranium molle*	Veroarve	*Veronica arvensis*
Gerapusi	*Geranium pusillum*	Verocham	*Veronica chamaedrys*
Gerasp	*Geranium* sp.	Verohede	*Veronica hederacea*
Glechoma	*Glechoma hederacea*	Veropers	*Veronica persica*
Heracleu	*Heracleum sphondylium*	Vicicrac	*Vicia cracca*
Holclana	*Holcus lanatus*	Violarve	*Viola arvensis*

Appendix 5. Summary data for each rare species.

Cover values are of all species and the sum can be greater than 100%.

Species: *Apera spica-venti* **No. of records:** 8

Grid ref.	Date	Field margin type	Soil texture	NVC	No. of individs
TL 94 85	25/06/04	uncropped wildlife strip	LS	OV3	2-10
TL 86 85	23/06/04	uncropped wildlife strip	LS	OV3	11-100
TL 86 85	23/06/04	uncropped wildlife strip	LS	OV3	2-10
TL 86 86	23/06/04	uncropped wildlife strip	LS	OV17	11-100
TL 88 86	24/06/04	uncropped wildlife strip	LS	OV3	101-1000
TL 91 83	23/07/04	uncropped wildlife strip	LS	OV16	101-1000
TL 74 68	21/07/04	uncropped wildlife strip	LS	OV3	>1000
TL 79 04	26/07/04	uncropped wildlife strip	LS	OV9d	2-10

Community data (means from three $4m^2$ quadrats):

	Total	Dicotyledons	Monocotyledons	Annuals	Perennials
Cover	61.7-102.0	21.0-76.3	15.0-78.7	9.3-96.3	4.1-72.0
Richness	18.7-29.7	13.3-24.7	3.3-7.3	12.0-19.3	1.7-8.7

Soil properties:

pH	P (mg l^{-1})	K (mg l^{-1})	Mg (mg l^{-1})
7.5-8.4	18-57	83-244	18-73

Species: *Papaver argemone* **No. of records:** 3

Grid ref.	Date	Field margin type	Soil texture	NVC	No. of individs
TL 86 85	23/06/04	uncropped wildlife strip	LS	OV3	1
TL 88 84	24/06/04	uncropped wildlife strip	LS	OV17	2-10
TL 88 84	24/06/04	uncropped wildlife strip	LS	OV3	2-10

Community data (means from three 4m^2 quadrats):

	Total	Dicotyledons	Monocotyledons	Annuals	Perennials
Cover	32.7-104.8	30.5-52.7	2.0-72.2	17.8-95.0	6.5-14.2
Richness	18.3-22.7	14.3-21.7	1.0-8.3	10.3-15.7	4.7-5.3

Soil properties:

pH	P (mg l^{-1})	K (mg l^{-1})	Mg (mg l^{-1})
8.2-8.3	19-35	64-151	12-21

Species: *Polygonum rurivagum* **No. of records:** 1

Grid ref.	Date	Field margin type	Soil texture	NVC	No. of individs
TL 84 99	22/7/04	uncropped wildlife strip	LS	OV3	11-100

Community data (means from three 4m^2 quadrats):

	Total	Dicotyledons	Monocotyledons	Annuals	Perennials
Cover	88.8	85.8	3.0	81.6	3.3
Richness	24.3	22.2	2.3	16.7	3.3

Soil properties:

pH	P (mg l^{-1})	K (mg l^{-1})	Mg (mg l^{-1})
8.4	24	182	27

Species: *Silene noctiflora* **No. of records:** 6

Grid ref.	Date	Field margin type	Soil texture	NVC	No. of individs
TL 91 83	23/7/04	uncropped wildlife strip	LS	OV16	11-100
TL 83 99	22/7/04	uncropped wildlife strip	LS	OV3	2-10
TL 74 68	21/7/04	uncropped wildlife strip	LS	OV3	11-100
TL 78 03	27/7/04	uncropped wildlife strip	LS	OV9d	2-10
TL 80 99	27/7/04	uncropped wildlife strip	LS	OV3	101-1000
TL 80 98	21/7/04	uncropped wildlife strip	LS	OV7	101-1000

Community data (means from three $4m^2$ quadrats):

	Total	Dicotyledons	Monocotyledons	Annuals	Perennials
Cover	51.2-109.7	13.3-109.3	0.3-68.7	7.8-98.5	0-72.0
Richness	18.7-33.0	17.7-27.0	0.7-6.0	13.0-19.7	0-9.0

Soil properties:

pH	P (mg l^{-1})	K (mg l^{-1})	Mg (mg l^{-1})
6.4-8.5	14-47	85-244	21-73