Defra Project MA01016

Hay-meadow Vegetation Monitoring in the Dartmoor ESA 1995-2003

August 2004

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Contents

1. INTRODUCTION

1.1 Hay meadows have been identified as a 'priority habitat' by the UK Biodiversity Steering Group (1995). High quality, traditional hay meadows (with a history of annual hay cutting) are relatively rare within Dartmoor ESA and are found mainly on the higher farms. According to the Dartmoor Biodiversity Profile and LBAP, there are only about a dozen covering about 20 ha (EN & DNPA, 2001; DNPA, 2001). Many of these are already subject to English Nature or Dartmoor National Park Authority management agreements. Many more meadows, often with a varied history of occasional hay cuts interspersed with years of being grazed, still retain a degree of species-richness and have formed the main target for Tier 2A (Species-rich Hay Meadows).

1.2 The Dartmoor BAP includes an action plan for hay meadows along with species-rich dry pastures with targets to 'ensure favourable management of all existing species-rich hay meadows which have greater butterfly orchid (around 20 ha)' and to 'establish hay meadow management on 100 ha of meadows identified as having potential for enhancement, by 2005, and on a further 50 ha by 2010'. At the time of the production of the BAP relatively little was known about the species-rich dry grassland resource of the ESA. Since then, a targeted survey in 2003 (due to be completed in 2004) located 494 ha of largely unimproved, dry grassland in 262 sites (DNPA, 2004). Of this, 262 ha were NVC community MG5 (see below), representing about 2% of the estimated national resource, though only a proportion of this would be hay meadows.

1.3 Dartmoor ESA was one of the Stage IV English ESAs launched in 1994 (for more detail on the scheme see ADAS, 1995). The general conditions for entry of land into Tier 2A include:

- high botanical diversity, or the potential for this to increase;
- the land being in a strategic position and capable of being mown;
- land not recently re-seeded; and
- land with a history of low level fertiliser application.

The prescriptions for Tier 2A (given in full in Appendix I) include exclusion of stock from 15 May until after cutting, a cutting date of on or after 15 July and, after 31 July at least once every five years and no fertiliser applications other than farmyard manure (FYM).

1.4 An initial botanical survey of a sample of hay meadows under Tier 2A ESA management was carried out in 1995 and a resurvey of these sites was undertaken in 2003. Soil samples were taken from these fields at the time of the initial botanical survey in 1995 as part of MAFF research contract BD1429 (Chambers *et al.*, 1998, 1999; Critchley *et al.*, 2002a) and this sampling was repeated in January-February 2004. This report outlines the methods used in the surveys and soil sampling. A description is presented of the vegetation sampled and changes occurring between the two surveys, and any relationships with soils data are highlighted.

Description of vegetation

1.5 Hay meadows have become increasingly rare throughout Britain, through agricultural improvement. On Dartmoor in-bye land, they can occur at a relatively high altitude for this type of grassland.

1.6 The best quality hay meadows in Dartmoor are semi-natural, neutral grassland. These tend to be dominated by many grasses such as sweet vernal-grass (*Anthoxanthum odoratum*), common bent (*Agrostis capillaris*), crested dog's-tail (*Cynosurus cristatus*) and red fescue (*Festuca rubra*), along with abundant herbaceous species. Agricultural improvement results in perennial rye-grass (*Lolium perenne*) becoming more dominant and a reduction in flowering herbs (an important nectar source for many insects in spring and summer). Scarce plant species which occur in the best examples on Dartmoor include greater butterfly orchid (*Platanthera chlorantha*), frog orchid (*Coeloglossum viride*), moonwort (*Botrychium lunaria*) and adder's tongue fern (*Ophioglossum vulgatum*). Within the National Vegetation Classification (NVC) (Rodwell, 1992), the best Dartmoor hay meadows are closest to MG5 *Cynosurus cristatus-Centaurea nigra* grassland. More improved meadows, which can still be relatively species rich, are MG6 *Lolium perenne-Cynosurus cristatus* grassland.

2. METHODS

2.1 This section describes site selection and the methods used to collect and analyse data. The methods used largely follow those set out in ADAS (1995, 1998) where appropriate, although amplified considerably by the inclusion of the 2003 botanical survey data and of soils data for both years.

Sites

2.2 A total of 20 sites were selected at random for monitoring from the 40 individual fields under Tier 2A agreement in 1995. However, agreement status checks prior to the resurvey in 2003 indicated that botanical assessments had been carried out in the wrong field at one site (Site 75) which was actually being managed under Tier 1C (Low Input Permanent Grassland) throughout. This site was resurveyed, but the results were not included in the statistical analyses described later. Two further sites from the original sample had been downgraded from Tier 2A to Tier 1C and Tier 1B (Improved Permanent Grassland) between the two surveys (Sites 66 and 73 respectively). Site 66 was included in the re-survey, but Site 73 could not be re-surveyed in 2003 as it had already been mown when visited on 1 July and any botanical data recorded would have been unreliable. In addition to Site 66, three other sites were being grazed at the time of the 2003 survey (i.e. Sites 61, 74 and 76), in contravention of the ESA Tier 2A prescriptions. Since this raised doubts as to the preceding management of these sites, they were grouped with Site 66 in some of the analyses described below to test for differences compared to the remaining sites.

Botanical surveys

2.2 Sites were surveyed between 5 June and 5 July 1995 and between 25 June and 11 July in 2003. This time period was set to ensure the majority of species were likely to be reliably recorded before the earliest cutting date of 15 July allowed under Tier 2A.

2.3 Botanical data were collected using a field method developed by ADAS for specific use in ESA monitoring (Critchley, 1997; Critchley & Poulton, 1998). Within each field, a plot was objectively located by selecting a random distance along the diagonal between the most southerly and northerly field corners on the O.S. map. The plot was placed at least 15 m from the nearest corner to exclude the field edge zone. The four corners of the plot were marked (with galvanised metal pipes driven into the ground) for subsequent relocation with a metal detector.

2.4 Data were recorded within each of the 8 m × 4 m plots (Figure 1). These were divided into thirty-two 1 m × 1 m units (or ‘nests’). In 1995 species and vegetation height were recorded using nested quadrats in each of these nests. In 2003, alternate nests were selected for re-survey, giving 16 per plot, this number being based upon recommendations resulting from Defra method development projects (Burke & Critchley, 1999; Critchley *et al.,* 2002b). All analyses of botanical data reported here are based upon data from these 16 nests per plot, both for 1995 and for 2003 data, with the exception of the initial NVC classification of plots carried out in 1995 (see below).

2.5 At each assessment, vegetation height was recorded using a ‘falling disc’ at the centre of each nest. Vascular plant species were recorded from each of the nests in turn. The species with first pin hit on above-ground parts recorded a score of 1. Cell 2 was then searched for all other species rooted in it, which were recorded with a score of 2. This procedure was then repeated for all subsequent cells, recording new species (with the cell number) as they were encountered, up to the full nest size.

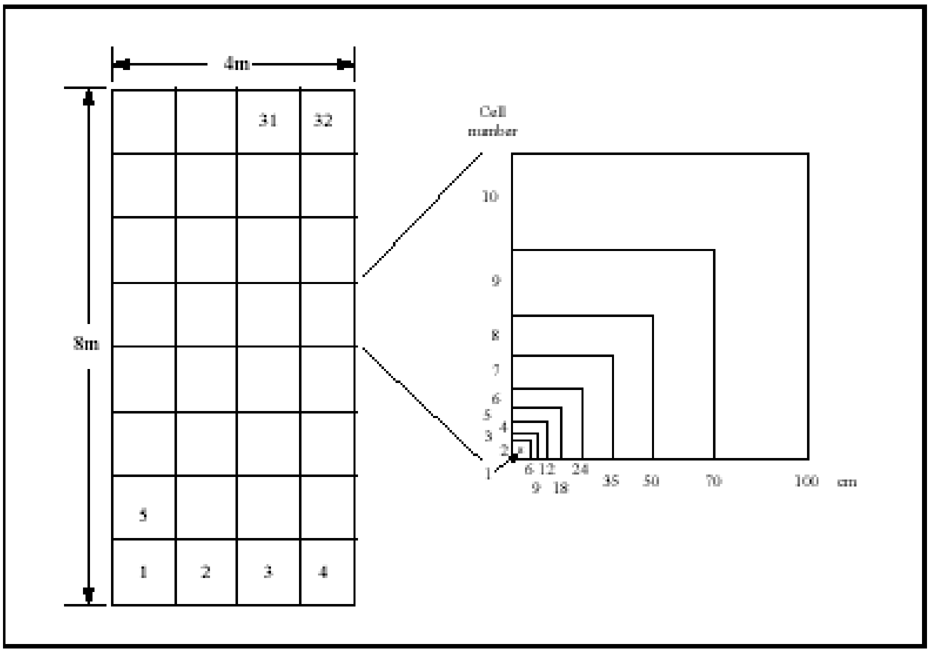

Figure 1. Plot design showing the layout of nests and the size and numbering of cells. Note that only 16 nests were resurveyed in 2003 in a ‘checkerboard pattern’ starting from nest 2.

2.6 This procedure allowed the ‘optimum scale’ (Critchley & Poulton, 1998) to be identified for each species present in 1995. The method is particularly precise with respect to changes between assessments. The optimum scale is defined as the scale (cell) for which the cumulative frequency for the plot is closest to 50%, i.e. 8 (the maximum cumulative frequency for a particular scale was 16, i.e. where the species is recorded at or below that scale in *all* the nests within a plot).

2.7 Plants were identified to species level where practicable. If plants could not be identified consistently in the field at this level, they were recorded to genus or as amalgams of species. Mosses and liverworts were recorded collectively, with no separation of species. For simplicity, the term ‘species’ has been used subsequently in this chapter to refer to individual species and amalgams.

NVC classification

2.8 In 1995, plots were assigned to the closest NVC communities and sub-communities (Rodwell, 1992), using data from all 32 nests per plot. Communities were assigned on the basis of between-nest frequencies of species, using the MATCH (Malloch, 1992) and TABLEFIT (Hill, 1996) computer programmes and by reference to keys, tables and descriptive text from the NVC, along with descriptive field notes and photographs. Most plots that were located across community boundaries or included mosaics were allocated to the dominant community or sub-community, although three of the plots that showed no clearly dominant community were classed as transitional (two MG5a/MG6b and the other MG6b/MG7e). The numbers of sites within each NVC class are given in Table 1.

2.9 The original classification of the plots was retained as a site grouping factor in the analyses of data for both years. In addition, coefficients of similarity to the MG5a (*Lathyrus pratensis*) NVC sub-community were calculated for all plots in 1995 and 2003, using the weighted Czekanowski Index option in the computer programme SIMIL (Dring, 1996). For both years, these calculations were based upon data from the sub-sample of 16 nests in each plot selected in 2003. The MG5a sub-community was chosen as the 'target' community since this most closely resembled the vegetation on the better quality sites in the initial survey.

Table 1. Closest NVC communities and sub-communities of hay meadow plots in 1995 (*n*=20).

Community or sub-community	**Number of plots**
MG5a *Cynosurus cristatus-Centaurea nigra* grassland (*Lathyrus pratensis* sub-community)	12‡
Transition between MG5a and MG6b	2
MG6a *Lolium perenne-Cynosurus cristatus* grassland (typical sub-community)	1
MG6b *Lolium perenne-Cynosurus cristatus* grassland (*Anthoxanthum odoratum* sub-community)	4†
Transition between MG6b and MG7e *Lolium perenne* leys (*Plantago lanceolata*)	1

† Includes Site 73, not surveyed in 2003
‡ Includes Site 75 (Tier 1C), not included in data analyses

2.10 The NVC tables used for calculating similarity coefficients do not contain species amalgams. So, for the SIMIL analyses, values for species recorded as amalgams were attributed to the most likely of the two components of the amalgam, or to the one most common in the target community, in order to maintain consistency between years. Thus, the *Festuca rubra/ovina* values were attributed to *F. rubra*, *Agrostis capillaris/stolonifera* to *A. capillaris* and *Poa subcaerulea/pratensis* to *P. pratensis*. *Lotus* species were recorded only as an amalgam (*L. corniculatus/pedunculatus*) in 1995, but as separate species in 2003. Values for the *Lotus* amalgam recorded in 1995 were attributed to whichever species was recorded on a particular plot in 2003. In most cases this was *L. corniculatus*, although *L. pedunculatus* was recorded on plots 63, 64 and 75. In most cases *Bromus* spp. were recorded solely as *Bromus* sp., for which there is no NVC code (there were 10 records in total in 1995 and 5 in 2003). These records were deleted from the data for the SIMIL analyses, except for one plot where *Bromus* was identified as *B. hordeaceus* in 1995; in this case (plot 62), the 2003 *Bromus* sp. values were also attributed to *B. hordeaceus*. In all the foregoing cases, a judgement was made that the loss of accuracy incurred by deleting all records for amalgamated species would be greater than any loss incurred by wrongly attributing data to particular species. All records attributed to ‘Bryophytes’, ‘Fungi’ and ‘Tree seedlings’ were not included in the data analysis, however.

Community variables and species-richness

2.11 Composite community variables were calculated based upon the ecological characteristics of the species present in each plot. Three approaches were used, the first based upon British Ellenberg indicator values. These values were originally developed by Ellenberg (1988) for individual species, on the basis of their association with particular environmental conditions, and were recently modified for British conditions by Hill *et al.* (1999). The values used were the N, F and R indicators for soil nitrogen, soil moisture and reaction (pH) respectively. These indicators have a 9-point scale, except for F, which is on an 11-point scale and composite scores for each indicator value on each plot were calculated on the basis of the mean score for all the species present. The second approach was based upon ‘suited species’ scores. These are derived by reference to a comprehensive database of individual plant species, developed by ADAS and based upon data from a range of published ecological sources (see Critchley *et al*., 1996). The Nu and G scores for a vegetation sample measure the proportion of species suited to soils of high or low nutrient availability (Nu scores) and suited or unsuited to grazed conditions (G scores), and are calculated from scores attributable to each of the individual species present. For each species, Nu scores can be -1.0 (suited to low fertility), 0 (showing no preference), or +1.0 (suited to high fertility) with G scores (tolerance of grazing) following the same scale. Ellenberg values are used in the derivation of the Nu species scores, although rule sets for the latter refer to other sources too. In each case, a suited-species score was derived for each nest in the plot, based on the number of species that were present at or below their optimum scale (Critchley & Poulton, 1998, see Methods section) that are suited (to high nutrient availability or grazing respectively) relative to the number unsuited.

2.12 The third set of composite community variables derived were scores for C- (competitor), S- (stress tolerator), and R- (ruderal) scores based upon Grime’s established ecological strategies (Grime, 1977; Grime et al., 1988; Thompson, 1994). Each species has a ‘radius’ score for each of the three attributes with values of between 1 and 5, and composite scores are calculated for each plot by virtue of the mean score averaged over all the species present.

2.13 A mean value for species-richness was calculated for each plot as the mean number of vascular plant species recorded per nest, i.e. the mean number per 1m^2.

Soil sampling

2.14 In 1995, twenty soil cores (0-7.5 cm) were taken at the time of the botanical survey from the area immediately adjacent to the edge of each plot. Cores were bulked prior to laboratory analysis for pH, extractable phosphorus (Olsen method), potassium and magnesium, total nitrogen, organic matter (by loss on ignition), laboratory density and hand texture. Sites were re-sampled in January-February 2004. Procedures and analyses carried out in 2003 followed those for 1995, except that at this sampling, the approximate location of each plot was found by reference to an

8-figure grid-reference and to photographs taken at the time of the 2003 botanical survey. The twenty cores were taken randomly from within an approximately 10 m diameter area around the estimated centre of the plot. A random sample of nine of the original soil samples from the 1995 sampling were re-analysed in the laboratory along with the 2004 samples to test for any overall difference between analysis runs. No systematic difference was identified for any of the soil variables, so that no adjustment was needed. The different time of year of sampling between the two surveys was not considered likely to have been a significant source of error for any of the variables measured. Of all these variables, soil pH is the one most likely to have been affected, with slightly lower values expected in general under the drier soil conditions in June compared to January-February (B. Chambers, personal communication).

Rapid condition assessment

2.15 A condition assessment was carried out at each site at the time of the 2003 survey. This used a protocol and criteria devised by English Nature to monitor the condition of lowland grassland Sites of Special Scientific Interest (SSSIs) in England (Robertson & Jefferson, 2000). Under this methodology, sites are classed as 'Favourable' or 'Unfavourable', with qualifications within each of these two basic classifications indicating whether condition has been maintained or has declined or improved since a previous assessment, or whether a site has recovered to favourable condition from a previously unfavourable condition. In the case of the sites reported here, no previous assessment had been made, so that sites could be classed only as either 'Favourable' or 'Unfavourable'. The method involves assessment of a range of specific attributes, classed as Mandatory or Discretionary attributes, and target criteria are set for each attribute. A site must meet the targets for each of the Mandatory attributes in order to be classed as 'Favourable'. Discretionary attributes provide additional information, mostly reflecting recent management of the sward (e.g. sward structure, litter cover) and can provide clues as to the causes of unfavourable condition or that might act as early warning signals.

2.16 For neutral lowland grasslands (MG5), the category appropriate for the meadows reported on here, there are six mandatory attributes:

1. Frequency of positive indicator species
2. Frequency of negative indicator species
3. Grass:herb cover ratio
4. Frequency and cover of scrub (including bracken) and tree species
5. Indicators of water-logging
6. Un-authorised reduction in extent of community (e.g. building a road across the site)

2.17 The assessments were applied to all fields in the sample irrespective of their initial NVC classification (the sample included six MG6/7 and two classed as transitions between MG6 and MG5, Table 1). Atypical areas of the field, such as gateways, were excluded from the assessment; thus the assessments were of stands of MG5 or related vegetation. No consideration was given to attribute 6 above in the assessments carried out at these sites. Attributes 1 and 2 are recorded during a 'structured walk' in a W shape across the field. Indicator species are recorded in a circular area of approximately 1m radius at each of 20 stops made at regular intervals.

Other attributes are recorded on a whole field/stand basis. More details of the above attributes and their target values are given in Appendix V, along with corresponding details of the Discretionary attributes and a summary of the results for each site.

Data analysis methods

2.18 The frequency of each individual species within each plot was calculated as the number of nests within which the species occurred at its optimum scale expressed as a proportion of the total (16). Before analysis of individual species data, each value was transformed to the arcsine of its square root to normalise data distribution. Twenty-one species were selected from those recorded in 1995 for individual analysis. These included all the constant species for MG5 and MG6 NVC communities, plus a range of other species characteristic of MG5 communities. *Ranunculus bulbosus* was included in view of its unusual abundance as noted in the Introduction.

2.19 All other variables were normally distributed and did not require transformation. For each variable, the significance of change between surveys over the sample of 18 sites as a whole was tested by paired t-tests. In addition, a repeated measures analysis of variance (ANOVA) was carried out on each variable to test for differences between original NVC groups and for the influence of NVC group on change between surveys, the latter by testing the NVC x Year interaction. Two alternative ANOVA models were applied in these analyses. In both cases, the single site classed as MG6b/MG7e was grouped with sites classed as MG6. This amalgamation gave the first ANOVA model, which was thus composed of three NVC groups: MG5a (n=11), MG5a/MG6b (n=2) and MG6/7 (n=5). In the second model, the two M5a/MG6b sites were amalgamated with the MG5a to give two groups: MG5a/MG6b (n=13) and MG6/MG7 (n=5). In most cases, the difference between the MG5a and the MG5a/MG6b groups was small and not significant, and in these cases interpretation is based upon the two-group model. Repeated measures ANOVA was also used to test for any difference between the four plots that had either changed tier between surveys (Site 66) or that were being grazed at the time of the 2003 survey (Sites 61, 74 and 76) compared to the rest. Each variable was also analysed in the form of a change variable calculated by subtraction of 2003 values from 1995 values. The significance of the change was tested by a one-way ANOVA for each of the two factors of interest (NVC grouping and ‘grazed’ v the rest).

2.20 For each variable showing a significant effect of NVC group or an interaction between NVC and Year, the significance of the difference between the relevant means was tested by calculating a least significant difference (LSD) at $P<0.05$, $P<0.01$ and $P<0.001$). Note that, where only two levels of a factor were involved (i.e. for Year or for NVC group when the two-group model was applied), the significance of the overall difference between levels corresponded to the significance of the F-test for that factor.

2.21 Correlations between all the community variables (including species-richness) were tested by creating a matrix of Pearson correlation coefficients. Correlation and regression analysis was also used to test the extent to which the magnitude of change between surveys of each variable was dependent upon the initial level of that variable. Similar analyses were carried out to test for the influence of initial soil status on either the initial values for each community variable or on the magnitude of change between 1995 and 2003 surveys. These influences were elucidated further in some cases by grouping sites according to soil status (e.g. soil K index) and using these groups as factors in a one-way ANOVA. Change in each plant community variable was also tested for correlation with change in each of the soil variables.

2.22 Principal Components Analysis (PCA) was used to illustrate and compare overall change in vegetation composition at each site, using the computer program CANOCO (ter Braak & Smilauer, 1998). The ordination was established using 1995 data, with 2003 data added as supplementary (passive) variables (i.e. the latter did not influence the ordination). A species ordination was also produced using the 1995 data alone.

3. RESULTS

3.1 In 1995, the majority of the sites (see Table 1) showed affinities to the semi-natural, species-rich meadow community, MG5a, typical of grazed hay meadows (Rodwell, 1992). As noted earlier, two plots were classified as transitional between MG5a and MG6b, a more improved, but still fairly species-rich community, whilst the most agriculturally improved site was transitional between MG6b and MG7e. The remaining sites were classed as MG6 (semi-improved) communities.

3.2 A total of 65 species or species amalgams were recorded in 1995 and 62 in 2003. Values for species-richness (number of species per 1 m^2) and data for other community variables for individual sites are given in Appendix I and summarised over the sample of sites as a whole in Table 2.

Overall changes in plant community variables 1995-2003

3.3 Statistics for all community variables in both years are shown in Table 2 and changes occurring between years are summarised in Table 3.

3.4 Species-richness increased at all but two sites (67 and 70) between surveys, resulting in a significant (P<0.01) overall increase from a mean of 18.0 species/m^2 in 1995 to 19.8 species/ m^2 in 2003. The magnitude of the range encompassed by the sample of sites was the same each year at 10.4 - 24.4 and 12.4 - 26.4 species/m^2 in 1995 and 2003 respectively (Table 2).

Table 2. Statistics for community variables. G and Nu score are calculated at optimum scale, all other variables are calculated at maximum scale (n = 18).

Variable	Year	Mean	Min	Max	Range	SE
Species-richness	1995	18.0	10.4	24.4	14.1	0.890
" "	2003	19.8	12.4	26.4	14.0	0.830
G score	1995	0.23	0.15	0.30	0.15	0.009
" "	2003	0.25	0.17	0.31	0.14	0.007
Nu score	1995	-0.03	-0.11	0.04	0.16	0.009
" "	2003	-0.05	-0.09	0.00	0.10	0.006
Ellenberg R	1995	5.92	5.77	6.06	0.29	0.020
" "	2003	5.44	5.16	5.70	0.54	0.031
Ellenberg N	1995	4.71	4.41	5.16	0.76	0.052
" "	2003	4.49	4.20	4.70	0.50	0.033
Ellenberg M	1995	5.19	4.97	5.43	0.46	0.031
" "	2003	5.23	5.03	5.38	0.35	0.022
C-radius	1995	2.64	2.44	2.94	0.51	0.036
" "	2003	2.95	2.85	3.02	0.17	0.010
S-radius	1995	2.51	2.29	2.83	0.54	0.028
" "	2003	2.57	2.39	2.74	0.35	0.024
R-radius	1995	3.11	2.86	3.28	0.42	0.028
" "	2003	2.55	2.33	2.67	0.34	0.020

Variable	Year	Mean	Min	Max	Range	SE

Table 3. Community variables, *P* values and differences between 1995 and 2003.

Variable	Probability (*P*)	Trend
Species-richness	**	1995<2003
G score	NS	
Nu score	*	1995>2003
Ellenberg R	***	1995>2003
Ellenberg N	**	1995>2003
Ellenberg M	NS	
C-radius	***	1995<2003
S-radius	NS	
R-radius	***	1995>2003

*, $P<0.05$; **, $P<0.01$; ***, $P<0.001$, NS = not significant

3.5 Nu score, Ellenberg N score and Ellenberg R (reaction) score all declined significantly between surveys ($P<0.05$, 0.01 and 0.001 respectively), suggesting an overall decline in soil fertility and pH during this period. The decline in Ellenberg R score was consistent over all plots, whereas Nu and Ellenberg N scores showed a slight increase in a small minority of plots (see Appendix II).

3.6 The competitor score (C-radius) increased significantly whilst the ruderal score (R-radius) declined (both $P<0.001$), possibly reflecting a general trend resulting from reduced grazing intensity and/or later cutting compared with management prior to ESA agreement. There was little overall change in G-score, however, although the change in G-score occurring at a site between the two surveys was negatively and significantly related to the magnitude of the initial (1995) score (r = -0.71 $P<0.01$, Figure 1a).

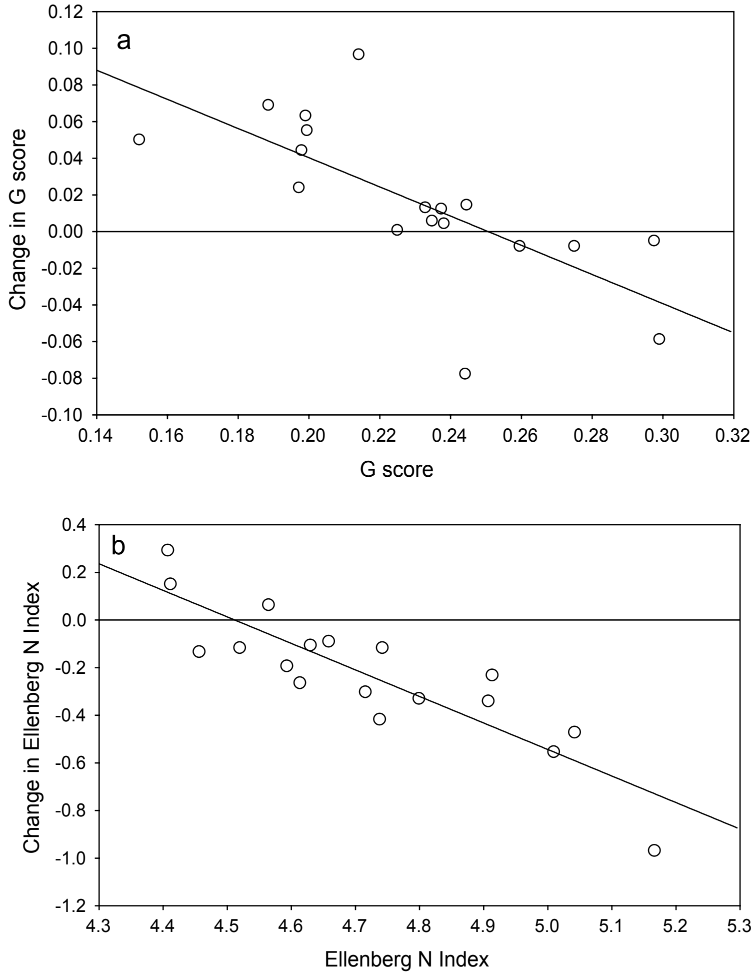

Figure 1. Relationship between change in (a) G score and (b) Ellenberg N index 1995-2003 and corresponding values in 1995. See Table 4 for *r* and *P* values.

Table 4. Correlation between change in community variables 1995-2003 and initial (1995) values.

Variable	Pearson *r*	Probability *(*P*)*
Species-richness	0.39	NS
G score	-0.71	**
Nu score	-0.77	***
Ellenberg R	0.15	NS
Ellenberg N	-0.87	***
Ellenberg M	-0.83	***
C-radius	-0.97	***
S-radius	-0.80	***
R-radius	-0.74	***

**, $P<0.01$; ***, $P<0.001$, NS = not significant

3.7 All other variables except species-richness and Ellenberg R showed this negative correlation (Table 4), with the relationship occurring whether the variable declined or increased at the majority of sites (see Figure 1, for example). These trends were highly significant and suggest a general diminishing of differences between sites, confirmed by the fact that variation across sites was lower in 2003 than in 1995 for each community variable (comparing means and standard errors in Table 2).

Botanical changes in relation to NVC community

Differences between NVC groups

3.8 There was very little overall difference in species-richness between the MG5a group and the two MG5a/MG6b sites, but when these two groups were combined the difference compared to the remaining sites was highly significant (*P*<0.001, Figure 2a). The overall effect of year was also significant (*P*<0.01) with both groups showing a similar increase, so that there was no NVC x Year interaction. By contrast, there was very little difference between plant communities in Ellenberg R (reaction) index in either year, but a highly significant (*P*<0.001) overall decline between years (Figure 2b). G scores tended to increase within both NVC groups, but the Year effect just failed to reach significance (*P*<0.057).

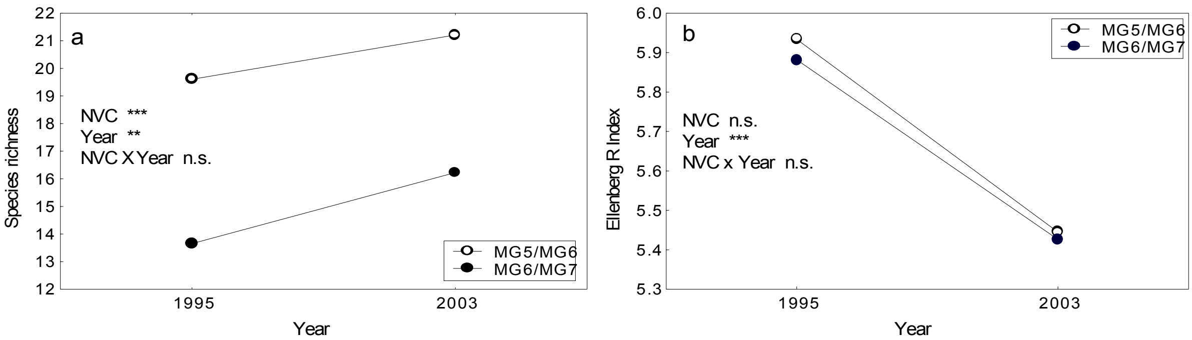

Figure 2. Changes in (a) species-richness and (b) Ellenberg Reaction index in relation to NVC community groups (see text).

3.9 There was no significant effect of NVC group on Ellenberg N index in either of the two ANOVA models, but there was a highly significant effect of Year in both (*P*<0.001) and a significant NVC x Year interaction (*P*<0.01 for the two-group model, P<0.05 for the three groups). Both models show that the decline was greatest at the more improved sites (MG6/MG7) than the less improved sites (Figure 3a,b), confirming the general diminishment of between-site differences during the period between surveys noted above. The difference between the MG5a/MG6b and MG6/MG7 groups was not significant in 1995 but N indices for both groups were very significantly greater (*P*<0.001) than at MG5a sites in this year (Figure 3a and b). The decline in Ellenberg N values was more marked at MG6/MG7 sites than others, and in 2003 values were significantly lower at these sites than at MG5a/MG6b sites (*P*<0.05).

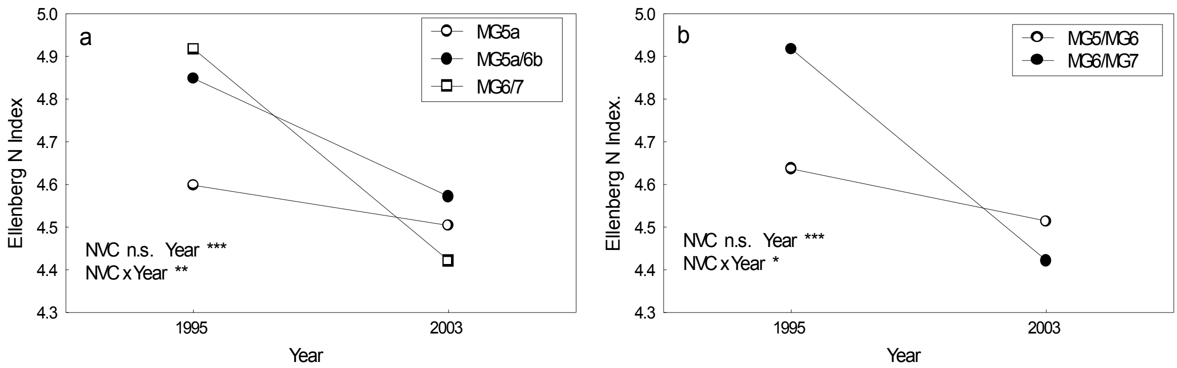

Figure 3. Changes in Ellenberg N index among the three or two initial NVC community groups (a and b respectively).

3.10 There was a tendency for Ellenberg moisture indices to increase between surveys at the more improved (MG6/MG7) sites and to decline at the more unimproved site (MG5a and MG5a/MG6b), but these effects were not significant. C-radius (competitor) scores, however, increased very significantly overall (*P*<0.001) with no difference between NVC groups (Figure 4a), whilst S-radius scores showed both a significant effect of year (*P*<0.05) and a significant NVC x Year interaction (*P*<0.05). Within the two group model, S-radius scores were significantly higher within the MG5a/MG6b group than at the more improved group of sites in 1995 (*P*<0.01, Figure 4b). Only the latter group increased significantly between surveys (*P*<0.001), so that there was no difference in S-radius score between NVC groups by 2003. The ANOVAs for R-radius score confirmed the significant (*P*<0.001) overall decline between surveys shown by the earlier paired t-tests, but revealed no difference between NVC groups, nor any NVC group x Year interaction.

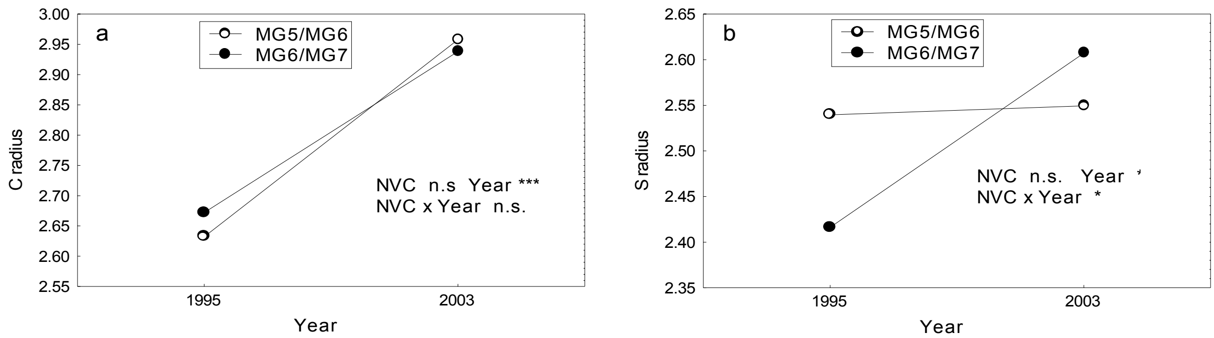

Figure 4. Change in (a) C-radius and (b) S-radius scores in relation to initial NVC community.

Changes in MG5a coefficient

3.11 Analyses of the data for change in MG5a coefficient confirmed both that a general overall shift towards this sub-community had occurred (*P*<0.01, Figure 5a) and that the shift was greater at the sites initially identified as more agriculturally improved and less species rich (MG6/MG7) than at MG5a or MG5a/MG6b sites (*P*<0.05) (Figure 5b). The change in MG5a coefficient did not differ significantly between the latter two groups.

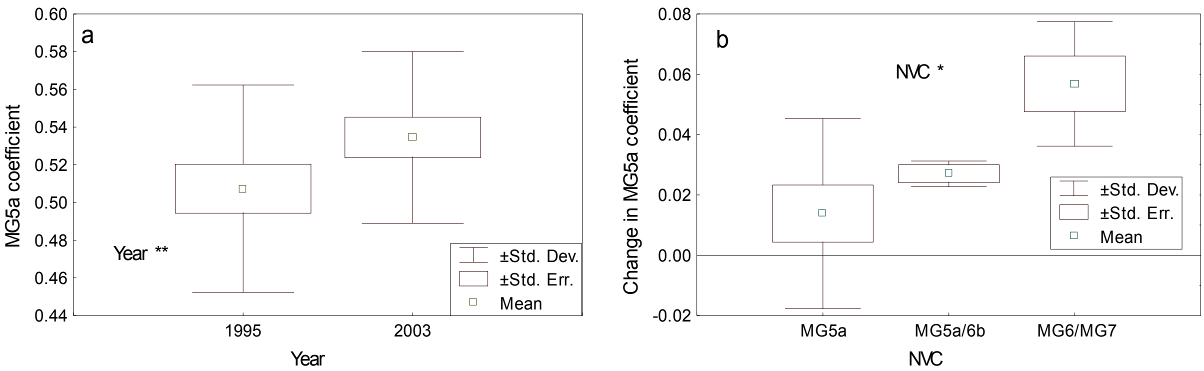

Figure 5. Change in MG5a coefficient (a) overall and (b) in relation to initial NVC community.

3.12 MG5a coefficient in 1995 (calculated by SIMIL) was positively correlated with 1995 S-radius scores (r = 0.51, P<0.05) and particularly with 1995 species-richness (r = 0.80, P<0.001). Change in MG5a coefficient 1995-2003 was positively correlated with change in species richness (r = 0.64, P<0.01) and negatively correlated with initial S-radius (r = -0.66, P<0.01).

Soil properties

3.13 1995 and 2003 soils data for each site are given in Appendix II. In 1995, soils ranged in pH from 5.3 to 6.4, average 5.8 with soil phosphorus (P), potassium (K) and magnesium (Mg) levels averaging 15.1, 120.4 and 87.2 mg/l of dry soil respectively. These levels are equivalent to ADAS soil indices of 1 for P and K (moderate availability), and 2 (satisfactory) for Mg. Soils P levels were at 10 mg/l or more (i.e. index 1 or higher) at all but three sites (70, 71 and 72). All sites were at K index 1 or more and at Mg index 2 or greater. The organic carbon content of the soils (calculated from the percentage loss on ignition) averaged 6.0% and total soil nitrogen (N) averaged 0.66%, with an average C:N ratio of 9.2.

3.14 Paired t-tests showed that extractable P and K both declined significantly overall between 1995 and 2003 (P<0.001 and P<0.05 respectively) whilst the C:N ratio increased (P<0.05) (see Appendix II). Although the increase in C:N ratio was particularly marked within the MG5a/6b group compared to others (Figure 6d), only soil K showed a significant (P<0.05) interaction between NVC group and Year (Figure 6c). The MG5a and MG6/7 groups differed significantly in soil K in 1995 (P<0.05) but there was no significant difference between the groups in 2003. The decline was greatest in the MG6/7 group and least in the MG5a group, with the difference between years significant only for the MG6/7 group (P<0.05). There was no difference between surveys in mean soil pH of MG5a sites, whereas pH declined at other sites, but only the overall difference between years across all sites was statistically significant (Figure 6a).

3.15 The high mean soil P levels within MG5a sites in 1995 was largely attributable to an exceptionally high value for Site 78 (53 mg/l – see Appendix II). Soil P levels appeared to decline markedly between surveys at this site, but in 2003, were still more than twice as high (at 29 mg/l) as at any other site.

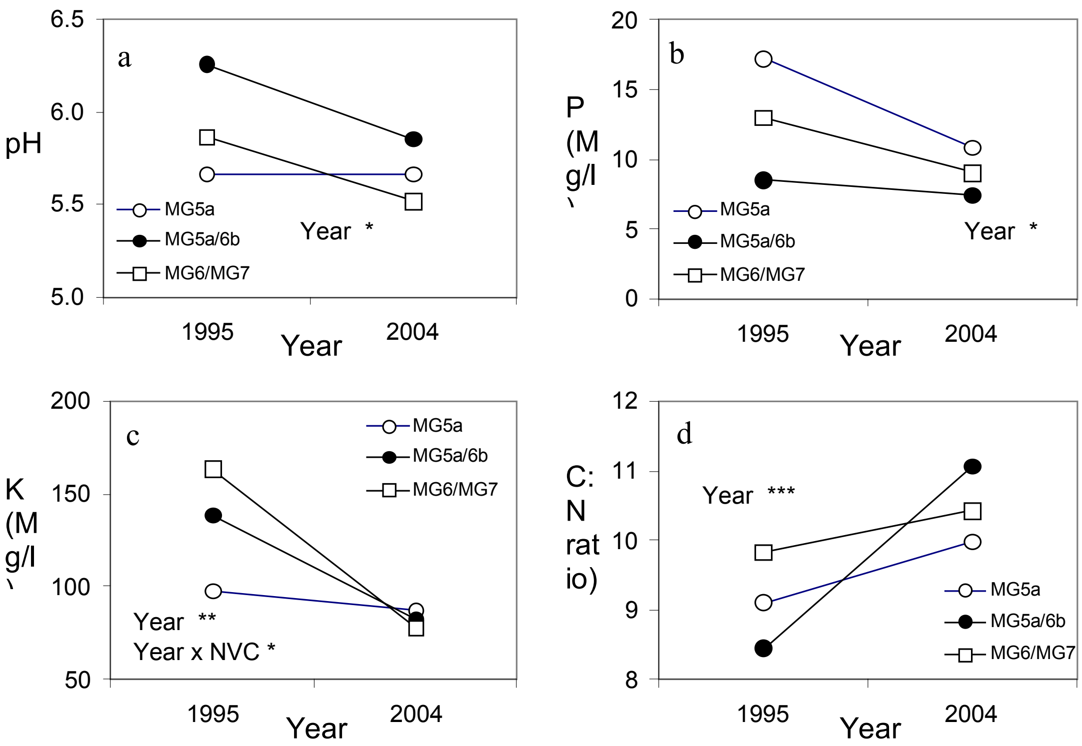

Figure 6. Change in soil properties between 1995 and 2004: (a) soil pH; (b) extractable phosphorus(P); (c) extractable potassium (K); and (d) carbon:nitrogen (C:N) ratio. Asterisks indicate the significance level of the effect or interaction in an ANOVA: *, $P<0.05$; **, $P<0.01$; ***, $P<0.001$.

Botanical change in relation to soil properties

Relationships with 1995 soil properties

3.16 Ellenberg N values in 1995 were positively correlated with soil pH ($r = 0.57$) and total N ($r = 0.48$, both $P<0.05$) and soil K ($r = 0.68$, $P<0.01$, see Figure 7a). Change in Ellenberg N scores between surveys was negatively correlated with initial soil K ($r = -0.66$, $P<0.01$, Figure 7b). Increases in Ellenberg N occurred only at sites where 1995 soil K levels were below about 90 mg/l (i.e. within the lower half of the soil K index 1 range). Nu score in 1995 was not significantly correlated with any soil variable, but change in Nu score was positively related to soil Mg levels in 1995 ($r = 0.48$, $P<0.05$).

3.17 Species-richness in 1995 was negatively correlated with C:N ratio ($r = -0.48$, $P<0.05$) and 1995 G-scores were negatively related to soil P ($r = –0.49$, $P<0.05$). No plant community variable was significantly correlated with soil pH, and whilst 1995 Ellenberg R values were positively related to 1995 soil pH as might be expected, the correlation was not significant ($r = 0.32$, NS). However, it should be noted that several of the soil variables were significantly inter-related in 1995. For example, both soil pH and soil K were positively correlated with soil organic matter content ($r = 0.48$, $P<0.05$ and $r = 0.67$, $P<0.01$ respectively) and with total N ($r = 0.61$ and 0.60 for pH and K respectively, both $P<0.01$). C:N ratio was negatively related to soil P ($r = -0.50$, $P<0.05$), which was in turn positively correlated with soil Mg ($r = 0.47$, $P<0.05$).

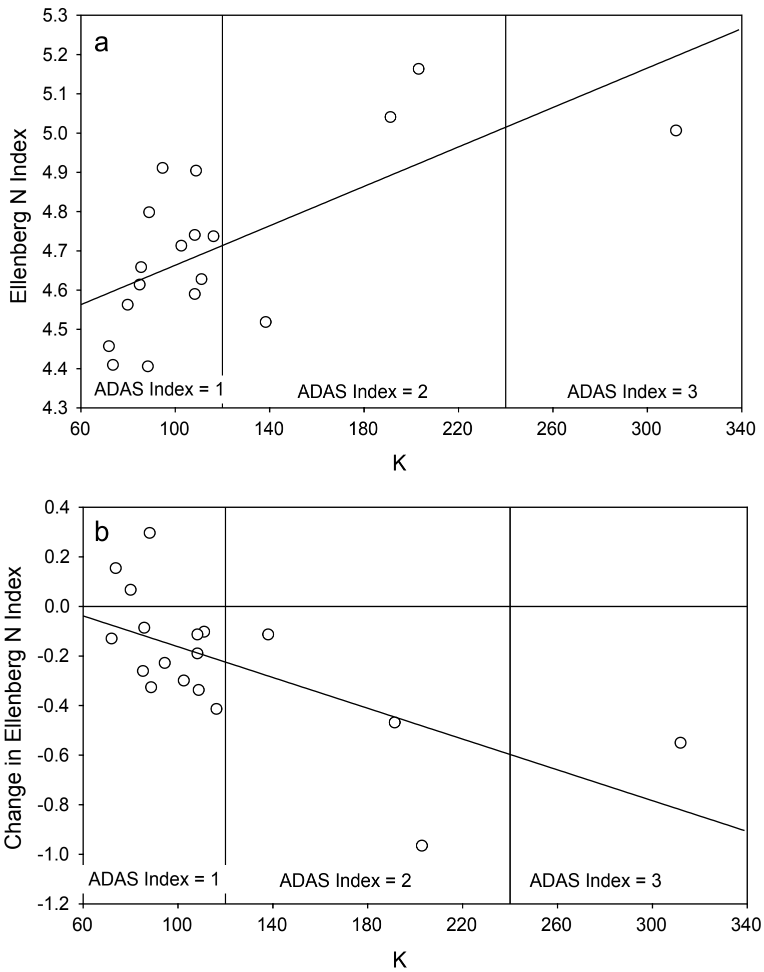

Figure 7. Ellenberg N values in 1995 (a) and change in Ellenberg N 1995-2004 (b) in relation to soil K in 1995.

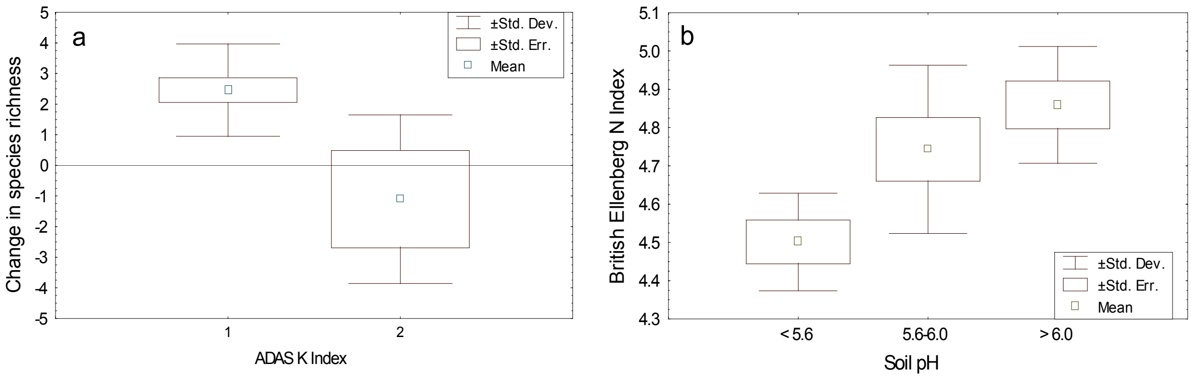

Figure 8. Relationships (a) between change in species-richness 1995-2004 and soil K index and (b) between Ellenberg N scores and soil pH category in 1995.

3.18 One-way ANOVAs on botanical variables, using soils data grouped into categories, revealed further relationships between soil and plant community variables (Figure 8). Species-richness increased between 1995 and 2004 at all sites where soil K index was below 61 mg/l K (i.e. index 1) in1995, and the increase was significantly less (P<0.01) at sites with a soil K index of 2, including two sites where species-richness declined (Figure 8a). Ellenberg N indices in 1995 were significantly lower ($P < 0.05$) where soil pH was below 5.6 compared to higher pH levels (Figure 8b).

Relationships with change in soil status 1995-2004

3.19 Of the four soil variables noted above as showing significant change between surveys, only the changes in extractable K and soil pH were correlated with changes in vegetation. The overall decline in Ellenberg N index was closely correlated with

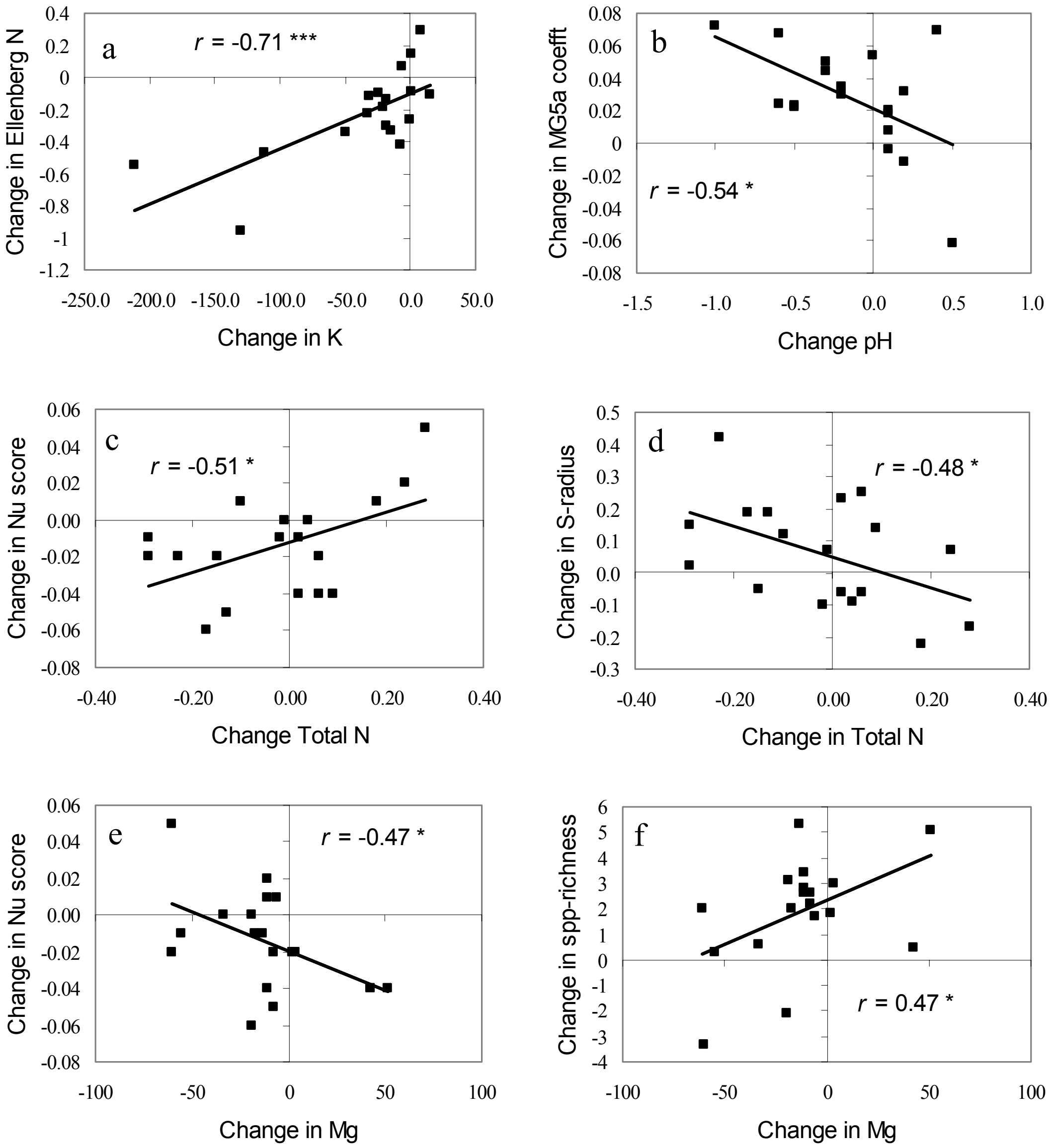

Figure 9. Relationships between change in plant community variables and change in soil properties 1995-2004: (a) Ellenberg N index and extractable K; (b) MG5a coefficient and soil pH; (c) Nu score and total soil N; (d) S-radius and total soil N; (e) Nu score and extractable Mg; and (f) species-richness and extractable Mg. Values shown are Pearson correlation coefficients (*r*), with asterisks indicating the probability of the correlation; *, $P<0.05$, ***, $P<0.001$).

declining soil K ($P<0.001$), whilst change in soil pH was correlated with changes in the MG5a coefficient ($P<0.05$) (Figure 9a,b). However, the strength of the latter relationship was heavily dependent upon the results of one site (Site 67), at which the MG5a coefficient declined markedly whilst pH increased by about 0.5. When data for this site were excluded the relationship was no longer significant. Changes in total soil N were correlated with those in Nu score (P<0.05, Figure 9c) and inversely correlated with change in S-radius (P<0.05, Figure 9d).

3.20 Extractable Mg declined between surveys at most sites and the change was inversely correlated with change in Nu score (Figure 9e) and positively correlated with change in species-richness (Figure 9f). Both relationships were fairly weak, however, though both were significant at P<0.05.

Sites and species ordination

3.21 The Principal Components Analysis (PCA) ordination for sites shows a general shift at each site from left to right on the first Axis, apparently representing a trend towards vegetation of higher conservation value (Figure 10). Species such as *Lolium perenne*, *Trifolium repens*, *Cerastium fontanum* and *Ranunculus repens* are located to the left on Axis 1, whereas *Trisetum flavescens*, *Trifolium pratense*, *Centaurea nigra*, *Euphrasia officinalis*, *Rhinanthus minor and Ranunculus acris* are located to the right. The shift in sites is particularly noticeable with the MG6/MG7 and the two MG5a/MG6b sites, with most MG5a sites in the right half of the ordination in 1995 and all these sites located in this area in 2003. Of the MG5a sites, Site 67 was exceptional in that its position on the ordination shifted substantially from right to left on Axis 1. Other changes recorded at this site in particular are discussed later in the section describing the results of the rapid condition assessment.

3.22 For the MG5a/MG6b sites and, particularly, for the MG6/MG7 sites, movement along Axis 2 was small compared to movement on Axis 1, whilst the opposite was generally true for MG5a sites. There was no consistent trend in the direction of movement along Axis 2, however, either among any of the three NVC groups or among all sites in general. Neither did the sites that were being grazed at the time of the 2003 survey show any trend that differed noticeably from other sites within the same communities. This latter finding supports the conclusion reached above that these sites did not differ significantly from the remainder in characteristics that might reflect differences in management maintained over a long period. In the case of Site 66, for example, this probably reflects the fact that the site was downgraded to Tier 1C only during the year before the 2003 re-survey.

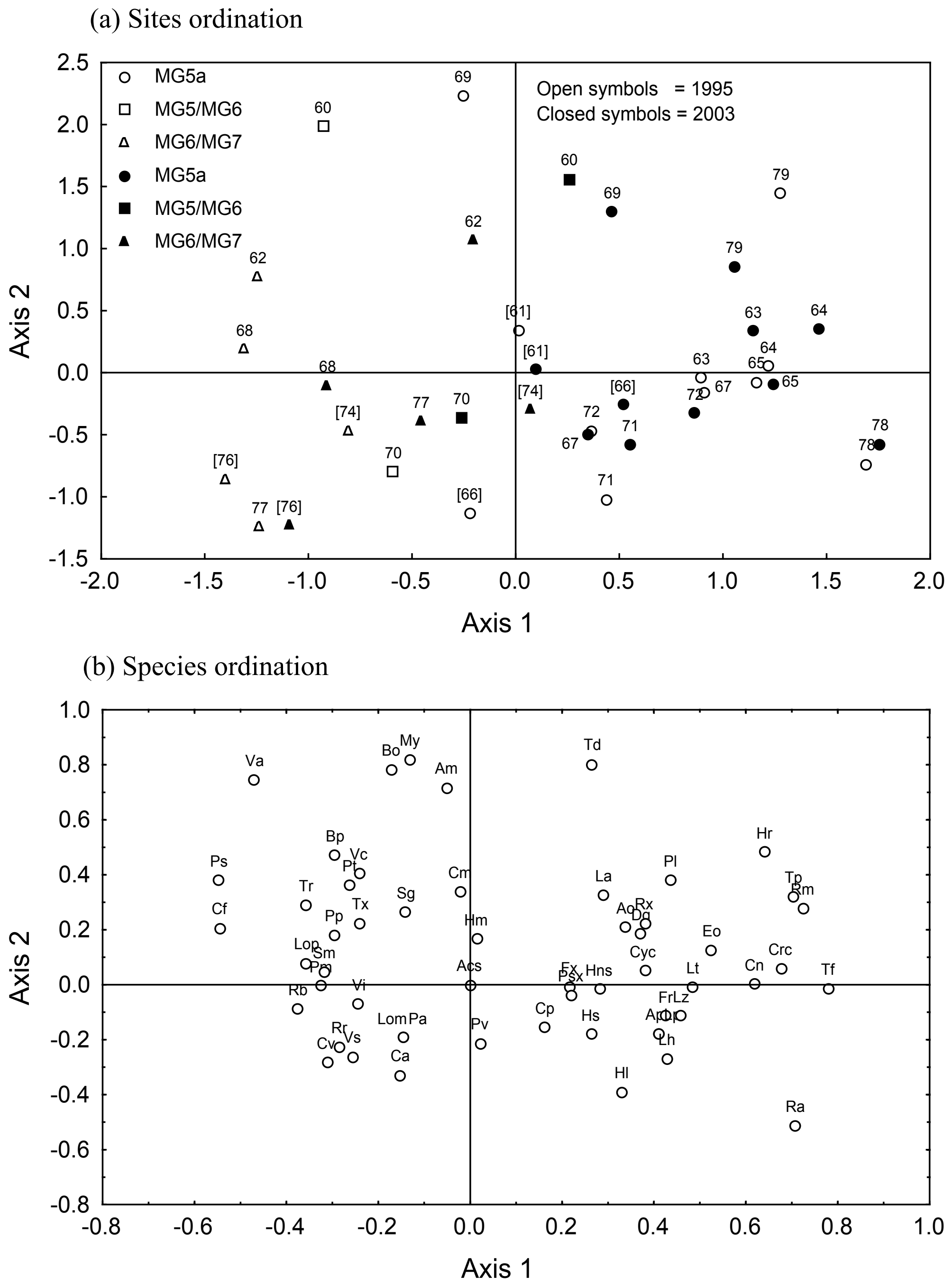

Figure 10. PCA Sites and species ordination. 2003 data are fitted as passive variables in the sites ordination (a) to show relative changes in botanical composition 1995-2003 at each site. Bracketed labels indicate sites that were being grazed in June 2003. Species labels (b) are as follows: *Achillea millefolium,* Am; *Agrostis cap/stol,* Acs; *Alopecurus pratensis,* Ap; *Anthoxanthum odoratum,* Ao; *Bellis perennis,* Bp; *Bromus sp.,* Bo; *Cardamine pratensis,* Cp; *Centaurea nigra,* Cn; *Cerastium fontanum,* Cf; *Cirsium arvense,* Ca; *Cirsium vulgare,* Cv; *Conopodium majus,* Cm; *Crepis capillaris,* Crc; *Cynosurus cristatus,* Cyc; *Dactylis glomerata,* Dg; *Euphrasia officinalis,* Eo; *Festuca ovina/rubra,* Fr; *Fraxinus excelsior,* Fx; *Heracleum spondylium,* Hs; *Holcus lanatus,* Hl; *Holcus mollis,* Hm; *Hyacinthoides non-scripta,* Hns; *Hypochaeris radicata,* Hr; *Lathyrus pratensis,* Lp; *Leontodon autumnalis,* La; *Leontodon hispidus,* Lh; *Lolium multiflorum,* Lom; *Lolium perenne,* Lop; *Lotus corniculatus/uliginosus,* Lt; *Luzula campestris/multiflora,* Lz; *Myosotis sp.,* My; *Phleum pratense,* Pp; *Pimpinella saxifraga,* Psx; *Plantago lanceolata,* Pl; *Plantago major,* Pm; *Poa annua,* Pa; *Poa sp.,* Ps; *Poa trivialis,* Pt; *Prunella vulgaris,* Pv; *Ranunculus acris,* Ra; *Ranunculus bulbosus,* Rb; *Ranunculus repens,* Rr; *Rhinanthus minor,* Rm; *Rumex acetosa,* Rx; *Stellaria graminea,* Sg; *Stellaria media,* Sm; *Taraxacum officinale agg.,* Tx; *Trifolium dubium,* Td; *Trifolium pratense,* Tp; *Trifolium repens,* Tr; *Trisetum flavescens,* Tf; *Veronica arvensis,* Va; *Veronica chamaedrys,* Vc; *Veronica serpyllifolia,* Vs; *Vicia cracca,* Vi.

Individual species

3.23 Of the 21 species selected for individual analysis, none declined significantly, either overall or within a particular NVC group, and 11 species showed no significant change (Table 5). The remaining 10 species increased, either overall or in relation to NVC group, although only *Cerastium fontanum* and *Dactylis glomerata* showed a significant Year x NVC interaction (Figure 11).

Table 5. Frequency within plots of 21 selected species, including MG5 and MG6 constant species, in 1995 and 2003. Species are grouped into those that did or did not show a significant change in frequency at optimum scale between years.

Species	Number of sites		Mean number of nests/ plot		Notes on ANOVAs of frequency at optimum scale
	1995	2003	1995	2003	
Species that increased significantly					
Centaurea nigra[1]	8	10	2.4	4.5	Increase in MG5a plots
Cerastium fontanum[2]	18	18	12.2	13.8	Increase in MG5a and MG5/MG6
Cynosurus cristatus[1,2]	16	18	13.9	15.8	Overall increase
Dactylis glomerata[1]	14	14	7.8	8.6	Overall increase, especially in MG5/MG6
Festuca rubra[1,2]	13	12	6.6	8.7	Increases in MG5a and MG6/MG7. Absent from MG5/MG6
Plantago lanceolata[1]	17	17	14.1	14.2	Overall increase
Prunella vulgaris	4	7	1.3	4.4	" "
Trifolium pratense[1]	15	16	10.4	13.1	Overall increase. Low in MG6/MG7
Hypochaeris radicata	14	13	7.7	12.4	Overall increase
Rumex acetosa	19	16	14.6	15.2	" "
Species that declined significantly					
None					
Species showing no significant change					
Agrostis capillaris[1] /*stolonifera*	18	18	16.0	16.0	No discernible effect
Anthoxanthum odoratum[1]	17	17	15.1	15.1	" " "
Holcus lanatus[1,2]	18	18	15.5	15.8	" " "
Lolium perenne[2]	18	18	14.8	13.4	" " "
Lotus corniculatus1/uliginosus	6	8	1.7	2.1	" " "
Trifolium repens[1]	18	18	13.7	15.7	Apparent increase in MG5a plots, but not significant.
Conopodium majus	6	5	2.3	1.1	Lost from three sites but gained in two
Leontodon hispidus	2	3	0.7	0.9	Too infrequent to analyse
Ranunculus bulbosus	18	16	12.2	13.6	No discernible effect

Species	Number of sites		Mean number of nests/ plot		Notes on ANOVAs of frequency at optimum scale
	1995	2003	1995	2003	
Rhinanthus minor	7	6	5.7	5.6	Found only in MG5a in 1995, in all three NVC groups in 2003
Trisetum flavescens	8	5	3.2	2.5	Lost from four sites, gained by one and increased notably at one site

[1] MG5 constant
[2] MG6 constant

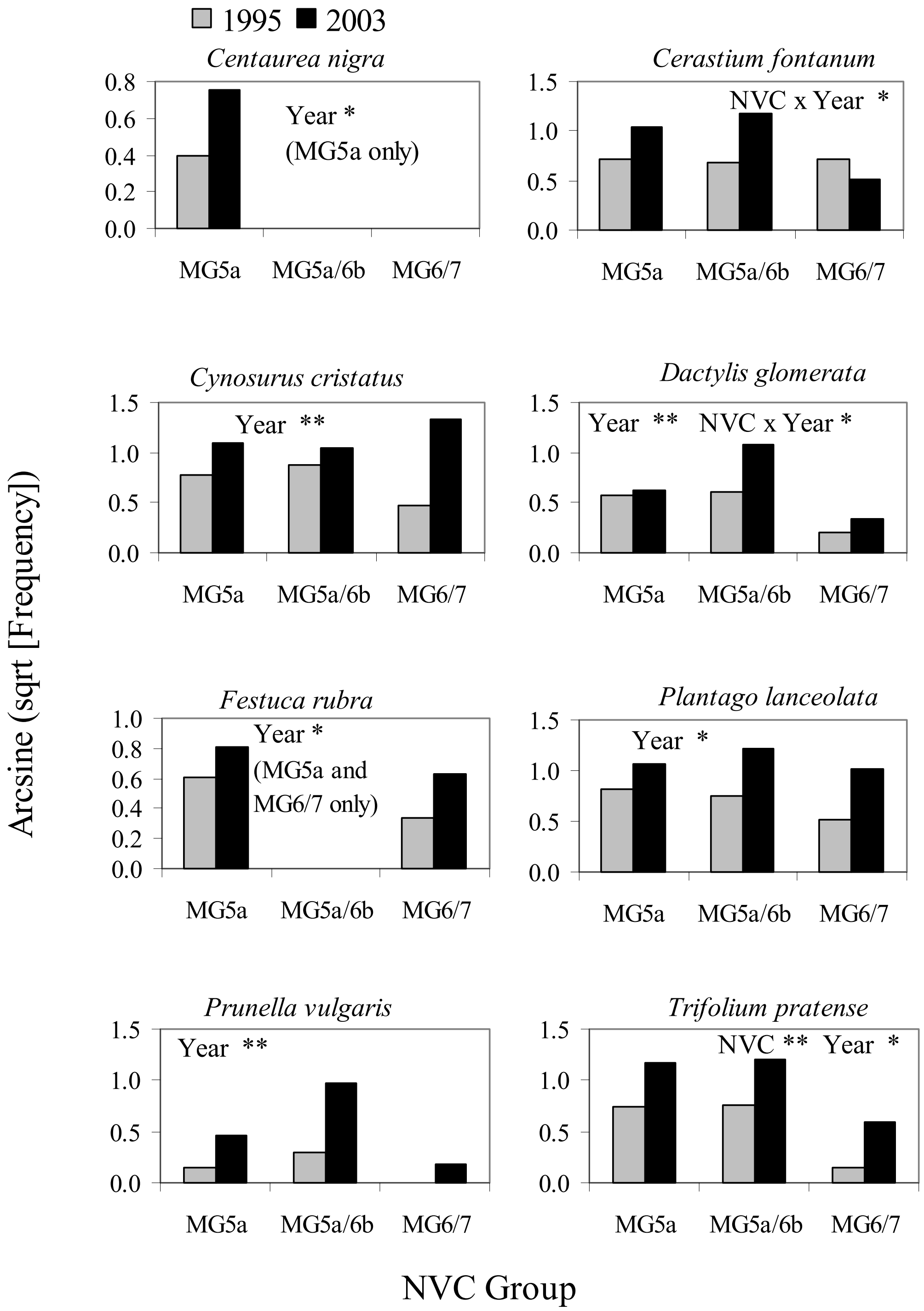

Figure 11. Frequency (arcsine [square root x F]) of species showing significant ANOVA effects of NVC and/or Year or a significant NVC x Year interaction.

3.24 Of the constant species for MG5 communities (Rodwell, 1992), several were present at all or nearly all sites and were often at or close to maximum frequency where they occurred (see Table 5). These were *Agrostis capillaris/stolonifera*, *Anthoxanthum odoratum*, *Holcus lanatus* and *Plantago lanceolata*. It was not therefore possible to identify differences between communities or changes in frequency at maximum scale among this group. However, analysing the frequency of species at their optimum scale highlighted significant effects in several of the species analysed individually (Table 5 and Figure 11). Note that, although *A. capillaris* is a constant species for MG5 communities whereas *A. stolonifera* is not, the abundance of both species differs little between MG5 and MG6 communities (Rodwell, 1992). This means that, had these species been recorded individually, it is unlikely that either would have been any more sensitive as indicators of plant community change than when recorded as an amalgam.

3.25 Of the MG5 constants, neither *Agrostis*, *Anthoxanthum odoratum*, *Holcus lanatus*, *Lotus*, nor *Trifolium repens* showed any significant ANOVA effect, although the latter appeared to have increased on MG5a plots (P=0.092 for Year effect). There was no change in *Lolium perenne* frequency, nor any difference in frequency between communities. *Cerastium fontanum* was equally abundant in all communities in 1995 but increased both in the MG5a and MG5a/6b groups, so that in 2003 this species was significantly more abundant in both these community groups that at MG6/7 sites (Figure 11).

3.26 *Centaurea nigra* was recorded only at MG5a sites in both years, where it increased significantly (P<0.05) between surveys (Figure 11). *Cynosurus cristatus, Plantago lanceolata* and *Festuca rubra* all increased overall between the two surveys, although none of these species showed any significant effect of plant community (Figure 11). Note, however, that *F. rubra* was not recorded on MG5a/6b plots in either year, so this group was excluded from the ANOVA for the species. *Prunella vulgaris* is not a constant species to either MG6 or MG5, though it is more common in the latter (particularly MG5c). It is among the species identified as having potential as an indicator of restorability in improved grassland (Robertson *et al.*, 2002). The frequency of *P. vulgaris* increased significantly between years (P<0.01), with the increase apparently greatest at MG5a/6b sites (Figure 11).

3.27 *Dactylis glomerata* frequency did not differ between communities in 1995 but increased overall between years (P<0.01). The increase was particularly marked at MG5a/6b sites where the species was significantly more frequent than at MG6/7 sites in 2003 (P<0.05, Figure 11). *Trifolium pratense* was less frequent overall at MG6/MG7 sites than at each of the other two groups of sites (P<0.01 compared to both) and increased significantly between years (P<0.05), but with no significant NVC x Year interaction (Figure 11).

3.28 In addition to the species represented in Figure 11, both *Hypochaeris radicata* and *Rumex acetosa* increased significantly between surveys (P<0.05 and P<0.01 respectively). *H. radicata* was significantly less abundant at MG6/MG7 sites overall than at others (P<0.05), but there was no discernible difference between NVC groups in the degree of change shown by either species.

3.29 Of the rarer species, greater butterfly orchid (*Platanthera chlorantha*) was found in one nest in one MG5a plot in 1995 (Site 65), but was not recorded in any plot in 2003. However, it is not known whether or not this species persisted within the plot at Site 65 because the nest in which it had occurred was not among the 16 selected for re-survey on that plot. The species was noted as occasional-frequent in the remainder of the field in 2003.

Differences between 'grazed' and 'ungrazed' plots

3.30 Vegetation was taller at most sites in 2003 compared to 1995, reflecting the somewhat later average date of assessment in 2003. However, as would be expected, at the 2003 survey, vegetation was significantly shorter ($P<0.05$) at sites that were being, or had recently been, grazed than at ungrazed sites (Figure 12). There was no difference between these two groups in 1995. No other variable showed a significant difference between the two groups, therefore providing no evidence that differences in grazing management had been maintained regularly or over an extended period.

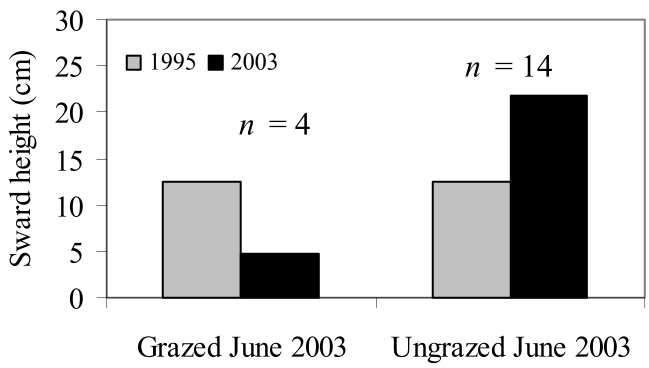

Figure 12. Vegetation height at sites that were grazed or ungrazed in June 2003.

Rapid condition assessment

3.31 None of the sites was assessed as being in 'Favourable' condition according to the English Nature Condition Assessment criteria (Robertson & Jefferson, 2000 – see also Appendices V and VI). In every case, the target for the number and frequency of positive indicators (two frequent and four occasional) was not met, and in several cases the threshold value for proportion of herbs in vegetation cover (40%) was not met, i.e. at Sites 62, 67, 68, 70 and 76 (Tables 6 & 7). Of the latter, only Site 67 had been classified as MG5a, with all the remainder either MG5a/6b, MG6 or MG6/MG7 communities (Table 6). Site 67 was also one of only three MG5a sites for which the MG5a coefficient decreased between 1995 and 2003, with the magnitude of change more than five times that shown by the other two MG5a sites. Change in other community variables at this site also indicated a decline in conservation value, including a decline in both species richness and S-radius score and a slight increase in Nu score, though not in Ellenberg N index (see Appendix II). Although both extractable soil P and extractable K declined between surveys at this site, total soil N increased, with the increase (+0.28%) greater than at any other site (Appendix III). As noted earlier, Site 67 was exceptional among MG5a sites in the response shown by the PCA ordination (Figure 10), again supporting other indications that the conservation value of this site has declined. Despite these trends, this site still contained five positive indicator species for MG5, two of which were frequent at the site (Table 7).

3.32 Site 76, the only site classified as MG6a in 1995, failed to meet targets for a further attribute in addition to the two so far mentioned, i.e. that for negative indicator species. *Cirsium arvense* was widespread at the site (recorded at 13 of the 20 stops within the field) accounting for most of the estimated 5% aggregate cover of negative indicators. This site was one of the three Tier 2A sites that were being grazed at the time of the assessment, in contravention of the prescriptions for that Tier. Nevertheless, other indicators suggested an improvement at this site, with a slight increase in MG5a coefficient (Table 6), an increase in species richness by 2 species/m^2 (albeit from a low initial value of 10.4 species/m^2), an increase in S-radius score and a fairly substantial decline in Ellenberg N index (Appendix II).

Table 6. Results of rapid condition assessment in relation to MG5a coefficient and reasons for 'Unfavourable' assessment at all sites.

Site	NVC	MG5a coefficient 1995	2003	Change	Attribute accounting for 'Unfavourable' condition
60	MG5a/6b	0.494	0.518	0.024	Frequency of positive indicator species[1].
61	MG5a	0.556	0.544	-0.012	Frequency of positive indicator species[1].
62	MG6b	0.457	0.524	0.067	Frequency of positive indicator species[1].
"					Grass/herb (ie non-Graminae) ratio[2]
63	MG5a	0.498	0.518	0.020	Frequency of positive indicator species[1].
64	MG5a	0.481	0.516	0.035	Frequency of positive indicator species[1].
65	MG5a	0.500	0.496	-0.004	Frequency of positive indicator species[1].
66	MG5a	0.494	0.544	0.050	Frequency of positive indicator species[1].
67	MG5a	0.576	0.514	-0.062	Frequency of positive indicator species[1].
"					Grass/herb (ie non-Graminae) ratio[2]
68	MG6b/7e	0.452	0.524	0.072	Frequency of positive indicator species[1].
"					Grass/herb (ie non-Graminae) ratio[2]
69	MG5a	0.549	0.567	0.018	Frequency of positive indicator species[1].
70	MG5a/6b	0.519	0.549	0.030	Frequency of positive indicator species[1].
"					Grass/herb (ie non-Graminae) ratio[2]
71	MG5a	0.567	0.611	0.044	Frequency of positive indicator species[1].
72	MG5a	0.580	0.603	0.023	Frequency of positive indicator species[1].
74	MG6b	0.469	0.538	0.069	Frequency of positive indicator species[1].
76	MG6a	0.413	0.435	0.022	Frequency of negative indicator species/ taxa.[3]
"					Frequency of positive indicator species[1].
"					Grass/herb (ie non-Graminae) ratio[2]
77	MG6b	0.404	0.458	0.054	Frequency of positive indicator species[1].
78	MG5a	0.563	0.571	0.008	Frequency of positive indicator species[1].
79	MG5a	0.559	0.591	0.032	Frequency of positive indicator species[1].

Attribute targets:
[1] At least two species/taxa (see Appendix V) at least frequent (>40% of stops) and four occasional (>20%) throughout the sward
[2] 40-90% herbs relative to grasses
[3] No species/taxa (see Appendix V) more than occasional throughout the sward, or singly or together more than 5% cover

3.33 The number of positive indicator species at each site ranged from nil to five, averaging about three species (Table 7). *Leontodon hispidus* and *L. saxatilis* are both classed as MG5 positive indicators (Appendix V). *Leontodon* spp. were not identified to species level at some sites, and in these cases, records of *Leontodon* sp. were included in the number of positive indicators (indicated by numbers in parentheses in

Table 7). Both species may have been present in some fields potentially leading to under-recording of indicators.

3.34 Six sites contained two or more positive indicators at least at the 'frequent' level, i.e. >41% frequency (nine stops or more out of the 20 made per field), as required by Condition Assessment criteria (Robertson & Jefferson, 2000). These were Sites 64, 67, 69, 71, 78, 79. However, none of these sites also contained enough indicator species at the 'occasional' level (21-40%, 5-8 stops) to meet the overall target for positive indicators of at least two species frequent and four species at least occasional. Site 78 was the closest to meeting these criteria, with all five of the positive indicator species present recorded at 16 stops or more. Provisional revised lower thresholds for non-statutory sites were proposed by Robertson *et al*. (2002). For the positive indicators attribute, the target is reduced to 2 frequent and 2 occassional. On this basis site 78 meets the criteria.

Table 7. Presence and frequency of MG5 positive indicator species and the proportion (%) of herbs in the vegetation at each site in 2003. The number in parentheses against each species indicates the frequency at which it was recorded at the site. *Leontodon* spp. are counted as a single positive indicator at sites where they were not identified to species level. Numbers in parentheses in the Present, Frequent and Occasional columns include *Leontodon* sp..

			Number of indicators			
Site	Community	Species (and frequency)	Present	Frequent	Occasional	% herbs
60	MG5a/MG6b	*Rhinanthus minor* (20)	1	1	0	65
61	MG5a	*Centaurea nigra* (2), *Leontodon* sp. (16)	1 (2)	1 (1)	0	55
62	MG6b	*C. nigra* (2), *Leontodon* sp. (9), *R. minor* (10)	3	1 (2)	0	35
63	MG5a	*C. nigra* (1), *Lotus corniculatus* (1), *R. minor* (10)	3	1	0	70
64	MG5a	*C. nigra* (16), *Euphrasis* sp. (16), *Leontodon hispidus/saxatilis* (4), *Lotus corniculatus* (1), *R. minor* (20)	5	3	0	75
65	MG5a	*C.nigra* (2), *Euphrasia* sp. (6), *Lathyrus pratensis* (2), *L. corniculatus* (1), *R. minor* (20) *[Platanthera chlorantha* O-F*]*	5	1	1	80
66	MG5a	*C. nigra* (1), *L. pratensis* (2), *L. corniculatus* (12)	3	1	0	65
67	MG5a	*C. nigra* (18), *L. pratensis* (1), *L. corniculatus* (11), *Pimpinella saxifraga* (1), *R. minor* (3)	5	2	0	30
68	MG6b/MG7e	*None*	0	0	0	35
69	MG5a	*C. nigra* (3), *Leontodon* sp. (10), *L. corniculatus* (3), *R. minor* (20)	3 (4)	2	0	75
70	MG5a/MG6b	*C. nigra* (2), *L. corniculatus* (1)	2	0	0	30
71	MG5a	*C. nigra* (19), *L. pratensis* (1), *L. hispidus/saxatilis* (12), *L. corniculatus* (5)	4	2	1	50
72	MG5a	*C. nigra* (15), *L. hispidus/saxatilis* (7), *Leontodon* sp. (1), *L. corniculatus* (1), *R. minor* (6)	4 (5)	1	2	40
74	MG6b	*L. corniculatus* (4)	1	0	0	50
76	MG6a	*Leontodon* sp. (1), *L. corniculatus* (1)	1 (2)	0	0	15

			Number of indicators			
Site	Community	Species (and frequency)	Present	Frequent	Occasional	% herbs
77	MG6b	*Leontodon* sp. (5)	[1]	0	[1]	60
78	MG5a	*C.nigra* (16), *Euphrasia* sp. (17), *L. pratensis* (20), *L. hispidus/saxatilis* (18), *R. minor* (16)	5	5	0	50
79	MG5a	*C. nigra* (14), *Euphrasia* sp.(20), *L. pratensis* (1), *L. corniculatus* (2), *R. minor* (5)	5	2	1	40
		Mean per site	2.8 (3.1)	1.28 (1.33)	0.28 (0.33)	51.1

4. DISCUSSION

4.1 The general picture is one of improving conservation value between 1995 and 2003 within the sample of sites as a whole, as indicated by factors such as an increase in species-richness, decline in Ellenberg N values and an increase in MG5a coefficient. These changes were most noticeable at the more agriculturally improved sites compared to those that were closest to MG5a communities in 1995, so that the overall range of conservation value encompassed by the sample had narrowed by 2003.

4.2 However, several species typical of MG5a communities, for example *Leucanthemum vulgare*, *Centaurea nigra* and *Lotus corniculatus*, were generally scarce. Despite the general improvement in conservation value and the relatively high species-richness of several of the sites, none was classed as being in 'favourable' condition according to criteria set for Sites of Special Scientific Interest (SSSIs) and only one (Site 78) matched the provisional lower criteria for non-statutory sites. In most cases this was due to a lack of a sufficient number and/or frequency of positive indicator species for MG5 grassland, although in some cases, mainly in the MG6 and MG7 communities, herb cover was also below target. Given the general improvement recorded between surveys and that Tier 2A management appears suitable, it may be appropriate for at least those sites classed as MG5 to be regarded as in 'recovering' condition.

4.3 There were other indications that the quality of meadows on Dartmoor may be moderate compared to MG5 grasslands elsewhere. Nu suited species scores in particular were quite high at –0.09 to 0 in 2003, compared to typical values of –0.6 to –0.3 for MG5 sites elsewhere, whilst S-radius scores were low at 2.4–2.7, compared to typical values of 2.9-3.1 (Critchley *et al.*, 1999). S-radius scores increased significantly between surveys only at the more agriculturally improved sites.

4.4 Nevertheless, several of the sites were comparatively species-rich. By 2003, average species-richness across all sites approached average values for MG5 sites in some of the better ESAs (Critchley et *al.*, 1999), whilst values at the richest sites (25-26 species/m^2) were equivalent to those typical of high quality MG5 meadows (Gibson, 1997). Soil P levels at two-thirds of the sites were below 15 mg/l, i.e. within the range at which maximal species-richness might be expected (Critchley *et al.*, 2002a), although there was no direct correlation between soil P and any of the variables indicating conservation value. Species-richness increased mainly at sites where initial soil K availability was low, providing a clue that soil fertility may have impeded ecological improvement at some sites. Nevertheless, at most sites soil K levels in 1995 were typical of MG5 grasslands within English ESAs as a whole (Chambers *et al.*, 1999). The subsequent declines in soil K were closely correlated with declines in Ellenberg N indices across the sample of sites, suggesting that trends in the latter may be a precursor to changes in species-richness.

4.5 The typical ranges of several of the generalised plant community criteria noted above (Nu, S-radius and species-richness) are not specific to MG5 grasslands, and are largely shared by MG3 meadows, for example (Critchley et *al.*, 1999). However, it would be wrong to dismiss the quality of the Dartmoor hay meadows simply because their properties do not conform closely to those of typical MG5 communities. They are mostly at the upper altitude limit of such meadows and are located in an area of distinctive edaphic and climatic character. It is possible that these communities on Dartmoor may be relatively impoverished examples, or possibly local variants, of this community type. This may reflect a history of grazing with hay cut only in some years. This is supported by the fact that bulbous buttercup (*Ranunculus bulbosus*), which was present at all but one site in 1995 and at all sites in 2003, is a common component of species-rich permanent pastures that are often heavily grazed (Grime *et al.*, 1988). Conversely, however, yellow rattle (*Rhinanthus minor*), which was found at more than half the sites, is typical of hay meadow management, suggesting that past management may have varied between sites.

4.6 Recent unpublished guidance on the application of rapid Condition Assessments produced by the Joint Nature Conservation Committee has recognised that there may be indicators of local distinctiveness that could be classed as primary attributes for a site. This concept is primarily intended to account for the presence of rare or scarce species, or of areas of transition between different habitat types, but it would seem to leave scope for the recognition of local variants of recognised plant communities.

4.7 However, the prescriptions under which most Dartmoor ESA hay meadows are currently managed represent significant de-intensification compared to previous management. The potential of these meadows may become apparent only after a longer period of optimal management. A worthwhile exercise would be to compare in detail the best of these sites with known high quality SSSI sites in the area. Two important components of such comparisons would be, firstly, to include soils data from the high quality sites and secondly to acquire as much historical management information as possible, both from the ESA sites and from SSSIs.

4.8 This exercise could indicate, for example, whether or not declining soil pH might have been a factor limiting the further improvement of the better sites, as has been suggested elsewhere (Tallowin, 1988). Preliminary results of current research have already provided some evidence to support this suggestion (Kirkham & Tallowin, unpublished data from Defra contract BD1415). The range of pH values shown by soils at the sites reported on here was fairly typical of those for MG5 sites in English ESAs in general (Critchley *et al.*, 2002a). Whilst there was a general decline in Ellenberg R indices and an overall decline in soil pH between the two surveys, these two trends were not significantly correlated across the sample and the decline in Ellenberg R index was much more general and more marked than that in soil pH. However, differences in the time of soil sampling between years may have masked the true extent of any decline in soil pH. As noted earlier, values would tend to be lower under the drier soil conditions in June (when samples were taken in 1995) than in January-February 2004 (when 2004 samples were taken). A two-phase scenario has been postulated to attribute apparent trends in the quality of upland hay meadows in the Pennine Dales to trends in soil pH (Dave Martin, personal communication.). With declining soil pH, species suited to more acidic conditions may establish or spread whilst the more mesotrophic species persist for a number of years. This would be reflected in increases in species-richness and an overall decline in the Ellenberg R score, and would also be consistent with an expected response to declining soil fertility. However, in the longer-term, a subsequent change to a less species-rich acidic community may occur as the less acid-suited species decline. The fact that the sites in this sample with the lowest soil pH values in 1995 tended to be those supporting MG5a communities may be coincidental. It may simply reflect a longer history of less intensive management at these sites, of which less frequent or no lime application was only one element.

4.9 A survey of all unimproved or species-rich enclosed dry grassland on Dartmoor was carried out during 2003 by the DNPA and will be completed in 2004. This will provide useful contextual information on the unimproved grassland resource in the ESA and complements the present detailed monitoring of a small number of Tier 2A agreement sites. An interim report for 2003 (DNPA, 2004) suggests that the majority of species-rich mesotrophic grasslands on Dartmoor correspond to the MG5c (*Danthonia decumbens*) sub-community, rather than to MG5a (typical sub-community). The NVC classification of sites in the survey was done more subjectively than in the present surveys reported here. Species abundance data were collected on a field scale and compared 'by eye' to contingency tables in Rodwell (1992). Nevertheless, *Danthonia decumbens* itself was not recorded at any of the ESA sites reported here. The *Danthonia decumbens* sub-community is recognised as being more calcifugous than MG5a (Rodwell, 1992), and on Dartmoor (as elsewhere) this community reportedly occurs more often at higher altitudes and closer to the moorland fringe than those identified as MG5a in the DNPA report. That report suggests that a specific variant of MG5c, possibly definable as a 'southern' upland hay meadow community, may be worthy of recognition. If this is so, then relatively low soil pH and poor soil fertility in general compared to other MG5 sub-communities may well be distinctive features. The comparative studies suggested above would be a valuable contribution to placing both this 'southern upland' community and the sites reported here within a better defined context.

4.10 The 2003 DNPA survey located 494 ha of largely unimproved grassland of which 262 ha was MG5. In addition, about 150 fields were targeted for survey in 2004 to complete the survey. The unimproved grassland sites were graded A (SSSI quality) to D (relatively species-poor MG5/6 or U4/MG6 intermediates). Of the total resource, 22 ha (13 sites) were classed as Grade A, 133 ha (72 sites) Grade B, 181 ha (94 sites) Grade C and 153 ha (80 sites) Grade D. Of the 262 sites, 132 (50%) were under ESA agreement (and eight under DNPA agreement), of which 6 were Grade A (5%), 29 Grade B (22%), 60 Grade C (46%) and 37 Grade D (28%). There were 49 sites under Tier 2A agreement (probably under half of the total under the tier, see below), of which most were in the lower classes (two Grade A, 10 Grade B, 21 Grade C and 16 Grade D) confirming that much of the grassland in the tier is unimproved/semi-improved.

4.11 Of the sites included in the present resurvey, ten were included as unimproved grassland sites in the DNPA survey; all as Grade C or D (five as D, three as C, and one as C/D) except for one (Site 78) which was classed as C/B (Appendix VII). The majority (six, including one classed as MG5c/MG1) were classed as MG5c (c.f. MG5a in the present surveys, Table 1 and Appendix VII; see also comments above), with the remaining four MG6. This is consistent with most of the fields in the present sample being regarded as relatively species-poor or semi-improved examples, even by Dartmoor standards. It is interesting that Site 78 came out as the highest graded in the DNPA survey as it was the closest to favourable condition in the present survey, though it only had the second highest species-richness/plot (Appendix II) and third highest MG5a coefficient (Table 6).

4.12 Up to 1997, 137 ha were under agreement in Tier 2A (ADAS, 1998). This had subsequently risen to 160 ha by 2002 (Defra RDS, unpublished). Although accurate information is not currently available on the number of fields under agreement, it is thought to be between 130 and 250. This suggests that the Dartmoor BAP target 'to establish hay meadow management on 100 ha of meadows identified as having potential for enhancement, by 2005, and on a further 50 ha by 2010', has already been met by the ESA scheme. The additional target to 'ensure favourable management of all existing species-rich hay meadows which have greater butterfly orchid (around 20 ha)' is less easily assessed. Of the 13 Grade A sites (covering 23 ha) identified in the 2003 DNPA survey, six were under ESA agreement and four under DNPA agreement, suggesting that the majority are under agreement. One of the sites in the present survey (Site 65) had greater butterfly orchid present in both survey years. The general enhancement in quality/condition suggests that the tier may also be contributing towards the UK BAP restoration and re-establishment targets for Lowland Meadows (UKBG, 1998).

4.13 The results from the present survey contrast with the results of a similar recent resurvey of upland hay meadow-related vegetation in the Pennine Dales ESA (Critchley *et al*., 2004). Here there was relatively little evidence of improvement of the semi-improved sample, whilst the improved sample showed a small improvement and the few samples most characteristic of MG3 showed some deterioration. Analysis of vegetation and management variables together identified some relationships, including that late cutting was beneficial, while prolonged spring grazing, reduced grazing due to foot and mouth disease and inorganic N applications were deleterious. Unlike the present Dartmoor ESA sample which was restricted to Tier 2 sites, the Pennine Dales sample included both Tier 1 and Tier 2 sites. This may at least partly explain some deleterious management-related impacts, though overall changes were similar between tiers suggesting that other factors may be involved.

4.14 The NVC classification of sites carried out in the Dartmoor survey in 1995 used both MATCH and TABLEFIT computer software, but nevertheless also involved a significant element of subjectivity (ADAS, 1998), partly because MATCH and TABLEFIT do not always agree on the closest fitting community. It was therefore considered unwise to try to repeat this process using 2003 data, not least because fewer nests were assessed per plot in 2003 than in 1995. However, calculating MG5a coefficients objectively (by SIMIL), using both years' data, was an effective means of quantifying vegetation change in relation to a feasible target community. MG5a coefficients were closely correlated with other measures of conservation value, although the actual coefficients averaged only 0.53 (i.e. 53% fit to MG5a) in 2003 and exceeded 0.60 in only two cases. This supports the view that none of the sample was typical of this community, but does not help to establish whether or not MG5a (or any other MG5 sub-community) represents the ideal target for such sites. However, it must be stressed that the data derived from the ADAS plot does not conform with sampling procedures recommended for NVC classification (Rodwell, 1992). It also seems likely that the appropriate target community will vary according to location and edaphic conditions and in some cases may not conform closely to any of the so far recognised NVC sub-communities. Thus, this creates problems resulting from the way the NVC has been closely linked as descriptor of BAP habitat communities such as hay meadows (i.e. MG5) and in quantifying their resource.

4.15 The results of the surveys reported here lead to the conclusion that management under ESA Tier 2A prescriptions has been successful in bringing about an increase in the conservation value of sites initially identified as of poorer quality. At the same time, these prescriptions have at least maintained the value of the better quality sites (with one particular exception, Site 67). It is not clear, however, to what extent there is still room for ecological improvement even at the better sites and this aspect is worthy of further investigation. Furthermore of the original sample of 19 Tier 2A sites, it is of some concern that two (Sites 66 and 73) had subsequently been downgraded to Tier 1 (C/B) and that three sites (Sites 61, 74 and 76) were being grazed at the time of the resurveys in contravention of the scheme prescriptions (Appendix I)

4.16 One of the original objectives of the scheme was 'to maintain and enhance the wildlife conservation value and landscape quality of hay meadows' (ADAS, 1995). Associated with this were performance indicators (PIs) that '200 ha of species rich haymeadows are under Tier 2A agreement' and that 'vegetation that is characteristic of species rich hay meadows increases on land under Tier 2A agreement'. The first PI has not quite been met yet (160 ha), but evidence from the present resurvey suggests that the second has been met.

5. SUMMARY

- The 18 fields monitored in both 1995 and 2003 represented a range of Dartmoor hay meadows, from fairly high quality species-rich examples through to more agriculturally improved meadows with the potential to develop more floristically diverse swards.

- Most sites increased in conservation value between surveys, with the greatest increases occurring at sites that were initially more agriculturally improved.

- These changes were mirrored by a general trend of declining soil fertility and a narrowing of the differences between sites in the availability of nutrients such as phosphorus and particularly potassium.

- Increases in conservation value were characterised by overall increases in species-richness and coefficient of similarity to the MG5a NVC sub-community, by declines in Ellenberg N Index, and by an increase in stress-tolerator (S-radius) score at the initially more agriculturally improved sites.

- All sites failed to reach a 'favourable' classification (in relation to SSSI criteria) in an English Nature Condition Assessment, though one reached the provisional lower threshold for non-statutory sites. In all cases this was due to a lack of a sufficient number and/or frequency of MG5 positive indicator species, and in some cases, herb cover was also below target. Given the general improvement recorded between surveys and that Tier 2A management appears suitable, it may be appropriate for at least those sites classed as MG5 to be regarded as in recovering condition.

- Management agreements under ESA Tier 2A prescriptions have been successful in increasing the conservation value of poorer quality sites and have at least maintained the value of the better quality sites, although it is not clear to what extent there is still room for ecological improvement even at the latter. It is of some concern that two sample sites had been downgraded to Tier 1 and that three sites were being grazed at the time of the resurveys in contravention of the scheme prescriptions (Appendix I). However, based on the sample, the original performance indicator that 'vegetation that is characteristic of species rich hay meadows increases on land under Tier 2A agreement' appears to have been met.

6. ACKNOWLEDGEMENTS

This work was funded by the Department for Environment, Food and Rural Affairs (Defra). We are grateful to Mark Darlaston (RDS) for his help as Defra technical liaison officer for the project. We also thank him and David Glaves (RDS) for assistance during the project and for comments on an earlier draft. Botanical field data were collected by James Towers, Sonia Brunton, Rosie Whichlowe and Angie Bond. We also thank Simon Poulton (BioEcoSS Ltd) who advised on use of the AEMA database, Laura Workman (RDS) for provision of uptake data and Nigel Critchley and James Towers for comments on a draft version of the report.

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APPENDIX I

Management prescriptions for the Dartmoor ESA

TIER 1

Purpose: To maintain the landscape and wildlife value of the Dartmoor ESA, particularly the areas of permanent grass and roughland.
To increase the length of traditionally managed hedges and characteristic stockproof stone walls and banks.
To conserve and protect the range of archaeological and historic features

Conditions of entry: Enter all farmland within the ESA boundary, including all arable land, ley grassland, improved permanent grassland, low input permanent grassland, unimproved pasture, enclosed rough land, moorland and woodland.

TIER 1A ALL LAND

Management prescriptions: The prescriptions set out below apply to **all farmland** and are also pertinent to moorland within the ESA boundary.

- Retain hedges, walls and banks and do not remove any part thereof.
- Maintain stockproof hedges, walls and banks in a stockproof condition using traditional materials.
- For a supplementary payment, you may agree a programme to manage stockproof hedgerows in a traditional manner, so that laying of the hedge occurs at the appropriate time in the management cycle. You must agree to manage at least 10 metres of stockproof hedges per hectare of land in your agreement
- For a supplementary payment, you may agree a programme, for a minimum of five years and a maximum of ten years, for the restoration of stone walls and banks. You may choose to restore between 0.25 and a maximum of 1.5 metres of stone walls and banks per hectare per year.
- Retain and manage existing watercourses, ditches, ponds and wetland (including margins and banks) for which you are responsible. Carry out any maintenance by mechanical means, not pesticides. Do not construct any new ponds without the Ministry's prior written approval.
- Do not remove large boulders or rock outcrops.
- Manage scrub.
- Any bracken control must be carried out in accordance with a programme agreed in advance with the Project Officer and any other consents obtained. Where bracken cannot be controlled by mechanical means and the use of a herbicide is necessary, then use only asulam.
- Dispose of sheep dip safely. Do not spread sheep dip where it may affect areas of nature conservation value.
- Do not damage, destroy or remove any feature of archaeological or historic value or interest.
- Obtain written advice on the management of known archaeological or historic features on your land. Where advice on agricultural management is provided this should be implemented within 12 months. Where more specific advice is required this should be obtained within the first 12 months of your agreement and appropriate advice implemented within two years.
- You must identify on your application any common land where you have grazing rights and your current use of those rights. Where common land that is not subject to agreement you must not increase your use (stock numbers and period of grazing) of common land except by prior written agreement with the Department.
- You must abide by the Codes of Good Agricultural Practice for the Protection of Soil, Air, and Water, published by the Department (references PB 0617, PB 0618 and PB 0585) as amended from time to time.

TIER 2A SPECIES-RICH HAY MEADOWS

Purpose: To improve the botanical and other wildlife diversity of species-rich hay meadows.

Conditions of entry: At the Ministry's discretion you may enter, all or any of your species-rich hay meadows or meadows which have the potential to develop a species-rich sward

Management prescriptions: All the Tier 1A (All Land) prescriptions apply *plus* the additional prescriptions set out below.

- Do not plough, level or reseed. Cultivate only with a chain harrow or roller except during the period 1 April to 15 July.
- Graze with cattle or sheep or both and avoid poaching, overgrazing or undergrazing. Exclude stock from hay meadows by 15 May until the end of cutting. Cut hay meadows annually for hay, but not silage. Do not cut in any year before 15 July. Cut hay meadows after 31 July at least once every five years. Remove the cut crop and graze the aftermath.
- Do not apply any organic or inorganic fertiliser except for farmyard manure (FYM). Do not exceed your existing application rates of FYM and, in any event, do not apply more than 20 tonnes of FYM per hectare in any three year period. Do not apply slurry, pig or poultry manure or sewage sludge.
- Do not apply lime, slag or any other substance designed to reduce soil acidity.
- Do not apply fungicides or insecticides.
- Do not apply herbicides except to control bracken, spear thistle, creeping or field thistle, curled dock, broadleaved dock or ragwort or to carry out stump treatment of cleared scrub. With the exception of bracken control, apply herbicides only by means of a wick applicator or by spot treatment.

APPENDIX II

Community variables in 1995 and 2003 for each plot.

	Richness		G score		Nu score		Ellenberg R		Ellenberg N		Ellenberg M		C radius		S radius		R radius	
Plot	1995	2003	1995	2003	1995	2003	1995	2003	1995	2003	1995	2003	1995	2003	1995	2003	1995	2003
60	20.6	22.4	0.28	0.27	-0.04	-0.06	5.90	5.35	4.66	4.57	5.04	5.31	2.48	2.97	2.52	2.47	3.26	2.63
61	19.8	20.4	0.30	0.24	-0.06	-0.06	5.92	5.48	4.59	4.40	5.12	5.22	2.69	2.90	2.54	2.61	3.14	2.53
62	17.8	20.0	0.24	0.24	0.01	-0.04	5.92	5.61	4.80	4.47	5.23	5.13	2.60	2.95	2.41	2.60	3.22	2.45
63	17.3	20.3	0.19	0.26	-0.04	-0.06	5.80	5.48	4.46	4.32	5.20	5.11	2.94	2.91	2.46	2.71	2.86	2.46
64	18.8	21.6	0.24	0.26	-0.05	-0.09	5.95	5.36	4.41	4.56	4.97	5.26	2.45	2.99	2.56	2.50	3.28	2.61
65	17.9	19.6	0.30	0.29	-0.05	-0.04	5.94	5.37	4.41	4.70	5.03	5.38	2.45	3.02	2.61	2.39	3.26	2.67
66†	15.2	20.3	0.20	0.24	0.01	-0.03	5.81	5.16	4.74	4.32	5.43	5.21	2.80	2.94	2.50	2.64	3.06	2.62
67	19.8	16.5	0.24	0.17	-0.11	-0.06	5.96	5.43	4.52	4.40	5.07	5.16	2.68	2.95	2.83	2.66	2.87	2.49
68	13.9	16.5	0.23	0.24	-0.05	-0.04	5.91	5.33	5.01	4.46	5.22	5.24	2.70	2.96	2.45	2.57	3.05	2.61
69	23.1	23.4	0.26	0.25	-0.08	-0.09	5.84	5.44	4.63	4.53	5.04	5.23	2.44	2.95	2.54	2.56	3.11	2.58
70	19.7	17.6	0.20	0.25	0.04	-0.02	6.03	5.46	5.04	4.57	5.32	5.33	2.74	2.95	2.29	2.48	3.17	2.58
71	17.1	22.4	0.20	0.22	-0.03	-0.04	6.05	5.63	4.91	4.69	5.26	5.22	2.83	3.01	2.59	2.49	2.99	2.48
72	19.8	20.3	0.24	0.25	-0.03	-0.07	5.95	5.45	4.74	4.63	5.25	5.36	2.71	2.97	2.48	2.42	3.15	2.60
74	15.3	17.9	0.20	0.26	-0.01	-0.03	5.84	5.47	4.91	4.57	5.39	5.20	2.68	3.00	2.40	2.55	3.16	2.54
75‡	18.8	17.4	0.27	0.25	-0.09	-0.04	6.00	5.63	4.52	4.19	5.12	5.07	2.62	2.84	2.72	2.78	3.08	2.38
76	10.4	12.4	0.23	0.25	0.02	0.00	5.96	5.47	5.16	4.20	5.31	5.18	2.80	2.85	2.32	2.74	3.07	2.46
77	11.0	14.4	0.21	0.31	-0.06	-0.04	5.77	5.24	4.71	4.41	5.24	5.33	2.58	2.93	2.51	2.58	3.19	2.63
78	21.6	24.7	0.15	0.20	-0.04	-0.04	6.06	5.49	4.56	4.63	5.17	5.29	2.51	2.98	2.58	2.49	3.07	2.55
79	24.4	26.4	0.23	0.23	-0.06	-0.07	5.94	5.70	4.61	4.35	5.12	5.03	2.50	2.91	2.49	2.72	3.14	2.33
Mean	18.0	19.8	0.23	0.25	-0.04	-0.05	5.92	5.44	4.72	4.49	5.19	5.23	2.64	2.95	2.50	2.57	3.11	2.55
S.E.	0.89	0.83	0.009	0.007	0.009	0.005	0.020	0.031	0.052	0.033	0.031	0.022	0.035	0.010	0.028	0.024	0.028	0.020

† This site was downgraded from Tier 2A to Tier 1C in 2002.
‡ This site was in Tier 1C throughout. Data for this site are not included in summarised data nor in statistical analyses.

APPENDIX III

Soils data for 1995 and 2004 Means and standard errors (S.E.) calculated excluding Site 75.

Site	pH		Loss on ignition (%)		Organic C (%)		Total N (%)		C:N ratio		Extractable nutrients (Mg/l) P		K		Mg	
	1995	2004	1995	2004	1995	2004	1995	2004	1995	2004	1995	2004	1995	2004	1995	2004
60	6.4	5.8	14.8	14.6	6.4	6.3	0.76	0.61	8.4	10.3	8.2	7.0	86	86	57	59
61	5.7	5.9	14.3	13.9	6.2	6.0	0.59	0.58	10.4	10.3	9.9	7.0	108	87	98	65
62	6.1	5.5	14.5	11.7	6.2	5.0	0.59	0.46	10.6	10.8	12.6	9.0	89	74	57	49
63	5.3	5.4	11.8	12.0	5.0	5.1	0.44	0.50	11.4	10.2	16.5	8.0	72	53	53	56
64	5.5	5.3	10.5	11.8	4.4	5.0	0.44	0.46	10.0	10.9	16.7	8.0	74	75	66	55
65	5.3	5.4	10.6	14.9	4.5	6.4	0.43	0.61	10.3	10.5	13.9	10.0	88	96	74	68
66	5.8	5.5	14.5	15.3	6.2	6.6	0.61	0.70	10.2	9.4	11.8	8.0	116	109	87	138
67	5.4	5.9	17.2	24.0	7.5	10.6	0.75	1.03	10.0	10.3	17.3	11.0	138	107	128	68
68	6.4	5.4	23.4	20.8	10.3	9.1	1.00	0.90	10.3	10.1	12.0	11.0	312	100	100	89
69	5.6	5.7	19.3	16.2	8.4	7.0	0.97	0.68	8.7	10.3	13.7	8.0	111	87	123	68
70	6.1	5.9	15.0	16.1	6.5	7.0	0.76	0.59	8.5	11.8	8.9	8.0	191	79	84	65
71	6.1	5.8	15.9	15.5	6.9	6.7	0.74	0.72	9.3	9.3	9.1	8.0	95	62	72	59
72	6.2	5.7	14.7	17.9	6.3	7.8	0.79	0.85	8.0	9.2	9.3	10.0	109	124	78	120
74	5.6	6.0	15.4	9.2	6.7	3.8	0.64	0.35	10.4	10.9	11.2	6.0	109	59	75	67
75‡	5.7	5.8	11.1	11.4	4.7	4.8	0.43	0.57	10.9	8.5	9.5	10.0	79	123	72	88
76	5.7	5.2	12.9	10.8	5.5	4.5	0.64	0.41	8.6	11.1	17.3	10.0	203	73	119	58
77	5.5	5.5	10.6	15.3	4.5	6.6	0.48	0.72	9.3	9.2	12.1	9.0	103	84	81	70
78	5.8	5.9	8.4	13.7	3.5	5.9	0.56	0.60	6.2	9.8	52.9	29.0	80	74	126	107
79	5.6	5.8	9.2	15.3	3.8	6.6	0.67	0.69	5.7	9.6	18.5	12.0	85	85	92	75
Mean	5.8	5.6	14.1	14.9	6.0	6.4	0.66	0.64	9.2	10.2	15.1	9.9	120.4	84.1	87.2	74.2
S.E.	0.08	0.06	0.87	0.83	0.40	0.38	0.039	0.041	0.36	0.17	2.35	1.18	14.12	4.31	5.70	5.68

‡ This site was in Tier 1C throughout. Data for this site are not included in summarised data nor in statistical analyses.

APPENDIX IV

Frequencies of plant species and species amalgams in 1995 and 2003 (i.e. the number of sites at which each species was recorded and the mean number of nests per plot at sites at which the species was recorded in each year, maximum = 16).

	Number of sites			Frequency	
Species	1994	2003	Change	1994	2003
Agrostis capillaris/ stolonifera	18	18	0	16.0	16.0
Holcus lanatus	18	18	0	15.5	15.8
Rumex acetosa	18	18	0	14.8	15.2
Lolium perenne	18	18	0	14.8	13.4
Trifolium repens	18	18	0	13.7	15.7
Cerastium fontanum	18	18	0	12.2	13.8
Taraxacum officinale	18	17	-1	12.9	13.2
Ranunculus bulbosus	17	18	1	12.6	13.6
Anthoxanthum odoratum	17	17	0	16.0	15.9
Plantago lanceolata	17	17	0	14.9	15.0
Bryophytes	17	17	0	13.8	14.9
Leontodon autumnalis	17	15	-2	8.2	8.6
Cynosurus cristatus	16	18	2	15.7	15.8
Poa trivialis	16	18	2	13.8	12.9
Trifolium pratense	15	16	1	12.5	14.7
Dactylis glomerata	14	14	0	10.1	11.0
Ranunculus acris	13	18	5	10.8	11.7
Hypochaeris radicata	13	15	2	10.4	14.9
Festuca ovina/rubra	13	12	-1	9.1	13.0
Luzula campestris/ multiflora	12	13	1	7.4	8.8
Ranunculus repens	11	16	5	11.2	7.8
Achillea millefolium	11	13	2	8.9	8.7
Trifolium dubium	9	15	6	9.1	10.1
Bellis perennis	9	9	0	8.3	6.8
Centaurea nigra	8	10	2	5.4	8.1
Veronica chamaedrys	8	9	1	5.1	5.9
Bromus sp.	8	6	-2	7.6	9.7
Trisetum flavescens	8	5	-3	7.6	9.0
Rhinanthus minor	7	8	1	15.4	12.6
Stellaria graminea	7	8	1	4.4	5.6
Phleum pratense	7	3	-4	5.6	1.7
Lotus pedunculatus/ corniculatus	6	8	2	5.0	4.8
Poa humilis/pratensis	6	8	2	4.3	3.1
Conopodium majus	6	5	-1	7.3	4.0
Heracleum sphondylium	6	3	-3	5.3	10.0
Crepis capillaris	5	10	5	11.4	10.9
Cardamine pratensis	5	6	1	2.0	7.0
Prunella vulgaris	4	8	4	5.8	10.0
Veronica arvensis	4	0	-4	8.5	0.0
Holcus mollis	3	4	1	7.7	4.5

Veronica serpyllifolia	3	3	0	3.3	2.7
Euphrasia officinalis agg.	2	4	2	16.0	13.5
Leontodon hispidus	2	3	1	6.5	5.3
Myosotis discolor	2	3	1	5.5	1.0
Vicia cracca	2	3	1	2.0	1.3
Cirsium arvense	2	2	0	7.5	2.0
Plantago major	2	1	-1	2.0	1.0
Cirsium vulgare	2	0	-2	1.5	0.0
Lathyrus pratensis	1	2	1	16.0	8.5
Hyacinthoides non-scripta	1	2	1	1.0	1.0
Pimpinella saxifraga	1	1	0	10.0	4.0
Alopecurus pratensis	1	1	0	1.0	4.0
Fraxinus excelsior	1	0	-1	16.0	0.0
Poa annua	1	0	-1	15.0	0.0
Bromus hordeaceus	1	0	-1	7.0	0.0
Myosotis arvensis	1	0	-1	7.0	0.0
Stellaria media	1	0	-1	2.0	0.0
Lolium multiflorum	1	0	-1	1.0	0.0
Vulpia bromoides	0	4	4	0.0	6.3
Tree seedling	0	4	4	0.0	1.3
Fungus spp.	0	2	2	0.0	2.5
Myosotis sp.	0	2	2	0.0	2.0
Oenanthe pimpinelloides	0	1	1	0.0	6.0
Acer pseudoplatanus	0	1	1	0.0	1.0
Ophioglossum vulgatum	0	1	1	0.0	1.0
Pedicularis sylvatica	0	1	1	0.0	1.0
Quercus sp.	0	1	1	0.0	1.0
Veronica filiformis	0	1	1	0.0	1.0
Veronica sp.	0	1	1	0.0	1.0
Bare ground	0	2	2	0.0	1.0

APPENDIX V

Results of the Rapid Condition Assessment for each site, showing mandatory (M) and discretionary (D) attributes, their targets and whether the target was met (Yes) or not met (No) at each site.

			Site																	
Attribute	Target	Mand. / Disc.	60	61	62	63	64	65	66	67	68	69	70	71	72	74	76	77	78	79
Frequency and % cover of all scrub and tree species, considered together.	No more than 5% cover	M	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Frequency of negative indicator species/taxa (see Appendix VI)	No species/taxa more than occasional throughout the sward or singly or together more than 5% cover	M	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Frequency of positive indicator species (see Appendix VI)	At least two species/taxa frequent and four occasional throughout the sward	M	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Herb (ie non-Graminae):grass ratio	40-90% herbs	M	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Indicators of water-logging (†see below).	No species/taxa together or singly covering more than 10% of the sward	M	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sward structure: average height. Upper target refers to pastures only.	5-15 cm	M	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Attribute	Target	Mand. / Disc.	Site																	
			60	61	62	63	64	65	66	67	68	69	70	71	72	74	76	77	78	79
Sward structure: extent of bare ground (not rock) distributed through the sward, visible without disturbing the vegetation.	No more than 5%	D	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sward structure: litter in a more or less continuous layer, distributed either in patches or in one larger area.	Total extent no more than 25% of the sward	D	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

†Cover % of *Juncus* spp, *Deschampsia cespitosa*, large *Carex* spp. (leaves more than 5mm wide) e.g. *Carex acutiformis*, large grasses (leaves more than 10mm wide, stout stems) ie *Glyceria maxima*, *Phalaris arundinacea*, *Phragmites australis*.

APPENDIX VI

Positive and negative indicator species for MG5 grasslands.

Positive indicators	Negative indicators
Agrimonia eupatoria	*Anthriscus sylvestris*
Alchemilla spp.	*Cirsium arvense*
Anemone nemorosa	*Cirsium vulgare*
Care flacca/nigra/panicea	*Galium aparine*
Centaurea nigra	*Plantago major*
Euphrasia spp.	*Pteridium aquilinum*
Filipendula ulmaria	*Rumex crispus*
Filipendula vulgaris	*Rumex obtusifolius*
Galium verum	*Senecio jacobaea*
Genista tinctoria	*Urtica dioica*
Lathyrus linifolius	
Lathyrus pratensis	
Leontodon hispidus	
L. saxatilis	
Leucanthemum vulgare	
Lotus corniculatus	
Pimpinella saxifraga	
Polygala spp.	
Potentilla erecta	
Primula veris	
Rhinanthus minor	
Sanguisorba minor	
S. officinalis	
Serratula tinctoria	
Silaum silaus	
Stachys officinalis	
Succisa pratensis	
Tragopogon pratensis	

APPENDIX VII

Comparison between results for sites included both in the present survey and included as unimproved grassland in the DNPA grassland survey inventory.

Site	Present survey			DNPA survey	
	NVC	Species-richness[1,2]	MG5a coefficient[1]	NVC	Grade
60	MG5a/6b	22.4	0.518	MG5c	C/D
61	MG5a	20.4	0.544	MG6	C
68	MG6b/7e	16.5	0.524	MG6	C
69	MG5a	23.4	0.567	MG5c	C
70	MG5a/6b	17.6	0.549	MG5c	D
71	MG5a	22.4	0.611	MG5c	D
72	MG5a	20.3	0.603	MG5c	D
76	MG6a	12.4	0.435	MG6	D
77	MG6b	14.8	0.458	MG6	D
78	MG5a	24.7	0.591	MG5c/1	C/B

[1] based on 2003 data (for 16 1 m^2 nests).

[2] mean per nest.

Data from DNPA, 2004 and D.J. Glaves, RDS, unpubl.