5. Findings

5.1 Variation among grasslands

A primary aim of the 1996 studies was to extend the vegetation range covered within MG5 grasslands through increasing the geographical range. Ideally this would extend the range of samples on all important axes of variation in the vegetation. A simple test of this (Figure 2) is to compare the positions of samples on a DECORANA (DCA) ordination. Here the ordination shown was "driven" by 1996 samples alone: 1995 samples are placed passively according to predictions from the new data set (in addition to the samples described in 4.2 and 4.3 above which were always passive). In practice it made little difference to the pattern whether or not 1995 samples were allowed to contribute to the ordination results, so the inclusion of both years' data together in the main analyses was judged to be appropriate.

The essential feature is that the 1995 samples are fully contained within the range of the 1996 data. The extended geographical coverage has therefore succeeded in extending the range of samples available for analysis in the most important sense, represented by the first two axes of the ordination.

Axis 1 includes samples at Berry Mound (BMB, BMC) with low scores which were reported in English Nature survey site cards (Worcestershire data) to be MG5 but by 1995 appeared to be heavily disturbed and/or likely to be MG6. They were included in the 1996 data set to extend the baseline for recovery monitoring at these sites. The remaining data clearly have the power to identify these samples as unusual in spite of their being only passive in the analysis.

At the opposite end of Axis 1 are a series of samples from widely spread geographical locations (eg BI - Bull Ings in Yorkshire, GF - Grove Farm in south Somerset, EM - Eades Meadow in Worcestershire). Some of these localities are important in containing the grasslands furthest removed in type from the semi-improved MG6 swards and their nature is explored in detail below.

The highest scores on axis 2 are defined by latrines and ungrazed areas in Hampshire (Woodland Cottage latrines - WCL) with a lightly grazed meadow in Worcestershire (Upper Beanhall Farm (Rookery Cottage) North field - RCN). The lowest scores on axis 2 all come from pastures rather than meadows but have a wide geographical range.

The species associated with the same axes in this analysis (Figure 3) fit in well with this pattern. Low scores on Axis 1 are associated with species of disturbance or improvement (e.g. *Poa trivialis* - POATRIV, *Ranunculus repens* RANREPE, *Senecio jacobaea* SENJACO, *Lolium perenne* LOLPERR), contrasted with many strong indicators of unimproved grasslands (e.g. *Carex caryophyllea* CARECAR, *Danthonia decumbens* DANTDEC, *Genista tinctoria* GENTINC, *Briza media* BRIMEDI) which have high scores on axis 1. A full translation between species and acronyms is given in Appendix 2.

High on axis 2 are a variety of species but including tall coarse species such as *Arrhenatherum elatius* ARRELAT and *Cirsium arvense* CIRARVE. This is contrasted with short-lived and/or low growing species with the lowest scores on Axis 2 (eg *Linum catharticum* LINUCAT, *Euphrasia* spp. EUPHRAS, *Trifolium dubium* TRIFDUB, *Gaudinia fragilis* GAUDFRA).

These patterns are strongly associated with species richness. Figure 4 shows that the richest samples mostly have high scores on axis 1 and moderate scores on axis 2 in the same DCA analysis. Further, the three richest sites which are cattle grazed (either pastures or meadows) and are new findings from the 1996 data set. In view of this it is important to decide if these samples are special cases or whether they merely reflect the end of a continuum of diversity.

5.2 Nature of the richest sites

These richest sites do not form a separate cluster in the DCA ordination shown in Figures 2 to 4. Nevertheless an ordination can conceal special features which would make the sites unusual. One of the most important is the richness of the mixture of Rowell and Robertson's (1994) indicator species of unimproved grassland (which include scarce and rare species). The species are listed in Appendix 4.

Figure 5 shows that the richest sites appear to form part of a continuum on this criterion as well. The frequency distribution of the number of indicator species in each quadrat (Figure 5a) is skewed but not bimodal. Likewise (Figure 5b), indicator species and total richness are closely and simply associated: the only visible patterns being that there are fewer very rich sites than moderate sites and possibly that the poorer sites may contain a relatively high number of species even when few indicators are present.

In conclusion, there is no justification for considering the "richest sites" as a separate set: they merely express the extreme of a continuum of variation within the sample set. Accordingly, subsequent analyses and the final judgement of the effects of grazing species consider all samples together.

5.3 Causes of variation

Environmental variables

Figure 6 shows the effect of all variables significant at $p<=0.01$ on the first two axes of a DCCA ordination of all sites with both 1995 and 1996 data active. Axis 1 primarily contrasts tall swards (high scores) with heavily grazed swards which tend to be at higher altitudes. Axis 2 contrasts rural sites, often larger and with an oceanic climate, against those with a group of climatic and other variables suggesting rank or disturbed grasslands often in the north and east with a high temperature range. Aside from latrine areas (high on axis 2), the effect of grazing species is very weak.

This suggests a division of sites and species according to the quadrant labels given. Abandoned sites (much litter) and/or areas left ungrazed in latrines should lie with high scores on both axes. Still high on axis 2, but low on axis 1 will be city-edge sites with a history of overgrazing: many of those in the data set happen to be horse grazed. In the opposite quadrant tend to be rural grasslands, with meadow sites in this group tending to have moderate Axis 2 scores and pasture ones low axis 2 scores. The final quadrant, negative on both axes, contains larger sites with relatively oceanic climates.

A selection of the species involved in the same analysis is shown on Figure 7. The selection is chosen automatically by CANOCO's graphics (CANODRAW) on the basis of the strength of their contribution to the analysis combined with physical space for labelling on the graph. Abandoned and latrine areas are most strongly characterised by the robust perennials *Cirsium arvense* (CIRARVE) and *Arrhenatherum elatius* ARRELAT). As in analysis of the 1995 data, the two *Poa* species (POATRIV, POAPRAT) are also associated with these areas, perhaps surprisingly with *Pimpinella saxifraga* (PIMPSAX), which is more often associated with managed unimproved grasslands.

Likewise the 1996 analysis adds little to the list of species characteristic of heavily grazed swards, containing both disturbance species (eg *Senecio jacobaeae* SENJACO and *Ranunculus repens* RANREPE) and low-growing and/or rosette perennials also present in unimproved grasslands (eg *Hieracium pilosella* HIERPIL, *Leontodon autumnalis* LEONAUT and *Bellis perennis* BELPERR).

The group of species associated with larger sites in oceanic climates indeed contains some known to be more characteristic of wetter, leached or acid soils within the range of MG5, including *Lotus uliginosus* (LOTULIG), *Danthonia decumbens* (DANTDEC), and *Potentilla erecta* (POTEREC).

The great majority of species generally found in MG5 are however in the region with moderate to high scores on axis 1 and moderate to low scores on axis 2. Within this group, a suite of probable "hay meadow" species can be identified of which the strongest indicators are *Hordeum secalinum* (HORDSEC), *Trisetum flavescens* (TRISFLA), and *Heracleum sphondylium* (HERASPH). A variety of other species are also revealed as meadow species including one of the MG5a subcommunity preferentials (*Lathyrus pratensis*) (LATHPRA).

Lightly grazed pastures appear to be especially associated with *Danthonia decumbens*, *Stachys officinalis* (STACOFF), *Serratula tinctoria* (SERRTIN), *Ranunculus bulbosus* (RANBULB) among others.

From the scores of all species, combined with the environmental variable effects shown in Figure 6, a list of "indicator species" of different conditions has been drawn up, shown in Table 1 below and as regions of Figure 7. It should be noted that it is the occurrence of these species in groups rather than individual occurrences of species which indicate particular conditions. Five groups have been identified: latrine, heavy grazed, meadow and pasture species as discussed above, and an agglomerate of all species lying within the region furthest from the heavy grazed and latrine species but including all others even when they are not particularly diagnostic between pastures and meadows. These species were generally associated with the best quality MG5 grasslands in terms of high numbers of species per m^2, high numbers of mesotrophic indicators (Rowell & Robertson 1994) and dissimilarity of the community to MG6 types. Such sites were often lightly grazed pastures or meadows in rural areas.

Table 1. Indicator species for different treatments derived from CANOCO analysis

Heavy grazing associates			**Meadow associates**		
12	ACHIMIL	Achillea millefolium	108	AJUGREP	Ajuga reptans
60	AGRSTOL	Agrostis stolonifera	81	AVEUPUB	Avenula pubescens
57	BELPERR	Bellis perennis	11	BROMOLL	Bromus hordeaceus
133	CAMPROT	Campanula rotundifolia	80	CONOMAJ	Conopodium majus
99	HIERPIL	Hieracium pilosella	4	DACGLOM	Dactylis glomerata
62	HYPORAD	Hypochaeris radicata	114	DAUCARO	Daucus carota
69	JUNCART	Juncus articulatus	149	FESARUN	Festuca arundinacea
102	JUNCBUF	Juncus bufonius	5	FESPRAT	Festuca pratensis
40	LEONAUT	Leontodon autumnalis	76	FILIULM	Filipendula ulmaria
93	POAANNU	Poa annua	30	GALVERU	Galium verum
59	PHLEPRA	Phleum pratense	31	HERASPH	Heracleum sphondylium
54	PLANMAJ	Plantago major	50	HORDSEC	Hordeum secalinum
34	RANREPE	Ranunculus repens	32	LATHPRA	Lathyrus pratensis
48	SENJACO	Senecio jacobaea	92	OPHIVUL	Ophioglossum vulgatum
23	TARXOFF	Taraxacum seedling/sp	21	RANACRI	Ranunculus acris
25	TRIFREP	Trifolium repens	41	RHINMIN	Rhinanthus minor
113	VEROFFI	Veronica officinalis	112	SENERUC	Senecio erucifolius
			63	TRIFDUB	Trifolium dubium
			9	TRISFLA	Trisetum flavescens
			82	VICISAT	Vicia sativa nigra
Latrine associates			**Pasture associates**		
10	ARRELAT	Arrhenatherum elatius	110	CARECAR	Carex caryophyllea
35	CIRARVE	Cirsium arvense	100	CIRSPAL	Cirsium palustre
111	CONVARV	Convolvulus arvensis	87	DANTDEC	Danthonia decumbens
47	ELYREPE	Elymus repens	96	JUNCINF	Juncus inflexus
73	GERDISS	Geranium dissectum	101	LEONTAR	Leontodon taraxacoides
61	PIMPSAX	Pimpinella saxifraga	45	LINUCAT	Linum catharticum
29	POAPRAT	Poa pratensis	22	RANBULB	Ranunculus bulbosus
119	POATRIV	Poa trivialis	77	SERRTIN	Serratula tinctoria
147	SAGPROC	Sagina procumbens	78	SUCCPRA	Succisa pratensis
71	STELGRA	Stellaria graminea			
37	VERCHAM	Veronica chamaedrys			
104	VIORIVI	Viola riviniana			

Table 1 continued

Indicators of the best quality grasslands

39	AGRIMEU	Agrimonia eupatoria	118	JUNCACU	Juncus acutiflorus
150	ANGSYLV	Angelica sylvestris	128	LISTOVA	Listera ovata
81	AVEUPUB	Avenula pubescens	38	KOELMAC	Koeleria macrantha
139	AVEUPRA	Avenula pratensis	15	LEONHIS	Leontodon hispidus
146	BRASYLV	Brachypodium sylvaticum	120	OENPIMP	Oenanthe pimpinelloides
2	BRIMEDI	Briza media	121	ONONSPI	Ononis spinosa
56	BROMERE	Bromus erectus	44	PLANMED	Plantago media
110	CARECAR	Carex caryophyllea	143	POLVULG	Polygala vulgaris
142	CAREPUL	Carex pulicaris	144	POTSTER	Potentilla sterilis
145	CIRACAU	Cirsium acaule	27	PRIMVER	Primula veris
87	DANTDEC	Danthonia decumbens	122	PULIDYS	Pulicaria dysenterica
114	DAUCARO	Daucus carota	22	RANBULB	Ranunculus bulbosus
149	FESARUN	Festuca arundinacea	49	SANGMIN	Sanguisorba minor
76	FILIULM	Filipendula ulmaria	77	SERRTIN	Serratula tinctoria
127	GAUDFRA	Gaudinia fragilis	79	STACOFF	Stachys officinalis
74	GENTINC	Genista tinctoria	42	TRAGPRA	Tragopogon pratensis
31	HERASPH	Heracleum sphondylium	117	TRIFMED	Trifolium medium
115	HYPPERF	Hypericum perforatum	9	TRISFLA	Trisetum flavescens
			52	VIOHIRT	Viola hirta

Note: Species numbers and acronyms are as used in the analysis (see Appendix 2).

Table 1 lists all species within the demarcated regions of Figure 7 except for the agricultural weed *Bromus sterilis* which occurred once in an otherwise very rich semi-natural grassland but is not included as an indicator of such grasslands. The demarcation lines are arbitrary but encompass the areas where particular variables (Figure 6) have the greatest influence.

The central region of Figure 7 shows species which are widespread in the grasslands studied but not particularly associated with any treatment or other environmental variable, ie they do not aid in the discrimination of any categories within the grasslands studied. They include many of the commoner grasses including *Cynosurus cristatus* (CYNCRIS) and *Lolium perenne* (not plotted), the MG6 name-species. The presence of *L.perenne* in this region in particular suggests that the impoverishment of mesotrophic grassland species associated with MG5, leading to a sward more akin to MG6, is at least as important a diagnostic feature as the persistence and increase of *Lolium perenne* there.

Examination of the sample scores (Figure 8) in conjunction with the above allows further understanding of the NVC communities related to the sample set and the causal relationships between them. Heavy grazing appears to "push" species-rich grasslands towards MG6 (*Lolio-Cynosuretum*) as suspected by Rodwell (1992). As even more mesotrophic indicator species are lost, the direction of change suggests MG7 composition is likely to be reached.

Ungrazed areas in latrines or abandoned areas subsequently used as latrines can in some circumstances resemble *Arrhenatherum elatius* (ARRELAT) grasslands (MG1), which in the data set only includes the Woodland Cottage latrine site (WCL).

Within the main range of MG5 sites, the subcommunities lie as predicted from previous results, with the exception that one of the major preferential species of MG5a (*Lathyrus pratensis*) lies nearer the suite of "meadow" species than the passive plot for the MG5 subcommunity.

The group of species rich sites seen in DCA ordination (Figures 2-4) is repeated in the predictive DCCA plot, with these sites distributed in the bottom right quadrant of Figure 8, spread according to their management as meadows with aftermath grazing or pure pastures. These sites are well separated from the passively placed "average" NVC subcommunities, indeed one characteristic of them is that individual quadrats or even 10x10cm cells, frequently contain a mixture of species "belonging" to two or more subcommunities, often with acidophiles and calciphiles growing in close mixture. They also contain many species not in the NVC table for MG5 (either because they were absent or recorded in less than 5% of the NVC samples).

Suggested explanations of these patterns and full judgement of the effects of different management is left to the Discussion below, after further considering the effects of management on attributes of the sward and groups of indicator species.

5.4 Distribution of species attributes and categories

Attributes of the sward and species categories are presented in Figures 9 to 18 below. Each Figure contains a pair of graphics, one for pastures and one for meadows, to allow the full interactions between grazing species, intensity and meadow versus pasture management to be seen. Two types of metric are used: the number of species per square metre (total or in a category) and the total score found by averaging the sum of all species frequencies in a given category over quadrats.

The differences shown between treatments are illustrative and their interpretation is limited. They are shown as a guide to the patterns expected and not a quantitative predictive tool. This is because there is no algorithm available for factoring out the effects of other variables on a single species' abundance (eg geographical variation) known to have significant effects under CANOCO. The Figures shown are therefore derived by necessity from simple averages of the abundance in the three key management variables of grazing species, meadow/pasture and grazing intensity. Interpretation of the abundance of groups must also be considered against a background of total abundance. An average score for a group per quadrat of 25 means that only the equivalent of a single widespread species or small number of sparser species has been found.

Results from the single abandoned field with no grazing or hay cut studied are presented by convention as "horse grazing 0, pasture" because this field was adjacent to a complex of horse pastures which also provided data for the study, although its previous history is not known.

Only patterns showing substantial differences between treatments, or adding substantially to interpretation, are shown.

Species richness

The richest sites (Figure 9) are either meadows or pastures but are always grazed lightly or moderately. Either overgrazing or abandonment substantially decreases diversity, but it makes little difference whether the grazers are horses or cattle.

Indicators of unimproved conditions

Two lists of grassland indicators are now available: the list of unimproved mesotrophic grassland indicator species (Mesodinds) (see Appendix 4) and the list derived from the CANOCO analysis derived above and presented in Table 1 as associated with the best quality grasslands.

First considering the mesotrophic indicators, whether only species occurrences (Figure 10) are considered or abundances are taken into account (Figure 11), the answer remains that abandonment or overgrazing has the strongest, and deleterious, effect. Cattle may give slightly better results than horses, but the difference is small.

In contrast, an abundance of CANOCO indicators (Figure 12) only forms a significant part of the vegetation in lightly grazed cattle pastures or meadows and are relatively sparse in all other treatments.

Meadows and pastures show no large or consistent differences in either indicator group.

Indicators of "damage" - overgrazing and latrines

CANOCO's high intensity indicators (Figure 13) occur in even lightly grazed or abandoned sites at a sparse background of up to 40 total score against the maximum of 25 for a single species. In such areas, either one or two species can be common or several survive as sparse members of the sward.

In moderately or heavily grazed pastures their abundance is doubled or trebled (the figure for heavy cattle pastures is based on data from only two sites and must be treated with caution). Instead of being sparse or few in species within a diverse grassland, they now form a major component of swards whose total and/or indicator richness is relatively low. In aggregate, they should form a valuable warning of such conditions, especially as they appear to be already abundant in some moderately grazed swards which are still of reasonable quality.

Latrine patches are totally different in nature to overgrazed swards, although occurring with them. Latrines in this study were observed in two different circumstances: the first the "normal" way when horses avoid areas where their fresh dung or urine lies. The second mode was observed at Woodland Cottage, where horses had been introduced some eight years before the study into a grassland which had been abandoned for at least two years previously. Here, unlike other latrines which were more similar to MG6, the latrine areas were more akin to MG1.

All the species involved, however, are present only at a low background level (total score 10-25 or less) in all pastures and horse meadows except heavy horse pasture (Figure 14).

In cattle meadows, the background level is higher, at up to score 40. Here these species occur as components of a very rich sward. In heavily grazed horse pastures the score is more than quadrupled (the figure for heavy horse pastures in Figure 14 is averaged across pasture and latrine mosaic components), and latrine associates dominate the sward to the exclusion of most other species.

Pasture and meadow species

As expected from the weak loading of "hay" in the CANOCO analysis, the indicators derived only offer a partial discrimination between pastures and meadows (Figures 15,16). The two figures cannot be directly compared because there are different numbers of pasture and meadow associates (Table 1). Differences in abundance of pasture associates in meadows and pastures are slight except in moderately grazed cattle pastures (Figure 15). Meadow indicators are more abundant in meadows but not consistently (Figure 16). The difference between meadows and pastures lies therefore in a relatively subtle gradient in abundance, not in clear cut presence and absence of a group of species.

Life history categories

In 1995, considerable attention was paid to examining the distribution of life history and other categories of species covered in Grime *et al* (1988). In 1996 it was found that many of these patterns simply reflected those derived from indicator species and other analysis as described above. For instance, species in decline in the neighbourhood of Sheffield have much in common with those associated with species-rich vegetation and in turn with indicators of unimproved grasslands. Analysis is further limited by the incomplete coverage of Grime *et al* (1988): although 126 out of the 150 species encountered in quadrats were covered, the omissions included sparse but important indicator species such as *Oenanthe pimpinelloides* and *Serratula tinctoria.*

Nevertheless, analysis of established strategies does add information to the categories already explored above. Ruderals are sparse and scattered in all the MG5 grasslands, but Grime *et al*'s stress tolerators and competitor species show clear distinctions between management classes.

Stress tolerators (Figure 17) are generally present at a background score of up to approximately 30, but this can double in some lightly or moderately grazed pastures. The apparent interaction between grazing species and intensity in Figure 17 may however be simply a chance effect.

Competitors are sparse except in a single management type: lightly grazed cattle meadows, with the second in rank being light grazed cattle pastures (Figure 18). This concurs with the generally less uniform grazing behaviour of cattle, which perhaps allows patches to become dominated by such species when grazing is light. Latrine areas (not shown separately) also become dominated by competitor species such as *Arrhenatherum elatius* and *Cirsium arvense.*

5.5 Monitoring plots

The series of monitoring plots at Berry Mound and Penorchard Farm have been chosen to cover a range of field situations and treatments within single farms, all heavily grazed by horses until 1995, where management on some fields is being improved under the Wildlife Enhancement Scheme. Both farms are within Worcestershire.

Tables 2 (Berry Mound) and 3 (Penorchard Farm) illustrate some of the principles presented above for all data using direct comparisons within farms. Both tables show the average number of cells occupied per $1m^2$ quadrat, with averages less than 1 shown as "tr" - trace. The tables are sorted to show decreasing abundance of species in the first heavily horse grazed MG5 grassland on the left and generally show increasing abundance in disturbed, latrine and/or MG6 areas on the right. Samples labelled Bmb and Bmc (MG6) were included in the ordinations described earlier only as "passive" samples.

At Berry Mound, the baseline shown in Table 2 includes:

a. Berry Mound D. An MG5 field regarded as heavily horse grazed (Bmd) but which has not developed any latrine patches. Management of this field will remain the same in the future, to form a control for heavy horse grazed MG5 where grazing pressure is being relaxed (Berry Mound A).

b. Berry Mound A. Part of a second heavily horse grazed MG5 field (the same as Berry Mound AA) but without latrine areas (Bma). Grazing pressure has been relaxed in this whole field.

c. Berry Mound AA. Part of the same field as 2 above which has been subjected to a variety of mechanical, manure and latrine-associated disturbance (Bmaa).

d. Berry Mound B and C. A field reported as MG5 in earlier surveys but which by 1995 appeared to be MG6, confirmed by monitoring data gathered in 1996. This has a closely grazed (B) and latrine (C) phases in a mosaic (Bmb and Bmc). The grazing regime is likely to remain the same and it would form a useful area to study the dynamics of latrines in a constantly managed site.

At Penorchard Farm, the baseline contains (Table 3):

e. Penorchard B. A heavily grazed MG5 horse field without latrine patches (Poa) and therefore similar in management to 1 above. Management in this field is likewise not intended to change.

f. Penorchard C and D. An MG5 field with closely grazed (Poc) and latrine (Pod) phases. Management here is likewise likely to remain unchanged.

g. Penorchard RG and RL. A heavily horse- and rabbit grazed pasture, on the borderline between MG5 and MG6, again with close-grazed (Porg) and horse latrine (Porl) phases. Grazing pressure is intended to be relaxed here and rabbits controlled.

Between the two farms, this baseline is intended to test the rate and nature of any recovery from overgrazing against control conditions. Meanwhile, using both the baseline data and knowledge of the history of these sites, hypotheses about the nature and dynamics of latrine areas can be made. Proper testing of these would usefully include photography from above (aerial or other means).

5.6 Dynamics of latrines and disturbance

All the disturbances and latrine areas at the monitoring farms share the following characteristics when compared to heavily grazed areas, some of which, when common to all latrine areas studied, have also been identified in the CANOCO analysis.

- Lower species richness per square metre.
- Much lower abundance of *Hypochaeris radicata* and *Lotus corniculatus*.
- Higher abundance of one or more of the grasses *Poa pratensis, P.trivialis* or *Phleum pratense*.

Other patterns, such as the general abundance of *Ranunculus repens*, are shared with all close grazed areas and thus are not always distinctive within the data set from these two farms.

Of particular note is that latrines sometimes, but not always (and therefore not highlighted by CANOCO), favour *Centaurea nigra*, with exceptionally tall and conspicuous plants. This show of one of the MG5 community constants can be misleading in a superficial assessment of quality. Despite its abundance, areas are heavily damaged with regard to overall diversity and the abundance of many other species.

The history and current vegetation of Berry Mound and Penorchard suggests the following **hypotheses** to account for the sequence of damage which takes place with continuous overgrazing by horses.

a. Horses start to avoid patches where dung or urine has recently landed and concentrate on the remainder.

b. In the closely grazed patches, the species identified in the CANOCO analysis as heavy grazing associates increase, with associated loss of other species.

c. In the latrine patches, more robust species start to take over, always including a *Poa* species, with *Arrhenatherum elatius* or other coarse grasses often involved. More robust MG5 species such as *Centaurea nigra* (in this study) and possibly others may be conspicuous, but other species disappear.

d. Eventually *C.nigra* and other robust MG5 species become sparse as well.

e. Meanwhile, the latrine areas shift. Some old latrine areas become grazed again, in other cases new dung patches are avoided and more latrine vegetation appears in the formerly close grazed patches.

f. In the fertile former latrine areas which become grazed, *Lolium perenne* and other MG6/MG7 species are favoured.

g. If this continues, the whole field becomes converted to a species-poor MG6. The field with samples Bmb and Bmc may illustrate this result.

If true, the change in the field with Bmb and Bmc, since first surveyed by EN in 1992 suggests that the above process can run its course within as little as five years. Future monitoring should aid understanding of the effects of heavy grazing and latrine formation and the potential for recovery. Additional work such as mapping or aerial photographs would be required to look at the spatial dynamics of latrines. Current research underway at Cambridge University may assist in illuminating the behaviour of horses in relation to latrines (E. O'Beirne-Ranelagh pers. comm.).

Table 2. Grasslands at Berry Mound

	MG5 Heavy		Disturbed	MG6	MG6 latrine
NAME	Bmd	Bma	Bmaa	Bmb	Bmc
AGRCAPI	25	25	25	16	3
FESRUBR	25	25	25	20	4
CYNCRIS	25	25	20	1	0
LOTCORN	25	23	4	tr	tr
CENTNIG	23	23	16	3	6
ANTHODO	22	20	9	0	0
PLANLAN	22	24	9	22	9
HYPORAD	21	12	1	1	0
LEONAUT	19	17	5	4	3
TRIFREP	9	11	11	24	21
POTREPT	8	0	0	0	1
PRUVULG	7	1	tr	0	0
BELPERR	6	0	0	0	0
LOLPERR	6	5	19	24	25
RANREPE	4	1	6	24	22
TARXOFF	3	5	2	5	3
HOLCLAN	3	2	11	6	4
RANBULB	2	2	1	0	0
LEONHIS	2	0	0	0	tr
TRIFPRA	1	0	4	2	tr
DACGLOM	1	3	1	tr	0
ACHIMIL	1	1	tr	0	0
SUCCPRA	1	0	0	0	0
LUZCAMP	1	5	2	tr	0
RUMACET	0	2	3	5	4
LEONTAR	0	0	tr	0	0
CERFONT	0	0	2	2	2
AGRSTOL	0	0	0	3	0
CAREFLA	0	4	0	0	0
POAPRAT	0	1	7	0	tr

	MG5 Heavy		Disturbed	MG6	MG6 latrine
NAME	Bmd	Bma	Bmaa	Bmb	Bmc
DANTDEC	0	1	0	0	0
EQUIARV	0	1	0	0	0
CIRARVE	0	1	0	1	0
MEDILUP	0	0	0	0	0
POATRIV	0	0	5	2	20
PHLEPRA	0	0	4	3	13
TRISFLA	0	0	1	0	0
LEUCVUL	0	0	tr	0	0
POAANNU	0	0	tr	0	0
FESPRAT	0	0	0	0	tr
POLAVIC	0	0	0	0	tr
JUNCCON	0	0	0	0	1
RANACRI	0	0	0	0	2
VERSERP	0	0	0	tr	0
LATHPRA	0	0	0	1	tr
PLANMAJ	0	0	0	1	1
CAREHIR	0	0	0	3	4

Table 3. Grasslands at Penorchard Farm

	MG5 Heavy		MG5/6 + Rabbit	Latrines	
NAME	Poa	Poc	Porg	Pod	Porl
FESRUBR	25	25	25	24	25
CYNCRIS	25	25	23	15	11
ANTHODO	25	23	10	25	13
LOTCORN	24	7	0	0	6
HYPORAD	24	13	1	0	tr
AGRCAPI	22	21	25	22	25
PLANLAN	19	15	16	8	13
EUPHRAS	16	0	0	0	0
HOLCLAN	14	22	21	25	24
POTEREC	12	8	0	tr	0
TRIFREP	12	21	25	13	19
TARXOFF	10	7	8	1	4
LOLPERR	10	9	12	6	19
LEONAUT	9	5	5	0	tr
RANREPE	8	13	18	18	8
LUZCAMP	8	12	1	0	1
LEONHIS	7	1	0	0	1
CENTNIG	5	6	8	18	24
BRIMEDI	5	tr	0	0	0
CAREFLA	4	0	2	tr	0
TRIFPRA	4	2	2	tr	6
RANBULB	3	0	1	0	0
FESOVIN	3	0	0	0	0
LATHPRA	2	0	0	0	0
CERFONT	1	1	12	4	6
PRUVULG	1	10	13	2	1
DACTFUC	1	0	0	0	0
EQUIARV	tr	0	0	0	0
DANTDEC	tr	1	0	0	0
POAPRAT	tr	1	0	14	0
CONOMAJ	tr	0	0	0	0

	MG5 Heavy		MG5/6 + Rabbit	Latrines	
NAME	Poa	Poc	Porg	Pod	Porl
BELPERR	0	13	13	2	1
SENJACO	0	6	8	1	3
POAANNU	0	5	1	0	0
RUMACET	0	4	3	2	4
AGRSTOL	0	tr	5	0	0
DACGLOM	0	tr	3	0	tr
PLANMAJ	0	tr	0	0	0
CENTERY	0	tr	0	0	0
POATRIV	0	0	1	0	16
PHLEPRA	0	0	1	0	0
STELGRA	0	0	1	0	0
JUNCBUF	0	0	tr	0	0
LEONTAR	0	0	tr	0	0
SAGPROC	0	0	tr	0	0
ALOPRAT	0	0	0	0	tr
FESPRAT	0	0	0	0	1
ACHIMIL	0	0	0	1	0
RANACRI	0	0	0	2	0

6. Discussion

6.1 Geographical variation

The sample of grasslands in this study extends outside the geographical range of only a few of the species encountered. *Oenanthe pimpinelloides* is entirely restricted to southern Britain, and *Cirsium acaule* is on the extreme northern edge of its British range in Northumberland. A third species, *Gaudinia fragilis*, is of doubtful status in Britain and confined to southern England. Stace (1991) regards this species as a naturalised alien, but there is a suspicion that it may be native in MG5 grasslands around the Dorset - Somerset border where it was encountered in this study (S Leach, English Nature, *pers comm*). Not surprisingly, these species were confined to MG5 samples from the southern English counties. No species encountered was wholly confined to the sites in northern England.

These restrictions are however relatively minor. Further, there is no indication that species richness varies systematically with geographical position, except that the 6 sites averaging 30 or more species per square metre happened to be from Worcestershire and south-west Britain. This deserves further investigation.

Geographical variation instead appears to reflect a more complex interaction between climate, geographical factors and altitude which on a wider vegetation range than MG5 is a major determinant of the semi-natural grassland community type (Rodwell 1992). The chief interest here is that position on this more complex gradient may affect a site's sensitivity to changes in management (Figure 6). The main features appear to be as follows, following Figure 6 with reference to the species positions shown in Figure 7.

a. In more oceanic climates, leaching is likely to be greater, leading to acidification. This is reflected by the most acid subcommunity (MG5c) being loaded towards oceanic climate, with acidophilous and/or wetter soil species in the same quadrant on Figure 7. At moderate or low grazing pressures and/or low altitudes, this produces a species-rich MG5 community. At higher altitudes where soils may again be wetter and at higher grazing pressures the sward becomes taken over by the "high-intensity" species. Grassland area appears to have a similar effect to oceanicity but this is difficult to explain.

b. This complex effect is distinct from the simpler north-south gradient in species composition reflected in axis 2 of DCCA (Figure 6).

c. The effects of grazing intensity and distance from urban areas are directly opposed. Either this simply means that town-edge sites are more likely to be overgrazed than others, or that there may be additional disturbances associated with towns which make careful attention to correct grazing levels even more important than otherwise.

The best grasslands on any vegetation measure, including species richness and indicator species groups, are generally those which receive low-intensity management either as meadows with aftermath grazing or pastures, in rural situations. Underlying soils may not have a great influence on species richness.

The data in the NVC (Rodwell 1992) indicate that acid grasslands, contrary to common perception, can be exceptionally rich (eg up to 62 species in $4m^2$ in U4a *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland, typical sub-community). In comparison, a maximum of 38 species in $4m^2$ in MG5 or 45 species in $4m^2$ in calcareous grassland (CG2a *Festuca ovina-Avenula pratensis* grassland, *Cirsium acaule-Asperula cynachica* sub-community) were recorded. Interestingly in the present study, the richest MG5 sites had much greater species richness than the NVC samples, eg Eades Meadow and Grove Farm had 55-60 species over four $1m^2$ samples. However, without detailed soil analyses it is not possible to say if high species richness correlates with high variation in soil types on a micro-scale.

6.2 The nature of "damage"

Damage to MG5 vegetation is apparent in two ways in this study: the loss of overall species richness and especially of species which are strongly associated with unimproved semi-natural grasslands, and the gain in species which can dominate species-poor swards.

These processes act together to produce impoverished swards which the CANOCO analysis clearly divided into two types. In heavily grazed sites, whether by horses or cattle, the grassland tends towards MG6. On abandonment, or where latrines develop, there are some circumstances where MG1 (*Arrhenatherum elatius* grassland) takes over. Over a longer time period, bracken or shrub invasion might occur, but such areas were not studied here. The indicator species for overgrazing and abandonment/latrine development derived in this study have been shown in Table 1.

6.3 Horses, latrines and cattle

Current knowledge of the mechanisms of latrine development and the nature of horse latrines was reviewed in the course of the Worcestershire study (Gibson 1996). In spite of previous suspicions (Archer 1973) that all pastures eventually become "horse-sick" and develop significant latrine patches, this study has shown that MG5 grasslands only appear to develop significant latrine damage when they are heavily grazed. Overgrazing by cattle produces equally unwelcome results, again producing an impoverished sward closer to MG6 than MG5.

Archer's (1973) conclusions may be due to her studies being concentrated on reseeded grasslands, more productive than the unimproved MG5 grasslands studied here. More productive grasslands allow a greater number of horses to be adequately fed on a smaller area but the area required for dung (per amount of food taken in) is likely to be similar to that on unimproved grassland.

Figure 6 does however show that the small but significant difference between horses and cattle operates in a similar manner (same direction on the plot) to overgrazing. This suggests that even more care should be exercised in avoiding heavy grazing with horses than with cattle. Further, overgrazing has no apparent benefits. With the single possible exception of *Hieracium pilosella*, no "desirable" (usually only common in unimproved grasslands) species requires overgrazing: the others are all present in at least small quantities under grazing regimes which allow a much greater variety of species to coexist.

Previous studies (Gibson 1996, Putman *et al* 1991, Putman 1986, Putman *et al* 1987) have noted a variety of species dominating the coarse species-poor swards of latrine areas. A possible explanation of this variety lies in the diversity of mechanisms whereby a particular area can end up as a species-poor patch. Four in particular would suggest different results.

a. Latrines developing where horses merely happen to dung first, with the only fertiliser effect (Archer 1978) being raised potassium levels.

   This is likely to produce an initial dominance by robust MG5 species such as *Centaurea nigra* and grasses such as *Poa* spp. and *Lolium perenne* without driving the grassland as far as MG6, at least in the short term.

b. Horses choosing to dung in areas which are already coarse for other reasons.

   This appears to have happened at Woodland Cottage Meadow where horses chose to graze areas kept short by rabbits during abandonment and to avoid and often dung in areas which had grown out to *Arrhenatherum elatius* grassland.

c. Horses in the long term moving latrine areas around a field, formerly grazed latrine areas moving further towards MG6 and even MG7.

   This mechanism is unproven but likely at Berry Mound (the field with Bmb and Bmc data series). Should it happen, it is an important danger for long-term overgrazing as not merely the initial latrine patches but a whole field may be affected.

d. Latrines coinciding with other areas of disturbance such as around stables, shelter and/or where horses have been given supplementary feed.

   Such areas have been avoided for sampling in the 1995 and 1996 studies because of the difficulty of disentangling the separate effects of latrine behaviour and other disturbance. However, conspicuous areas have been noted in several places, including Berry Mound and Priory Road Fields, in these situations. They often contain docks (*Rumex crispus* and or *R.obtusifolius*) and *Urtica dioica*, absent from latrine samples in these studies but noted by other workers (e.g. Odberg & Francis-Smith 1977).

Whichever the mechanism, overgrazing by horses impoverishes both the closely grazed portion of the mosaic and the tall latrine phase. Overgrazing by cattle, on the limited data available, appears to be simpler but just as damaging. Like overgrazing by horses, it is likely to lead to species-poor MG5 or even MG6 swards in the long term.

Light or moderate grazing pressure by horses and other equids, however, appears as able to maintain these species-rich grasslands as cattle grazing. There is a limit to the current understanding of this. Four of the six richest sites, averaging over 30 species per square metre, available for this study were grazed by cattle. There remains a possibility that these richest sites do depend on grazing by cattle for their maintenance.

6.4 Meadows and pastures

The difference between meadow and pasture vegetation within MG5 is quantitative, not qualitative. The 1996 study has confirmed the 1995 results in identifying a suite of species associated with taller, usually meadow, swards. Most are present under both types of management but are commoner in meadows. They include two of the MG5a preferentials (*Lathyrus pratensis, Festuca pratensis*), MG5b preferentials *Galium verum* and *Trisetum flavescens*, and MG5c preferential *Conopodium majus*.

Species differential to moderately or lightly grazed pastures are fewer in number but contain several MG5c subcommunity preferentials (*Succisa pratensis, Danthonia decumbens* and *Carex caryophyllea*) and strong indicator species of unimproved conditions (eg *Linium catharticum* and *Serratula tinctoria*).

Both pastures and meadows can be equally rich: of the two richest sites for instance one (Grove Farm 38.3 species m^{-2}) is a pasture and the other (Eades Meadow 37.0 species m^{-2}) is a meadow.

6.5 Other grazing regimes and grassland types

Not all MG5 grasslands are managed by either cattle or equid grazing: indeed the difficulty of finding grasslands with a consistent and known management history by one species or the other was a material limit on the scope of this study. For instance the Slough in Warwickshire has had a chequered history of grazing in recent years, with sheep, horses and cattle used in sequence. At Marden Meadows in Kent a County Trust reserve adjacent to the pasture studied has been managed as meadow with the aftermath grazed by sheep. Many surviving neutral grasslands are on commons where mixed stock grazing has been the norm for decades or even centuries, such as Staines Moor and Port Meadow (Putman *et al* 1991, Baker 1937).

Each type of stock, and even different breeds, has distinct foraging behaviour, and it has been suggested that mixing stock in sequence or together may be one way to reverse damage caused by overgrazing by one species, especially horses (Crofts & Jefferson 1994).

Such grazing regimes are outside the scope of this study and would need a similar investment in sampling to gain an equivalent understanding. It is clear from the comparison of cattle and horse grazing that the best examples of MG5, however judged, are associated with a long history of relatively light grazing pressure by whatever stock type. The differences between species only appear when overgrazing reveals the consequences of their different foraging behaviour. In view of this it would be wise to regard MG5 as a community which is sensitive to overgrazing by any stock species and it may matter much less what grazing species of stock is used.

Likewise caution must be exercised in extrapolating the results to other lowland grassland types. Many calcicolous grasslands for example reach maximum diversity under grazing regimes which would be regarded as "heavy" in this study, although the limited quantitative evidence suggests that horses can produce as good results as cattle or sheep (Bioscan 1995). A few grassland types, such as MG3 and MG4, appear to be exclusively "meadow" rather than "pasture" communities (Rodwell 1992), containing species much more sensitive to grazing in the period of hay growth than any covered in this study. Within these constraints, it may be that light or moderate grazing by any stock, including horses, is suitable for the grazing component of management of a wide range of species-rich, low-productivity grasslands. This hypothesis should be thoroughly tested before it is put into practice.

6.6 Management in practice

On the basis of the above, the following guidelines are set out. Some need further testing before application and these are indicated. The conclusions supersede and add to those from the 1995 study (Gibson 1996).

Where species thresholds are given below, they refer to thorough survey with total identification of vegetative grass species at the best time of year, ie mid-May to early July in most of England. Thresholds should be lowered if necessary to reflect less full survey or different seasons.

a. The over-riding rule for management is "if it isn't broken, don't mend it". Successful management which is traditional to a site, whether meadow or pasture, horse or cattle, should be changed only if absolutely necessary.

b. Light to moderate grazing as defined in Appendix 1 is important whatever the stock species used, but the avoidance of overgrazing is especially important with horses and perhaps especially in sites near the upper altitude limit of MG5.

c. Sites averaging fewer than five mesotrophic indicator species in the sward (excluding latrines) (Appendix 4) or 20 total species per square metre are almost certainly "damaged". All such sites in this study were either abandoned or overgrazed, or had been overgrazed in the recent past.

d. It is easy to overestimate the damage to heavily grazed swards. For instance areas between latrines often remain rich in spite of most surviving species being very inconspicuous in the short turf.

e. Equivalent thresholds for sites with NVC quadrats (4 square metres), where these have been as thoroughly recorded, are approximately 30 total and 8 indicator species (see Appendix 3 for calibration).

f. Sites with an average of more than 30 species per square metre (approximately 50 per NVC quadrat) require special care and exceptional efforts to keep up the management which has maintained them in this state in the past.

g. As concluded in the 1995 study, any remedial measures such as a rest period for damage must be combined with appropriate grazing pressure: it is not sufficient to apply remedies while continuing to overgraze.

h. Remedial measures such as switching to mixed stock, applying a period of cattle grazing or removing horse manure as it accumulates have not been tested. All of them are based on sound knowledge of animal behaviour and are worthwhile, but their effects and the speed of any recovery should be studied.

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