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The effects of horse and cattle grazing on English species-rich grasslands

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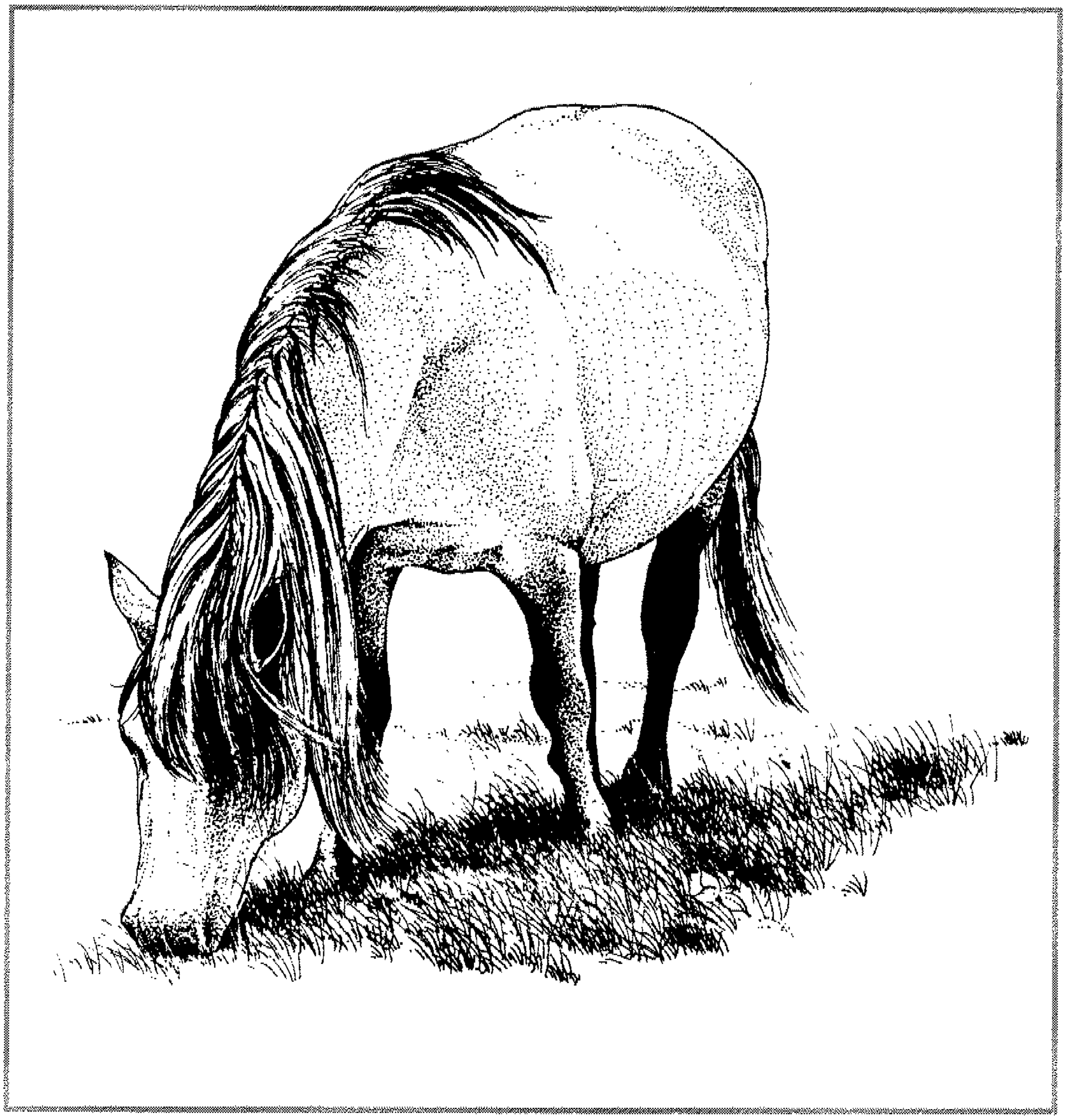

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The effects of horse and cattle grazing on English species-rich grasslands

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THE EFFECTS OF HORSE GRAZING

ON SPECIES RICH GRASSLAND

1996 FINAL REPORT

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1. Summary

1.1 This report describes an extension of the studies on horse grazing in MG5 grasslands (*Centaurea nigra - Cynosurus cristatus* grassland) in Worcestershire in 1995 which were the subject of English Nature Research Report No 164 (Gibson 1996). The purpose of the studies was threefold: to extend the range and number of grassland management types replicated, to extend the geographical range to cover the whole of England, and to provide a baseline for studying recovery from damage by overgrazing at key sites in Worcestershire.

1.2 Sites were chosen according to strict criteria to avoid confounding variables of interest with the effects of inconsistent management regimes or partial agricultural improvement in the past. This strictly limited the number of sites available, but 14 were found from Northumberland to Kent and Cornwall, with some sites having several different management types available.

1.3 Analysis used a variety of ordination techniques to explore the data structure and test whether or not the England-wide data were a logical extension of the Worcestershire subset. In the event this proved to be the case and all data were analysed together to give the most robust understanding of the effects of horse versus cattle grazing, grazing intensity and meadow versus pasture treatment.

1.4 The results have confirmed the key conclusions from 1995 that the effect of grazing stock species is weak compared to grazing intensity. The eventual result of overgrazing always appears to be a species-poor MG6 grassland. Abandonment has equally deleterious effects. Overgrazing by horses results in an additional type of damage, the formation of latrine areas.

1.5 The very richest grasslands are almost always cattle grazed and as much care as possible should be taken to keep up traditional management on these very high quality sites.

1.6 There are subtle interactions between grazing management, climate and altitude. However high quality MG5 grasslands occur in lightly or moderately grazed situations in most climatic conditions in England. Meadows and pastures can be equally rich.

1.7 The baseline for future recovery monitoring is described and a set of guidelines derived for detection of damage and appropriate means of managing MG5 grasslands. The results may also have wider application in the management of species-rich lowland grasslands.

2. Introduction

This report describes the results of contract number F80-32-06. The main purpose of the work was to extend the geographical and treatment coverage of a comparison of horse and cattle grazed MG5 grasslands (*Centaurea nigra - Cynosurus cristatus* grassland - Rodwell 1992 ed.) carried out in Worcestershire during 1995. The earlier work was published as English Nature Research Report No. 164 (Gibson 1996).

The purposes of extending the coverage were threefold.

1. To extend where possible the coverage of treatments rarely encountered in practice and thus sparse in the data set from Worcestershire, such as pastures heavily grazed by cattle.

2. To gain samples from MG5 grasslands throughout England and test whether or not the conclusions derived from Worcestershire sites could be applied more widely.

3. To set up a monitoring system on selected sites within Worcestershire where management is being changed and allow future testing of the nature and rate of recovery from damage from overgrazing by horses.

The 1995 studies confirmed that overgrazing by horses does damage species-rich grasslands, both by the generation of ungrazed "latrine" areas and by the loss of species diversity in the closely grazed sward. Some species were favoured by overgrazing: these included both "desirable" species characteristic of unimproved grassland (eg *Leontodon autumnalis* and *Hieracium pilosella*) and less desirable species commoner in disturbed or improved turf (eg *Lolium perenne*, *Ranunculus repens*).

However, heavy cattle grazing at the one site observed in 1995 caused an equal degree of damage. Analysis of the whole data set showed that, in the Worcestershire grasslands, the degree of grazing pressure far outweighed any difference between species of grazing stock (horses or cattle). Light or moderate horse grazing was as effective at maintaining diversity and other measures of sward quality as light or moderate cattle grazing. This appeared to apply equally well to meadows with aftermath grazing and to pastures, although no meadows were encountered which had been heavily grazed outside the seasons when shut up for hay.

Nevertheless, there are a number of features which could make Worcestershire a special case. The most important was an inevitable association between geographical position, altitude and the likelihood of grasslands being horse rather than cattle grazed. This is because urban fringe grasslands are often horse grazed, the conurbation of Birmingham lies to the north-east of the county, in countryside where surviving patches of MG5 grassland are often at relatively high altitude. This or a number of other special or unknown factors could have biased the conclusions.

Likewise some treatments are rarely carried out in practice. Ideally good replication was required for a number of different factors and all their combinations. These comprised two types of grazing animal (horse or cattle), two grassland management types (hay-with-aftermath or pasture) and three grazing intensities (light, moderate and heavy). Besides the absence of heavily grazed meadows (because heavily grazed areas will not produce a worthwhile hay crop) and only one heavily grazed cattle pasture, lightly grazed treatments were also poorly represented.

The 1996 studies have considerably extended this data set and at least one new grassland added to the most poorly represented treatments, including heavy cattle grazing. In this report, the process of site selection is described first, followed by explanation of the field sampling methods used and the derivation of explanatory variables.

Results and analysis are presented according to a strategy of data analysis similar to that used in 1995, and all data are analysed together after a critical justification for this procedure. The Discussion focuses on mechanisms explaining the effect of management and their consequences. These are used to derive a set of guidelines for managing MG5 and detecting damage from inappropriate management.

3. Sites and fieldwork

3.1 Site selection

a. Following contacts with English Nature Local Teams, by both the author and the Nominated Officer and with County Wildlife Trusts, the National Trust and others, a range of sites was selected fulfilling the following requirements.

- Containing homogeneous stands of MG5 grassland.
- Management known, consistent and continuous for at least the last five years.
- Grazing either by horses or by cattle and with no other species of stock involved. Donkeys have been included as equids with "horses".
- Either put up for hay every year with the aftermath grazed (Meadow), or continuous pasture (Pasture).
- Grazing intensity able to be assigned to "light", "moderate" or "heavy" categories as defined in the 1995 study.
- No known major disturbance such as ploughing or the application of inorganic fertilisers and/or pesticides for at least 100 years. English Nature Local Team staff stated that one site was shown as arable on tithe maps in the 1840s. This is likely to be the "youngest" grassland involved.
- No other confounding variables which might obscure understanding of the key variables, such as heavy rabbit grazing or unusually small stands.

b. Sites have been restricted to England for logistic reasons, but cover the full geographical range available, with the extremes being in Cornwall, Kent and Northumberland.

c. From the initial site selection, some sites were rejected because of access difficulties or because, on inspection, they proved to have unsuspected confounding variables (such as a Warwickshire site where management and stock species were both found to have changed year by year). Replacement sites were found where possible, the sites considered and/or sampled being listed below. Sites and treatments sampled are shown in **bold**. Other sites examined (but not those rejected before a field visit) are included as a useful reference for any possible extension of this or other studies where MG5 grasslands of known management history are needed.

3.2 Sites considered and/or visited

Sites from which samples were taken for the 1996 study are shown in **bold**. Their location is shown on Figure 1. The sites are shown in alphabetical order, but numbered consecutively from the last site studied in 1995 (number 19) in the order in which they were sampled.

Bugden's Copse, Verwood, Dorset

Moderate grazed horse pasture (after 2 years unmanaged). MG5 constants but with fen meadow species which are rare in MG5 also constant.

Bull Ings, Pickering, Yorkshire

44 **a Light grazed horse pasture on slope**

b Parts of same field likely to have had wartime ploughing and/or subsequent herbicide application

Carrine Common, Truro, Cornwall (Suitable but received too late for inclusion).

a Light grazed cattle meadow

b Light grazed cattle pasture

Corfe Mullen, Poole, Dorset

24 **Heavy grazed horse pasture**

Distillery Farm, Minety, Wiltshire

22 **a Heavy grazed cattle pasture** (Grazing now relaxed by Wiltshire Trust)

23 **b Moderate grazed cattle meadow**

Eades Meadow, SW of Redditch, Worcestershire

32 **a Moderate grazed cattle meadow**

b Moderate (but with uncertain history) grazed cattle pastures

Grove Farm, Yeovil, Somerset

37 **a Moderate grazed cattle pasture near Whitevine Farm**

b Heavy grazed cattle pasture (has had inorganic fertilizer application *c* 10 yr ago).

c eight other moderate grazed cattle pastures in a successional series of known ploughing approximately 1920-1976.

Kingweston Farm, Somerton, Somerset.

20 **a Moderately grazed cattle pasture**

Marden Meadows, Kent

21 **a Light grazed equid (donkey) pasture**

b Moderate grazed sheep meadow adjacent (Kent Trust for Nature Conservation reserve)

Muxton Meadows, Telford, Shropshire

38 **Moderate grazed horse pasture**

Priory Road Fields, Hull, Humberside

42 **a Latrine areas in pasture**

43 **b Heavy grazed horse pasture**

Rose End Meadows, Derbyshire (Suitable but access not available)

a Heavy grazed cattle pasture

b ?other consistent treatments

The Slough, Redditch, Warwickshire

Fields which have been intermittently pasture and meadow with horses, cattle and sheep.

South Close Field, Riding Mill, Northumberland

41 **Light grazed horse meadow**

Stocking Meadows, Ludlow, Shropshire

35 a **Moderate grazed cattle pasture**

36 b **Moderate grazed cattle meadow**

Sylvia's Meadow, Tavistock, Cornwall

25 **Moderate grazed equid (donkey) pasture**

Whitevine Farm, Yeovil, Somerset

26 **Moderate grazed cattle meadow**

Woodland Cottage Meadow, Cadnam, Hants

33 a **Heavy horse pasture**

34 b **Latrine areas** which may coincide with rough grassland after a period of abandonment >8 years ago.

Many sites, as in 1995, provided only one management type, but some provided two or more, and/or more than one subcommunity with the same management. Samples were taken from each management type (and subcommunity if available) at each site, by identical methods to those used in 1995. Sites with more than one treatment are of especial value for analysis as they can allow direct comparison without the risk of confounding variables.

3.3 Sites to extend baseline monitoring

Quadrat series have been taken at Berry Mound and Penorchard Farm in Worcestershire, to provide a baseline for monitoring future change. The baseline includes both 1995 and 1996 data and the full set now includes the following (new series in 1996 shown in **bold**).

Berry Mound

A Heavy grazed horse pasture (MG5) with grazing now relaxed.

AA Disturbed areas in same field as A, including extensive latrining, with grazing now relaxed.

B Heavy grazed horse pasture (MG5 previously, MG6 by 1995), with grazing regime to remain the same.

C Latrine areas in same field as B.

D Heavy grazed horse pasture (MG5) with grazing regime to remain the same.

Penorchard Farm

A Unmanaged MG5 area (future monitoring opportunities may not be available here).

B Heavy grazed horse pasture (MG5) but with no latrine areas in field and grazing regime to stay the same.

C Heavy grazed horse pasture (MG5) with grazing regime likely to remain the same.

D Latrine areas in same field as C.

RG Heavy grazed horse and rabbit pasture with rabbits to be controlled and grazing regime to be relaxed. (Borderline MG5/MG6)

RL Latrine areas in same field as RG.

3.4 Site environmental factors

In addition to the key factors for investigation summarised above, a number of "environmental" variables were recorded or estimated from external sources for each site and/or quadrat. These are defined in full in Appendix 1 and summarised here according to three categories.

Management variables comprise the three critical factors (species of stock, grazing intensity and hay cut) which might be expected to have a direct effect on species composition and are easily manipulated for nature conservation management. The use of winter and summer rests (aside from a hay cut) was not known from all 1996 sites and had proved to have weak or no effects in 1995, so they were omitted.

Other biological variables which may have a direct effect but are more likely to be expressions of other management factors or unmeasured environmental variables, or are not amenable to manipulation. Such variables were vegetation height, height range, the amount of bare ground and previous year's litter, and the occurrence of "latrine" areas. Also included here was the total area of grassland belonging to the same community known at a site, which may cause species-area effects in grassland composition and species range (Gibson 1986). The time period for which grazing or hay management with particular stock had been applied was at least five years in 1996 sites, but was otherwise usually unknown. As this variable only had weak effects in 1995, it was omitted from the analysis in 1996.

Geographical variables which, in this study, might affect vegetation and bias the results, but are not amenable to manipulation and could confound apparent effects of more "interesting" variables. In the 1995 data, the geographical range was narrow and position indistinguishable from the distance from the conurbation of Birmingham to the north-east. In this study a wider range of environmental variables was explored, including all which had a sufficiently wide range across the occurrence of MG5 to investigate. Of these, grid easting, grid northing, altitude and distance from the nearest large town were taken directly from Ordnance Survey maps or site cards. Climatic variables followed the usage of Averis (1991) and included water deficit, February temperature, annual temperature range, cloudiness, SO_2 concentration and an index of oceanicity (see Appendix 1).

3.5 Quadrat locations

Once a patch of apparently homogeneous MG5 vegetation had been identified, the following standard procedure was adopted. The system is designed to give a good approximation to a random distribution of quadrats within a patch without the need to grid-survey each site to locate random positions.

a. Pick a random position within the patch from a pair of random distances, walked at right angles into the patch. This becomes the starting point for a random walk.

b. Pick a random distance and a random angle (compass direction from 1 to 8 (north round clockwise to north-west).

c. Travel at this angle for the indicated distance. If an edge is encountered, bounce off the edge as if bouncing light off a mirror.

d. The point found becomes the south-west corner of a quadrat.

e. After recording the quadrat, pick another random angle and distance to find the next quadrat from the last recorded.

f. Repeat until the desired number of quadrats have been recorded.

g. No quadrat may lie within two metres of another (because of possible interference effects from recording the first one). Should this happen, the random walk continues, ignoring the "illegal" position.

A minimum of five quadrats was recorded in each patch. If there appeared to be continuous variation between quadrats greater than could be described from five quadrats, up to eight were recorded. To aid this assessment a running cumulative total of species encountered was kept during field recording, as shown in Text Figure 1 (page 11) of Gibson (1996).

3.6 Quadrat recording and data storage

The methods used for recording and storage were developed in 1984 for a long-term research project at Wytham, Oxford. They are described here in full so that the system can be used by others if desired, Bioscan has found the method to be useful and flexible in a variety of grassland and mire vegetation.

The quadrat used was a 1m square divided by fixed wires into 100 cells of 10 x 10cm square. Four such cells were regarded as a unit for recording, giving 25 20 x 20cm cells. These were numbered as shown below. The bottom left cell is the southwest corner of a quadrat.

Cell position numbers in a 1m square quadrat

5	10	15	20	25
4	9	14	19	24
3	8	13	18	23
2	7	12	17	22
1	6	11	16	21

On determining a quadrat position, the following sequence of records was made.

a. Three height estimates using a 30cm diameter dropped disc, to the nearest centimetre, positioned separately in a metre square to avoid interference.

b. Place the quadrat, on the ground if the vegetation was short enough to avoid disturbing the lie of the vegetation, otherwise on adjustable stilts placed at the quadrat corners.

c. Make a list of all vascular plants with above-ground parts present in each 20x20cm cell, on a standard data sheet with 25 columns.

d. Estimate the amount of visible bare ground and litter judged to be remaining from the previous year's growth, each to the nearest 1% (the wired division into 100 cells aids this).

The purpose of using numbered cells is to preserve positional information. Data are stored and retrieved in a manner which allows future analysis at different quadrat scales if required, developed by the author with TA Watt and the late HC Dawkins in 1983-4.

In data storage each species distribution in a quadrat is stored (using a BASIC program) as a decimal integer. For instance, suppose the distribution of *Briza media* in a quadrat was as shown below (present in the fifteen numbered squares).

Hypothetical distribution of *Briza media* in a quadrat

	10	15	20	
	9	14	19	24
	8			23
	7	12	17	22
			16	21

This distribution can equally well be represented by a string of 0s (for absence) and 1s (presence), placed in the order shown in the table on page 8 from left to right (reading each column from the bottom up), which in this case would be:

0000001111010111101111110, or the binary number 1111010111101111110

Converted to decimal notation, this is the integer 503,768. This integer is stored, and translated as necessary on retrieval.

The result is to allow the storage of a very large amount of data in a small space. Otherwise, the amount of space required to preserve positional information grows at a rate which is prohibitive even with modern computer systems.

The analyses described in this report are based on the simpler summary of cell frequency in a square metre, ie 15 in the example given above. The data are given at the end of this report and have also been copied in electronic format to English Nature.

4. Analysis

4.1 Analysis strategy

Data analyses carried out are described below in the order in which they were done. The order as well as the nature of the analysis is important because it was designed to avoid formal statistical and probability problems as far as possible. These are pointed out where appropriate. As far as possible the analysis strategy has followed that used in 1995 to ensure intercompatibility: special features included here are designed especially to test the effect of increased geographical coverage.

4.2 Dummy ("passive") NVC samples

Since the point of the study was to examine the effects of management on MG5 grasslands, it was important to relate the results to the NVC. Clearly, different recording methods were used in the NVC to those in this study, but the following translation process has proved adequate in other Bioscan studies and was adopted here. Quadrats recorded by cells almost invariably key to the same NVC community as equivalent DOMIN data. However, there are limits to interpretation of cover which arise directly from the difference between methods. Basically a widespread but sparse species which has low cover will have a low NVC cover score but a high cell frequency (the method used here). Likewise a robust, tussocky species can have a high NVC cover but be present in relatively few cells. This is not a serious problem because mesotrophic grasslands in the NVC are characterised by frequency of occurrence of species rather than cover.

Dummy NVC samples were generated for each of the subcommunities of MG5 and MG6 (*Lolium perenne - Cynosurus cristatus* grassland). Although field samples from MG6 were not included in the predictive part of the analysis (4.3 below), illustrating the position of this community proved useful in understanding the effects of overgrazing and latrines.

To make a translation the following procedure was carried out.

a. Select all species in the NVC tables with a constancy of III or more in any subcommunity. Then perform the remaining steps separately for each of the three subcommunities.

b. If a species has constancy V and a maximum Domin cover value of 7 or more, it is assumed to be present in all 25 cells in the dummy sample.

c. For species with lesser constancy or cover, the "cell count" is found by:

$$(\text{Constancy}/5) \times (\text{Domin}/10) \times 25.$$

The dummy samples do not influence the multivariate analyses described below but can be positioned directly in relation to the real samples from this study. The closer a quadrat is to a NVC dummy sample, the more similar it is to it.

4.3 Other passive samples

Quadrats suspected to be anomalies in a data set or gathered by non-random means should not contribute to predictive analysis and are therefore also used as passive samples. This occurred in two circumstances.

a. Samples known to be from MG6 areas (Bmb and Bmc at Berry Mound) before quadrats were recorded and therefore outside the formal scope of the main data set.

b. A single quadrat from Eades Meadow in Warwickshire, deliberately placed in a patch of vegetation to ensure that the main range present in the field was covered.

The above samples and those described in 4.2 were made passive in all analyses, in addition to particular tests in which all 1995 or all 1996 data were rendered passive to examine the homogeneity of the data sets.

4.4 Multivariate assessment procedure

In order to assess the relationship between the Worcestershire data set and the 1996 samples, three different items were required for each type of analysis performed.

a. The results from the equivalent 1995 analysis, using Worcestershire data alone.

b. The results of analysis of 1996 data alone, but examining the 1995 data as passive samples placed within the new analysis.

c. The results of combined analysis taking into account both data sets.

The key test is whether the 1996 data merely extend the understanding derived from Worcestershire data, or whether they give fundamentally different conclusions. Since all analyses performed did indeed provide extensions to previous understanding, rather than different conclusions, the main results presented in this report are based on combined data as in (3) above.

4.5 DECORANA

DECORANA (also called DCA) stands for detrended correspondence analysis, a standard ordination method originally developed by MO Hill (1973). It describes vegetation in terms of the most important independent patterns (axes) of variability in species composition between samples (here quadrats). By itself, it cannot identify the causes of variability.

Here, DCA was used to explore the data structure and check for anomalies which might suggest the need for data transformation, exclusion of outlier samples or species, or any other modifications.

Using the package CANOCO 3.1 (ter Braak 1987-1992), the environmental variables were then superimposed on the DCA ordination to provide a pictorial check of their likely influence.

Neither of these operations can test the influence of management: they are merely data exploration techniques used to check that the data structure was suitable for the subsequent analyses, which used DCCA (detrended canonical correspondence analysis) to test the influence of management and other key variables.

4.6 DCCA - investigating the effects of key variables

The core of DCCA is a double ordination in which an ordination of species composition is constrained to devise the most likely predicted relationship between the species composition data and linear combinations of the environmental variables.

Although more robust than older methods which make many assumptions about the underlying structure of the data, DCCA is still sensitive to sets of variables which are highly intercorrelated and explain little variation independently of each other. With each ordination carried out, DCCA provides summary statistics which help in defining variables which do have independent explanatory power without being confounded. In the combined data set which is the main basis of this report, some of the climatic variables were found to be highly intercorrelated and to have high variance inflation factors (VIF), which risks invalidating the answer (ter Braak 1987-92).

Accordingly, ordination statistics were examined and variables were deleted until a set was found which combined good explanatory power with low intercorrelations with low VIFs. This process is inevitably arbitrary in relation to cause and effect but it is nevertheless possible to make broad inferences about the relationship between geography, climate and species composition.

The explanatory models were then built and tested using CANOCO's facility for forward selection of environmental variables. Relations between environmental variables and vegetation have been built up stepwise, for instance by first taking the variable with the greatest explanatory power and testing the significance of its effect by Monte Carlo permutations, followed by repeating the process for each variable in turn. If the effect of a variable is significant, it is retained, otherwise it is left out of the model.

Variables were only included if they had an individual effect at a significance level of at least 0.01: this superficially "conservative" procedure is the correct one where a sequence of variables is being tested.[1]

In 1995, the narrow range of geographical variation within Worcestershire was considered relatively uninteresting compared to the absolute effects of each management activity. Accordingly, environmental variables which could not be manipulated by a nature reserve

1 For instance, if one does a sequence of 20 tests, an average of one of them would be expected to be "significant" at the p=0.05 (1 in 20) level by chance alone.

manager were removed from the analysis as covariables, leaving the "true" effect of management when other variables had been factored out.

The wide geographical range of the 1996 study suggested that this approach would be too limiting. Where practical management of grasslands from Northumberland to Cornwall is considered, the reserve manager needs to know the way in which climate may interact with management. Geographical and climate variables have not therefore been removed as covariables. In fact, it appears that relatively continental climate tends to favour similar species to abandonment, so in such areas the consequences of neglect may take effect even more rapidly than elsewhere.

4.7 Species, categories and other attributes

By testing ordinations and environmental variables, CANOCO identifies significant effects of variables of interest. Plant species and species groups which are associated with their effects can be identified from their positions relative to the effects of variables. Such indicator groups, derived from the analysis, are referred to as "CANOCO indicators" in this report.

It is also of interest to examine these effects with reference to other aspects of the vegetation, such as species richness, abundance of mesotrophic grassland indicators and similar categories derived from independent studies, ie outside the particular vegetation data studied here. Strictly, a probability level, and therefore significance tests, cannot be assigned to such effects and any effects related to CANOCO groups, because testing them is not independent of the statistical tests already carried out by CANOCO. However, if for instance there are many fewer indicator species in heavily grazed sites, this means that such indicators have made an important contribution to the high significance level shown by CANOCO for the effects of grazing intensity on the vegetation. Demonstration of the effects on such categories is therefore illustrative, not formal, but is essential for practical management decisions.

Attributes of the vegetation chosen for such illustration were as follows.

a. Species richness.
b. Life history attributes from a classification originally developed in Grime et al (1988).
c. Indicator species scores as supplied to Bioscan by English Nature (Rowell and Robertson 1994), in which species are scored from 1 to 8 with increasing strength of restriction to unimproved mesotrophic grasslands.
d. CANOCO indicators of the main axes of environmental influence derived from the DCCA analysis, taking species strongly biased towards environmental variables (such as grazing intensity) as indicators of their effects.

Where species are grouped in this analysis, such as by life history attributes, the results have been expressed, except where otherwise indicated, as the total number of cell occurrences for all members of the group, i.e. the possible score is more than 25 cells.