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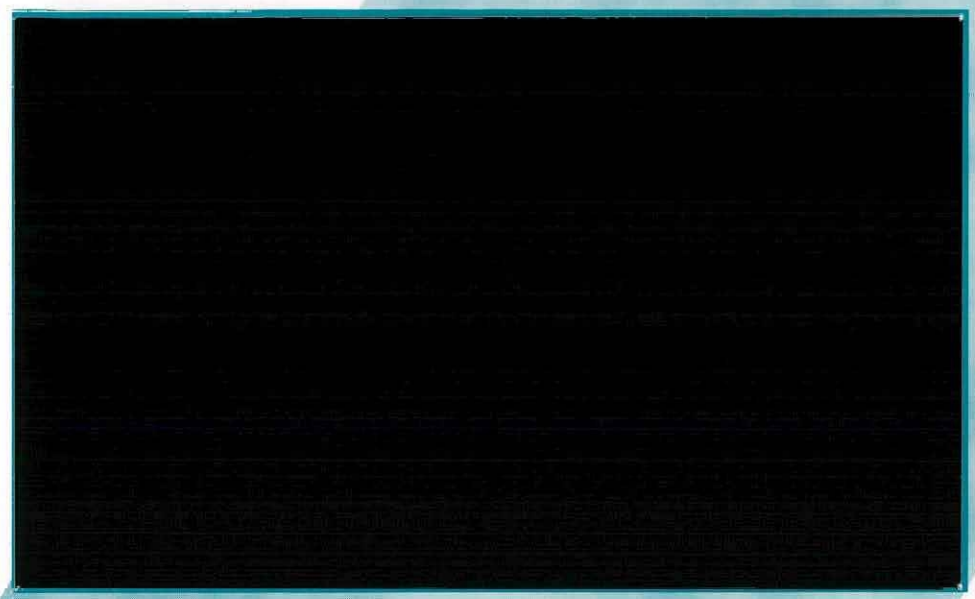

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FINAL REPORT

REVIEW OF CALCAREOUS GRASSLAND AND HEATHLAND MANAGEMENT

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EXECUTIVE SUMMARY

1. Both lowland heaths and calcareous grasslands are products of centuries of utilisation by man. Past management practices have included livestock grazing, burning and cutting;

2. These practices have produced habitats and landscapes of great structural and biological diversity which are greatly valued for nature conservation and their aesthetic qualities;

3. Cessation of these practices will lead to the development of woodland and scrub and an associated loss of the characteristic assemblages of plants and animals associated with these habitats. Intensification or alteration of management practices may lead to the dominance of a few species and a similar loss of biodiversity.

4. In this review we differentiate between conservation or 'maintenance management' and those, more drastic management practices, required to restore the ecosystem structure and function when these changes have taken place ('restoration management');

5. The objectives of conservation management include preservation of the original structure and function of the ecosystem, prevention of unwanted successional changes and the provision of an economic return;

6. This review aims to identify and evaluate practical, cost-effective management procedures for achieving these objectives. This was achieved from the study of: (a) long term management experiments: fully randomised, replicated experiments incorporating different management treatments; (b) sites of known management history, where it was possible to relate past and present vegetation types to given management regimes.

7. Grazing by cattle or sheep was found to be the traditional and preferred management of calcareous grassland, producing the greatest floristic and structural diversity.

8. Livestock grazing has three important ecological impacts on the calcareous grassland ecosystem: selective defoliation, trampling to create gaps, and nutrient addition and removal. The nature of these impacts will vary considerably depending upon the type, breed and age of the livestock. Lowland breeds may provide an economic return from extensive grazing systems, but are considered unsuitable for coarse vegetation. Hardy breeds are able to eat unpalatable species and utilise herbage of poor nutritional quality. However, they are more difficult to obtain and handle, and provide a lower agronomic return.

9. It is difficult to derive precise rules for grazing management because of local variation in soil fertility, climate, productivity and palatability. These grasslands are of lower productivity and produce less digestible herbage than improved grasslands. Extensive beef and sheep grazing systems are likely to be the preferred agronomic management option. Grazing should aim to remove most of each year's herbage, either during the summer growth period or during the winter. Flexibility in approach is required to allow for between-year variations in productivity. Timing of grazing should be carefully controlled to avoid harming sensitive plant and invertebrate species. Rotational management regimes are likely to be the most advantageous for nature conservation management. Moderate stocking densities (e.g. 0.6 - 1.4 LU ha^{-1} for longer periods (e.g. 16 - 20 weeks) are likely to be the most beneficial. However, high stocking rates for short periods have been effective in controlling unpalatable species. Frequent measurement of sward structure and height is likely to be the best means of regulating grazing rather than target stocking rates as recommended in the current ESA guidelines.

10. In some situations it is neither economic nor practical to maintain grazing animals outside the farming system. This is particularly the case where predominantly arable farms have only small and relatively inaccessible grazing areas, or are on the urban fringe. In such cases, cutting may be the only management option. Cutting has markedly different effects from grazing on the ecology of grassland. Mowing causes an immediate and uniformly drastic alteration in the structure of the sward. It is non-selective and does not create the valuable mosaic of gaps in the sward associated with livestock trampling. Removal of hay also causes a gradual depletion of nutrients and loss of productivity. Finally, the timing of cutting will strongly influence the eventual composition of the sward as some species are prevented from setting seed.

11. Considerably less is known about the management of lowland heaths. This reflects their marginal use in the agricultural system.

12. Heathland management practices should aim to create a mosaic of different vegetation types at a variety of successional stages and spatial scales. This will provide habitat for a wide diversity of plant and animal species.

13. Degraded, degenerate or mature heathland may require an initial, one-off treatment to remove invasive species or excessive biomass before maintenance management can be initiated. This could take the form of winter burning or cutting to provide fresh growth for grazers. Additional control of invasive species (e.g. Bracken) with herbicides may also be required. It may be more cost-effective to initiate regeneration of some severely degraded heaths from relic seed banks.

14. Extensive grazing by cattle, ponies or sheep is the preferred and traditional management to maintain lowland heath. Hardy breeds are recommended. The stocking rate and grazing period should be based on local tradition,

management objectives and the welfare of the animals. The intensity of grazing is important: overgrazing will cause the suppression of heath vegetation and cause a change to acid grassland; under-grazing will have little effect in halting succession. Summer grazing is more typical.

15. It may be desirable to superimpose a rotational system of burning and cutting on this grazing system with the aim of producing a mosaic of different successional stages on a scale of > 0.5 - 1 ha. Burning and cutting alone are not an adequate substitute for grazing, especially in terms of diversity of plant species and vegetation structure. However, they will prevent succession to scrub. Burning should be carried out in the winter, following the MAFF code. It may be desirable to burn or mow only parts of the heath each year, to establish a mosaic of vegetation types. The frequency of burning or cutting will depend upon the rate of vegetation growth. Other management should also be considered, e.g turf-stripping to remove nutrients and rotovation to create bare ground.

16. If the conservation management of calcareous grassland and heathland is to be successful, it is important to first determine the objectives of management. This requires the evaluation of individual sites, together with knowledge of the plants and animals associated with the ecosystem. These objectives will need to consider local factors, such as access, topography, skills and tradition. This should produce a suite of viable and practical management options which will achieve the conservation objectives of management. It is citically important that the site is regularly monitored so that adjustments to the management regime can be made. This monitoring could take the form of simple sward measurements.

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1.0 INTRODUCTION

Management is required when the conservation of a particular type of ecosystem is dependant upon the prevention of unwanted changes. This applies to most lowland grasslands and heaths as they are situated under conditions of climate and soil where some type of woodland is the natural 'climax' vegetation type. In this review we differentiate between this type of preventative or '*maintenance management*' and those, more drastic management practices, required to restore the ecosystem structure and function when these changes have already taken place ('*restoration management*')

1.1 Objectives

The aims of this review can be summarised as follows:

- compare the effects of different management techniques on the structure and diversity of calcareous grassland and lowland heath;
- identify and evaluate management procedures for the maintenance and enhancement of the botanical diversity of these habitats;
- derive effective, practical guidelines which can be used by MAFF for managing calcareous grasslands and heathlands within the ESA and Countryside Stewardship schemes.

1.2 Background

A number of schemes are available to farmers and land managers which provide advice and financial incentives for management practices that benefit wildlife and landscape. In 1987 the Ministry of Agriculture, Fisheries and Food (MAFF) designated 'Environmentally Sensitive Areas' (ESAs) of the United Kingdom where traditional farming practices had helped to create or protect distinctive landscapes, wildlife habitats or historic features. Land managers within these ESAs were eligible for grants to support the continuation of these practices and to encourage measures that would further enhance the environment. Initially the Ministry and farmers entered into management agreements for five years, but since 1994, ten year agreements have been offered. To date, twenty-two ESAs have been designated. It is estimated that some 2290 km^2 of calcareous grassland are present within the ESAs, with the largest areas occurring in the South Downs, South Wessex Downs, the Cotswold Hills ESAs. Similarly, there are approximately 1410 km^2 of lowland heath in the ESA, the majority of which occur in the Breckland, Black Down Hills and West Penwith ESAs.

Participants in the ESA scheme have to adhere to management guidelines laid down by the local Project Officer. The 'Guidelines for farmers' within each ESA are necessarily different, reflecting the very different climate, geology, soils and farming systems which created these semi-natural habitats the scheme seeks to protect and enhance. In general, the current guidelines seek to maintain and enhance existing calcareous grasslands through extensive livestock grazing (0.5 to 1.5 livestock units per ha). Conversely, farmers are advised to 'hard graze' lowland heath with unspecified amounts of cattle and sheep.

In 1989 the Countryside Stewardship Scheme (CS) was introduced by the Countryside Commission which offered farmers 10 year management agreements to enhance and conserve target landscapes and habitats, including lowland heaths and calcareous grasslands. Payments are offered to manage chalk grassland by light sheep and / or cattle grazing for at least 10 weeks in each year without damaging the sward. The aim is to remove the year's grass growth and to achieve an average sward height of about 75 mm by the end of the summer. Stocking should not normally exceed 0.75 livestock units per ha. CS also offers two levels of payment for the management of existing lowland heath; including a base payment for rotational cutting and additional payments for more comprehensive management programmes. This includes combinations of light summer grazing, rotational burning and measures to control scrub and bracken.

2.0 INTRODUCTION TO LOWLAND CALCAREOUS GRASSLANDS

2.1 Definitions

Lowland calcareous grasslands can be defined as plant communities occurring on calcareous substrata where a high proportion of the vegetation comprises native grass and forb species. The distribution of these grasslands is shown in Fig 2.1. These grasslands are typically short, rarely exceeding 30 cm in height. They have an open structure and usually have few woody shrub species. Lowland calcareous grassland is usually situated at altitudes not exceeding 250 - 300 m O.D. The species composition of these grasslands has not been substantially altered by recent cultivation, or the use of herbicides and fertilisers.

2.2 History and development

Lowland calcareous grasslands are largely the products of human activity. They have developed through the systematic clearance of forest and farming which began in Neolithic times (Box 2.1). Hence, calcareous grasslands are regarded as 'semi-natural' rather than 'natural' vegetation.

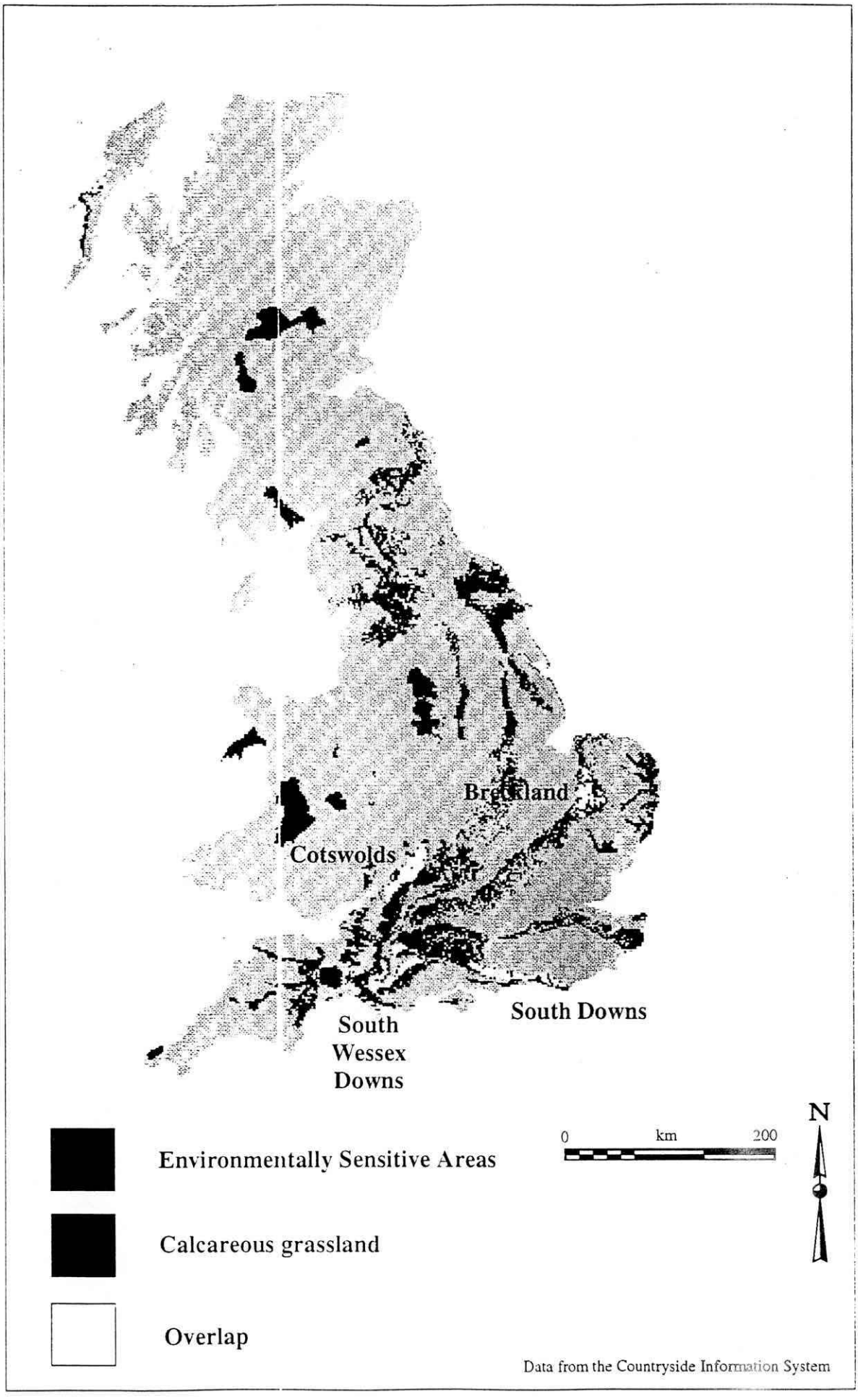
2.3 The grassland environment

Calcareous grasslands occur wherever there are soils derived from rocks rich in calcium carbonate. These principally comprise the Cretaceous chalk, and the Jurassic and Carboniferous limestones (Fig 2.1). Soils on the slopes are ususally thin, skeletal and freely drained. These rendzina soils are characterised by high pH (6.5 to 8.5), high calcium ion concentration and low available levels of major plant nutrients (nitrogen, phosphorus and potassium). Deeper, more fertile calcareous brown earth soils occur on flatter areas in the valley bottoms.

2.4 Calcareous grassland types

The National Vegetation Classification (NVC; Rodwell 1992) provides a systematic phytogeography of the British vegetation and identifies discrete plant communities from calcareous grassland. Groupings are obtained from the multivariate analysis of field samples. The resulting phytosociological groupings are defined by weighted criteria of species composition and dominance. The NVC identifies 7 distinct lowland calcareous grassland communities in Britain (Box 2.2). These are often products of different type of management and land use. Thus, the NVC

Fig. 2.1 Extent of calcareous grassland and ESAs within Britain



provides a useful framework within which to monitor the effects of different management practices.

Box 2.1 Development of calcareous grassland

Human activities associated with the development of lowland grassland from woodland:

Woodland clearance for cultivation, pasture, fuelwood, industry (e.g. shipbuilding / smelting);

Burning the woodland and grazing or cultivation of the burnt area;

Grazing the woodland (horses, cattle, deer etc.) thus preventing the regenaration of the trees.

Significant historical events associated with the development of lowland grassland from woodland:

Neolithic - small-scale forest clearance and cultivation (landnam);

Bronze Age - systematic clearance of large areas of forest in order to fuel smelting industries;

12th & 13th centuries - dramatic increase in population following Norman Conquest and incresed demand for grain and livestock;

Fourteenth century - population decline resulting from the Black Death and reversion of large tracts of cultivated land to grass for sheep;

Napoleonic Wars and the First Agricultural Revolution - increased demand for grain as a result of the 'Continental Blockade' and subsequent 'mechanisation' of agriculture in the mid 19th C (enclosure, seed-drills, animal husbandry etc.) resulted in the most significant period of conversion of grass to arable in modern times;

The 'Great Depression' - abandonment of marginal arable land due to cheap foreign grain (esp. North American) and reduced demand;

First World War - increased domestic demand during war years and subsequent decline during the 20s and 30s;

The Second Agricultural Revolution - the transformation of agricultural practices following the Second World War (mechanisation, intensification) and nationalisation of agriculture through CAP Price Support encouraged and enabled farmers to convert grassland to arable;

1950s - myxomatosis drastically reduced rabbit numbers leading to scrub invasion on many of the remaining chalk grasslands.

Box 2.2 Calcareous grassland communities defined by the National Vegetation Classification

CG1 *Festuca ovina - Carlina vulgaris* grassland
A warm, temperate limestone grassland characterised by short, open, tussocky turf. The distribution of this community is limited to scattered sites on the hard limestones around the southern and western coasts of Britain.

CG2 *Festuca ovina - Avenula pratensis* grassland
An extremely diverse mixture of grasses and forbs which is maintained by close livestock and rabbit grazing (Plates 1 & 2). This type of grassland was once extensive over southern lowland limestones and chalk. The community is divided into many sub-communities which reflect more subtle variations in topography and soil type.

CG3 *Bromus erectus* grassland
This grassland is considered to be an infrequently grazed counterpart of the CG2 grassland. It is dominated by coarse grasses with a lower abundance and diversity of low-growing species. This community is frequent over the Chalk and Jurassic Limestones of lowland Britain.

CG4 *Brachypodium pinnatum* grassland
Dominated by *B. pinnatum* and other coarse tussock grasses. Associated with the absence or a reduction in grazing pressure and the presence of slightly deeper, more fertile soils. The succession of CG2 into this community is considered a major management problem. This community is commonly found on the chalk of the North and South Downs, as well as the Oolitic limestones of Cotswolds.

CG5 *Bromus erectus - Brachypodium pinnatum* grassland
Co-dominated by tussocks or larger patches of these coarse grass species, but forbs can be abundant in the gaps. Maintained as open grassland by burning and grazing, restricted to the southern lowland Oolitic and Magnesium limestones where it can form a mosaic with the CG2 community. The centre of distribution for this community is the Cotswolds.

CG6 *Avenula pubescens* grassland
A somewhat ranker grassland with relatively few forb species. It is a product of little or no grazing on more mesotrophic calcareous soils on flat or gently sloping sites. This community occurs in scattered remnants over lowland limestone areas, although much of this grassland has been converted to arable land.

CG7 *Festuca ovina - Hieracium pilosella - Thymus praecox / pulegioides* grassland
An open grassland which is frequently dominated by rosette-forming forb species and bryophytes. This community occurs in scattered localities over the Chalk of south-east Britain, although Breckland has the greatest concentration of this vegetation. This community is associated with highly impoverished, free draining soils where there is a history of heavy rabbit grazing and disturbance.

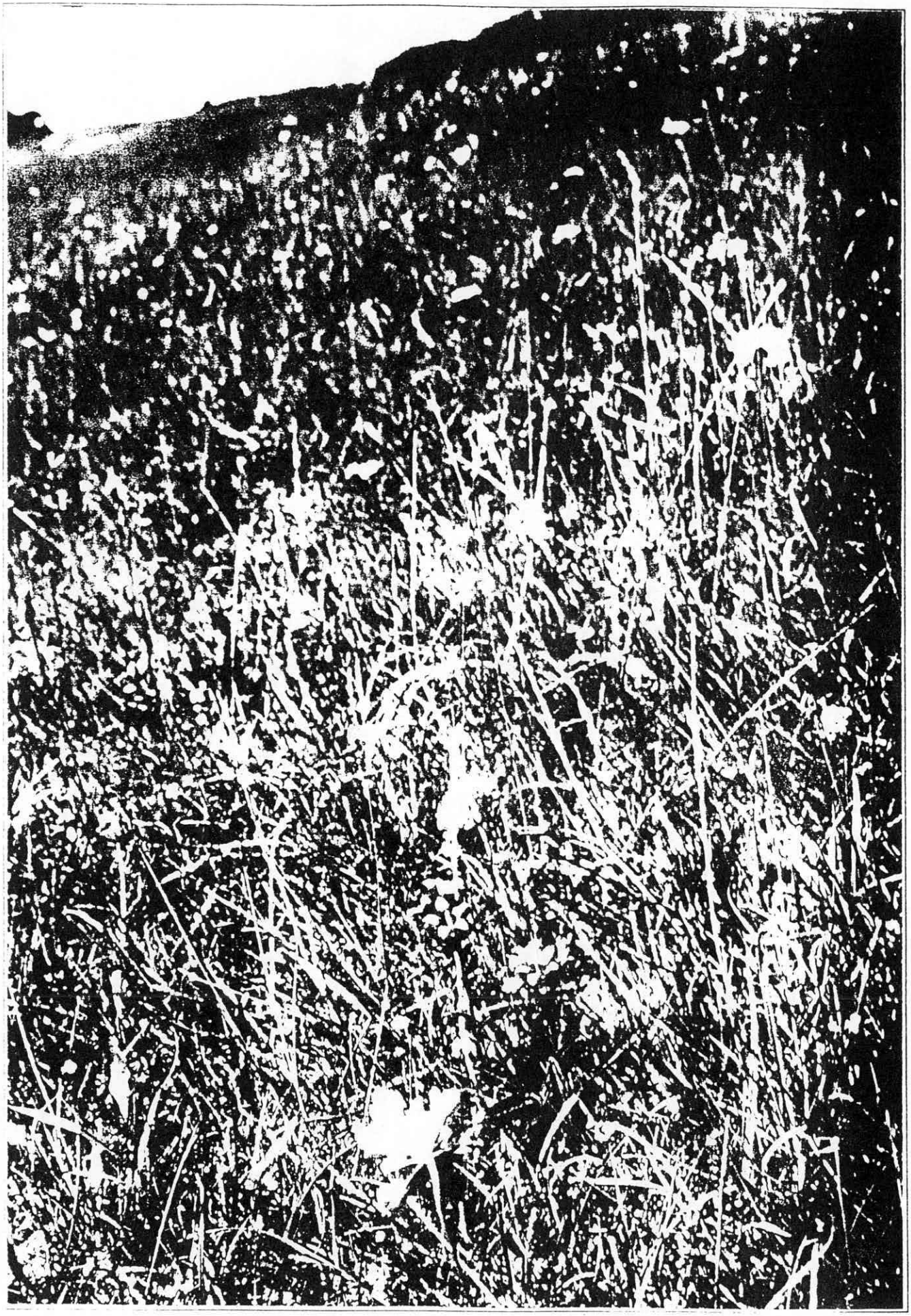


Plate 1. Diverse calcareous grassland maintained by cattle grazing on Ashey Down, Isle of Wight

Plate 2. A diverse chalk grassland community (CG2) containing more than 30 species of vascular plants

2.5 Nature conservation value of calcareous grasslands

Calcareous grassland have long been recognised as a resource of great ecological interest and value for nature conservation. Such grasslands are amongst the most diverse plant communities in Britain. They typically support between twenty and thirty vascular plant species per metre square and occasionally up to forty or fifty species (Plates 1 & 2). Although the grasslands can be classified into distinctive communities (Section 2.4), there are a large number of perennial forbs and grasses which are abundant in all of the communities. Many of the species found on calcareous grasslands are termed 'stress-tolerators' (Grime *et al.* 1988). Such species have a slow rate of growth and long life, and are able to tolerate episodic or chronic deficiencies of nutrients and water, as well as frequent defoliation. A high proportion of these plant species are classified as nationally rare, occurring in less than fifteen 10 km x 10 km squares of the UK, or nationally scarce, occurring in 16 - 100 squares (Table 2.1). Furthermore a number are included within the British Red Data list as either endangered or vulnerable (Perring & Farrell 1977). Many of these species have a southern European distribution and occur at the northern limit of their range in the UK. The short turf and southerly aspect of calcareous grasslands in lowland Britain provide idea micro-climatic conditions for these species.

Calcareous grasslands also support a wide range of invertebrate animals species. Many are 'thermophilous' species which favour the warm conditions provided by the short, open turf. Some of these are specialist feeders on the plants which are confined to chalk grassland. This group includes butterflies such as the nationally scarce Marsh Fritillary (*Eurodryas aurinia*), the caterpillar of which feeds on Devil's-bit Scabious (*Succisa pratensis*), the Chalkhill Blue (*Lysandra coridon*) and Adonis Blue (*L. bellargus*). The caterpillars of both species feed on the Horseshoe Vetch (*Hippocrepis comosa*). A small group of bird species rely on open calcareous grassland habitats for breeding. These include the Skylark (*Alauda arvensis*), Lapwing (*Vanellus vanellus*) and the nationally rare Stone Curlew (*Burhinus oedicnemus*). In addition, recently re-introduced red kites (*Milvus milvus*) in the south of England favour open downland where the densities of the rabbits are high.

Without appropriate management, the structure and composition of these grasslands would change, together with the diversity of different micro-climates. This would result in the loss of much of the biodiversity and conservation interest of this habitat

Table 2.1 Vascular plants of calcareous grassland which are classified as nationally rare (NR) or nationally scarce (NS). Red Data species are further classified as endnagered (e), vulnerable (v) or rare (r).

Scientific Name	English Name		Scientific Name	English Name	
Aceras anthropophorum	Man Orchid	NS	*Medicago sativa spp. falcata*	Sickle Medick	NS
Althaea hirsuta	Rough Marsh-mallow	NRe			
Ajuga chamaepitys	Ground Pine	NRe	*Minuartia hybrida*	Fine-leaved Sandwort	NS
Arabis scabra	Bristol Rock-cress	NRv	*Ophyrys fuciflora*	Late Spider-orchid	NRr
Artemisia campestris	Field Wormwood	NRe	*O. sphegodes*	Early Spider-orchid	NRv
Aster linosyris	Goldilocks Aster	NRr	*O. militaris*	Military Orchid	NRv
Bunium bulbocastanum	Great Pignut	NRr	*O. simia*	Monkey Orchid	NRv
Bupleurum baldense	Small Hare's-ear	NRv	*O. ustulata*	Burnt Orchid	NS
Carex ericetorum	Rare Spring Sedge	NS	*Orobanche artemisa-campestris*	Oxtongue Broomrape	NS
C. humilis	Dwarf Sedge	NS			
C. montana	Soft-leaved Sedge	NS	*Phleum phleoides*	Purple-stemmed Cat's	NRr
C. ornithopoda	Bird's Foot Sedge	NRr	*Phyteuma orbiculare*	Round-headed Rampion	NS
Cerastium pumilum	Dwarf Mouse-ear	NS	*Polygala amarella*	Dwarf Milkwort	NRr
Cirsium tuberosum	Tuberous Thistle	NRr	*Potentilla neumanniana*	Spring Cinquefoil	NS
Cotoneaster integerrimus	Wild Cotoneaster	NRe	*Primula farinosa*	Bird's-eye Primrose	NS
Cypripedium calceolus	Lady's Slipper	NRe	*Pulsatilla vulgaris*	Pasque flower	NS
Draba aizoides	Yellow Whitlowgrass	NRr	*Rhinanthus angustifolius*	Greater Yellow Rattle	NRv
Epipactis atrorubens	Dark-red Helleborine	NS	*Salvia pratensis*	Meadow Clary	NRv
Euphorbia portlandica	Portland Spurge	NS	*Scilla autumnalis*	Autumn Squill	NS
Euphrasia pseudokerneri	Eyebright	NS	*Sedum forsteranum*	Rock Stonecrop	NS
Galium pumilum	Slender Bedstraw	NS	*Seseli libanotis*	Moon Carrot	NRr
G. sterneri	Limestone Bedstraw	NS	*Sesleria albicans*	Blue Moor-grass	NS
Gastridium ventricosum	Nit-grass	NRv	*Silene conica*	Sand Catchfly	NR
Gentianella anglica	Early Gentian	NS	*S. nutans*	Nottingham Catchfly	NS
G. ciliata	Fringed Gentian	NR	*S. otites*	Spannish Catchfly	NRr
G. germanica	Chilern Gentian	NS	*Tephroseris integrifolius*	Field Fleawort	NS
Helianthemum apenninum	White Rock-rose	NRr	*Teucrium botrys*	Cut-leaved Germander	NRr
H. canum	Hoary Rock-rose	NRr	*Thesium humifusum*	Bastard-toadflax	NS
Herminium monorchis	Musk Orchid	NS	*Thymus serpyllum*	Breckland Thyme	NRr
Himantoglossum hircinum	Lizard Orchid	NRv	*Trinia glauca*	Honewort	NRr
Hornungia petraea	Hutchinsia	NS	*Veronica spicata ssp. hybrida*	Spiked speedwell	NS
Hypochaeris maculata	Spotted Cat-ear	NRr			
Iberis amara	Wild Candytuft	NS	*V. spicata ssp. spicata*	Spiked speedwell	NRv
Koeleria vallesiana	Somerset Hair-grass	NRr	*V. verna*	Spiked speedwell	NRe
Linum perenne spp. anglicum	Perennial Flax	NS	*Vulpia unilateralis*	Mat-grass Fesuce	NS

2.6 Grassland management

Calcareous grasslands have been traditionally managed by either sheep or cattle grazing. This has produced and maintained the floristic and structural diversity which is so valued for nature conservation. However, the precise effects of grazing on the grassland ecosystem are difficult to quantify. Breed of livestock, stocking density and time of grazing varied considerably between years depending on climate, agronomic conditions and availability of animals. Relaxation of the intensity of these activities, or their cessation, has led to the invasion of scrub and coarse grasses, and in some cases the reversion to woodland. Conversely, if the frequency and intensity of these management practices is too high and the grassland is disturbed, then many of the characteristic species of will be lost. Indeed. in previous studies commissioned by MAFF (Wells *et al.* 1994), it was found that many species of

calcareous grasslands took in excess of 50 years to re-colonise sites which were ploughed during the Second World War. In some cases, these sites were adjacent to existing, undisturbed chalk downland.

Table 2.2 Traditional management of calcareous grassland communities defined by the NVC (Rodwell 1992)

NVC grassland community	Livestock grazing	Periodic burning & grazing	Occasional periods of cutting / grazing / no management
CG1	✓		✓
CG2	✓		
CG3	✓		✓
CG4	✓		✓
CG5	✓	✓	✓
CG6	✓		✓

Box 2.3 Summary of the threats to calcareous grasslands

The calcareous grassland ecosystem contains some of the most diverse assemblages of plants and invertebrates in Western Europe. They are a product of hundreds or thousands of years of stable livestock grazing management and are easily disturbed. Once damaged or degraded, these communities may take a similar amount of time to re-assemble. Given the large scale loss and fragmentation of this habitat over much of lowland Britain, it is possible that once degraded, these ecosystems may never fully recover to their original state. The main threats to calcareous grassland are:

- **Lack of management** (grazing or cutting) allowing the invasion and dominance of coarse grass and scrub species.
- **Over-intensive management** leading to disturbance and species loss.
- **Inappropriate management**, including re-seeding, and the use of herbicides and fertilizers causing the invasion and dominance of competitive species.
- **Increasing atmospheric deposition** of nitrogen and other nutrients, possibly accelerating the invasion of coarse grass species.
- **Unregulated grazing** by feral rabbit populations causing loss of species through overgrazing and disturbance.
- **Habitat loss** due to conversion to arable land or other uses, such as road / rail development, housing, golf courses etc.

3.0 CALCAREOUS GRASSLAND STUDY SITES

3.1 Approach

The effects of different management practices on the structure and composition of vegetation was determined from:

(a) **Management experiments**: randomised and replicated experiments incorportating different management treatments;

(b) **Sites of known management history with the following** :

- detailed records of the management carried out at the site over the previous decade or more. Such records typically included livestock stocking rates, breed and time of grazing, together with the frequency of cutting and burning management;
- quantitative information on the composition and structue of the vegetation at some time in the recent past. This included species lists, as well as quadrat, pin and transect data. Datable photographs taken from fixed points were also sought. This enables the past and present vegetation types to be related to given management regimes.

There were a total of 24 calcareous grassland study sites situated throughout lowland Britain (Fig 3.1). Sites at Parsonage Down and Wylye Down (Wiltshire), Isle of Wight (Hampshire), Newtimber Hill (Sussex), Barton Hills and Knocking Hoe (Bedfordshire) and Aston Rowant (Oxfordshire) are all situated on Cretaceous chalk deposits. The sites at Barnack (Cambridgeshire), and Radcot (Oxfordshire) are situated on the Oolitic limestone deposits of the Jurassic.

3.2 Site recording

Management experiments

These were recorded according to the methods used previously (see relevant section for details).

Sites with known management history

At each site with a known management history a full list of plant species was made. In addition, uniform stands of vegetation considered to be characteristic of the site were described in a series of 1 m x 1 m quadrats. The percentage cover of each higher plant and bryophyte species was assessed by eye as a vertical projection onto the ground. Where necessary, these values were converted to the Domin scale to allow comparison with older data sets

Fig. 3.1 Location of the calcareous grassland study sites

- **1 Aston Rowant, Oxfordshire**
- **2 Parsonage Down, Wiltshire**
- **3 Wylye Down, Wiltshire**
- **4 Barton Hills, Bedfordshire**
- **5 Knocking Hoe, Bedfordshire**
- **6 Barnack, Cambridegshire**
- **7 Radcot, Oxfordshire**
- **8 Newtimber Hill, Sussex**
- **9 Martin Down, Dorset**
- **10 Old Winchester Hill, Hampshire**
- **11 - 19 Isle of Wight, Hampshire**

(Table 3.1). A photographic record was also made of the site. This information was supplemented by detailed notes on the structure of the vegetation, as well as management history, physiognomy and soil type.

Table 3.1 The Domin cover-abundance scale

Domin scale	Cover %
10	91-100
9	76-90
8	51-75
7	34-50
6	26-33
5	11-25
4	4-10
3	<4 many individuals
2	<4 several individuals
1	<4 few individuals

3.3 Analysis

Significant changes in the structure and composition of the vegetation were described, and related to management practices. In addition, a table of species frequency and abundance was produced for each stand of vegetation described. These were either displayed in the text or relevant appendices. In most cases the vegetation data has been compared to the data on the plant communities defined by the National Vegetation Classification (Rodwell 1992) using the computer programme TABLEFIT (Hill 1990). This allowed a more systematic examination of the effects of different management practices on plant community composition over time.

4.0 EFFECTS OF MANAGEMENT ON STRUCTURE AND FLORISTIC COMPOSITION OF CALCAREOUS GRASSLANDS

4.1 LIVESTOCK GRAZING

4.1.1 THE ASTON ROWANT GRAZING EXPERIMENT

4.1.1.1 Study site

Aston Rowant NNR, Oxfordshire (grid ref. SU 7297) extends to 130 ha of the Chiltern chalk scarp. The site includes beechwood, mixed scrub communities, juniper scrub and chalk grassland (Ratcliffe 1977). In the 1960s and 1970s, the chalk grassland at the site was described as mostly of the *Festuca ovina-Carex flacca-Sanguisorba minor* type with *Helianthemum nummularium* and *Thymus polytrichus* usually frequent, equivalent to the *Festuca ovina-Avenula pratensis* grassland (CG2) in the NVC (Rodwell 1992). A grassland where *Avenula pubescens* was more prominent was present on the north-facing slopes (CG6).

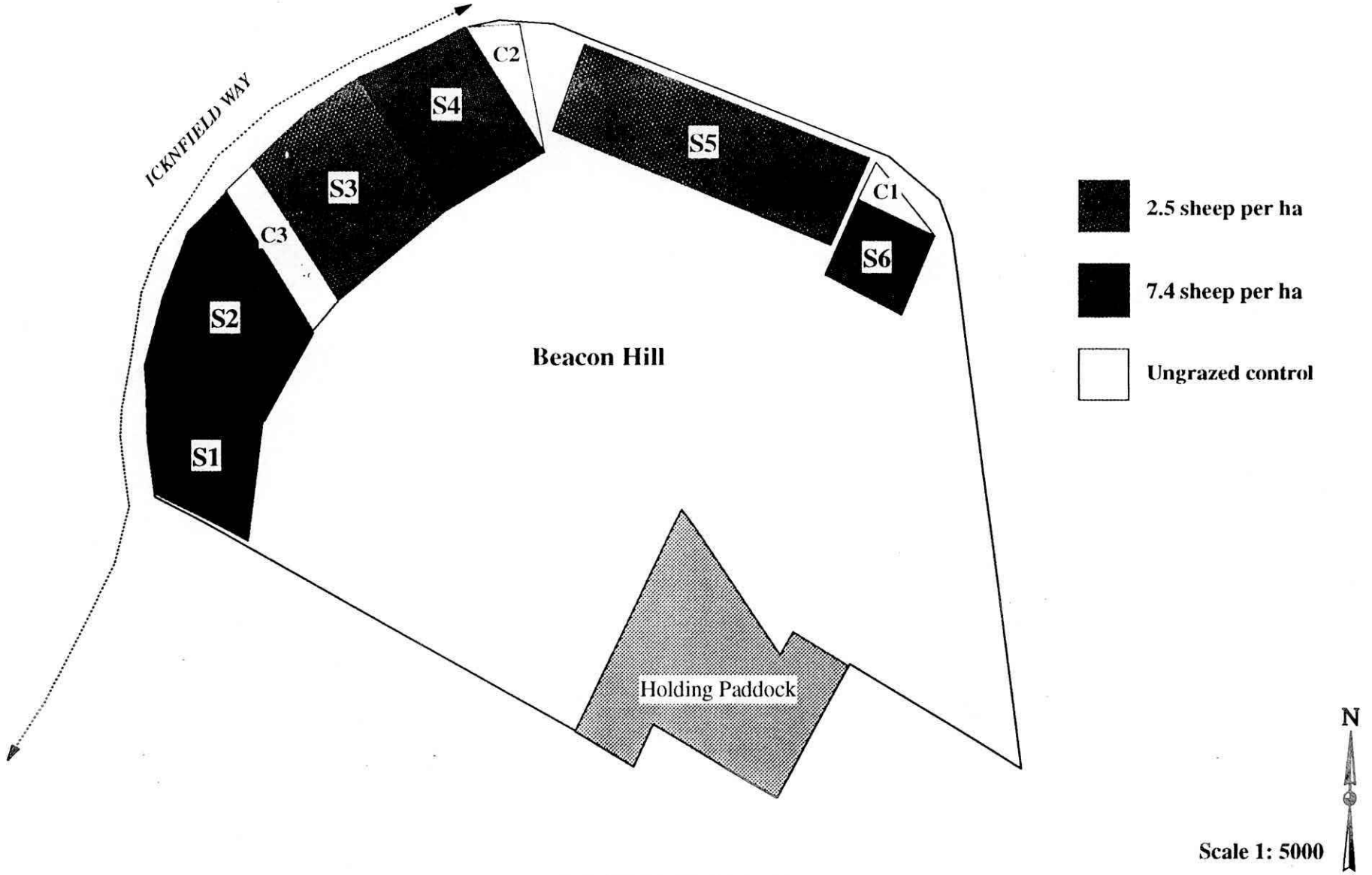
4.1.1.2 Methods

The objective of the experiment was to examine the effects of different intensities of sheep grazing on the structure and floristic composition of the chalk grassland. Between 1963 and 1964, six paddock plots (S1 - S6), each of approximately a hectare in area, were established on calcareous grassland adjacent to and above the Upper Icknield Way (Ridgeway Path), below Cuckoo Pen on the north- and west-facing slopes of Beacon Hill (grid ref. SU725975; Fig. 4.1). Three smaller, unmanaged control strips were established between the paddocks (C1 - C3). These were situated on a gentle slope (<5°) at an altitude of 165 - 170m A.O.D. Soils were of the Upton 1 series (grey rendzinas), described as shallow, well-drained, calcareous, silty soils over chalk.

Grazing regime 1964 - 1971

Plots S1, S3 and S5 were subject to light grazing of one sheep per acre (c. 2.5 sheep ha^{-1}; 0.38 LU ha^{-1}). Plots S2, S4 and S6 where subjected to three times the stocking rate (3 sheep per acre; 7.4 ha^{-1}; 1.1 LU ha^{-1}). The sheep were removed from the plots at the beginning of June and returned in October. This management regime was maintained between 1964 and 1971, and the site recorded annually.

Fig. 4.1 Lay-out of sheep grazing experiment at Aston Rowant NNR, Oxfordshire



Grazing regime late 1970s - present

The grazing regime during the late 1970s and early 1980s was less closely regulated, though all six plots were maintained under sheep grazing. Botanical recording was continued less frequently. In 1982, it was proposed that the more western plots (S1 - S3) be managed as in 1964 - 71 (with S2 having three times the grazing pressure of the other two plots). At the same time the eastern plots (S4 - S6) were to be used as handling areas when sheep-dipping, and as a holding ground for a Beulah ram, and wethers. From 1988, English Nature introduced a detailed planning and reporting system, which allows the stocking-rates to be calculated. This system reports considerable variation in the stocking rate i) between plots; ii) from year to year in the same plot; and iii) from week to week within the same plot in the same year (Table 4.1).

Despite this variation in intensity, sheep grazing has been maintained in the plots for 30 years. The plots have also been subject to rabbit grazing, particularly in S1 - S3 where extensive burrows and scrapes occupy the upper margins of the plots. In recent years, small areas of the plots have been temporarily fenced in order to allow fruiting and seed-shedding of species sensitive to intense grazing e.g. *Orchidaceae*. Invading shrubs (*Cornus sanguinea*, *Crataegus monogyna*, *Fraxinus excelsior* and *Ligustrum vulgare*) have been cut back to <50 cm. The lower margin of the plots is moderately shaded and there are scattered ant-hills present, most frequently in S4.

Botanical composition

Between 1964 - 1973 the structure and composition of the vegetation in each of the plots was described from a series of fifty 20 cm by 20 cm quadrats placed at random. The prescence of species was noted in each quadrat to give a root frequency of occurrence. The dates of recording varied between years, but was either in the month of June or September, or often both. In addition, the average sward height was recorded in every quadrat. In 1978 the experiment was recording once more using the same techniques. Finally, in September 1993, eighteen $1m^2$ quadrats were recorded in each of four plots (S1 - S4). Within each plot, six quadrats were positioned toward the top of the slope, six near the foot of the slope, and the remaining six approximately half-way between.

Table 4.1 Sample stocking rates and durations for plots S1-S6 during the period 1987-93.

S1 in 1987		**S3 in 1987**	
Before Apr 24:	ungrazed	Before Apr 24:	ungrazed
Apr 24-27:	30 ewes and 42 lambs	Apr 24-27:	30 ewes & 42 lambs
Apr 28:	ungrazed	Apr 28 - June 9:	ungrazed
Apr 29:	5 ewes	June 7-10:	21 hoggets
Apr 29 - June 6:	ungrazed	June 11-15:	ungrazed
June 7-10:	23 hoggets/wethers	June 16:	21 hoggets
June 11 - July 4:	ungrazed	June 17 - Sept.27:	ungrazed
July 5:	50 hoggets/wethers	Sept 28:	2 ewes and 18 lambs
July 6-8:	ungrazed	Sept 29-30:	ungrazed
July 9:	50 hoggets/wethers	Oct 1:	18 lambs
July 10 - Sept. 27:	ungrazed	Oct 2 - Nov. 4:	ungrazed
Sept 28:	94 ewes and wethers	Nov 5:	50 ewes
Sept 29-30:	ungrazed	Nov 6-11:	ungrazed
Oct 1:	96 ewes and wethers	Nov 12:	50 ewes
Oct 2-18:	ungrazed	Nov. 13 onward:	ungrazed
Oct 19:	87 ewes and wethers		
Oct 20-25:	ungrazed		
Oct 26:	87 ewes and wethers		
Oct 27 onward:	ungrazed		
S1 in 1988		**S1 in 1990**	
Before May 28:	ungrazed	Before Aug 21:	ungrazed
May 28 - June 5:	48 ewes & 75 lambs	Aug 21:	2 ewes
June 6 onward:	ungrazed	Aug 22 onward:	ungrazed
S4 in 1992:		**S4 in 1993**	
Before Oct 22:	ungrazed	Ungrazed throughout year	
Oct 22:	50 ewes		
Oct 23:	8 ewes		
Oct 24 onward:	ungrazed		

4.1.1.3 Results and discussion

Effects of management on floristic composition 1964 - 1973

In the early years of the experiment, the different grazing management regimes probably had the greatest effect on the structure of the vegetation. As expected, the sward was significantly shorter in the plots where stocking density was highest (S2, S4 and S6). These differences were most apparent in the July recording, one month after the sheep had been removed (Table 4.2). At the lower stocking density the grass ranged from 7.6 cm to 11.4 cm, whereas at the higher density the sward was 3.8 cm - 8.9 cm high. The grass in the unmanaged controls was much taller (10.2 cm to 34.9 cm). The greatest change occurred in plot S6 which was dominated by the tall grass species *Arrhenatherum elatius*. The vegetation was reduced from an average height of 45.7 cm to 8.9 cm by the highest rate of sheep grazing. There was considerable growth of grass following the removal of the sheep each year. On average the *Fesuca* - dominated plots increased 2.5 cm between July and September, wheras the *Arrhenatherum* - dominated plots increased by 5 cm to 12.5 cm in height.

Table 4.2 Mean sward heights under different grazing regimes

Plot No.	Sheep ha^{-1}	Sept. 1964	July 65	Sept. 1965	July 66	Sept. 1966
S1	2.5	12.7	8.9	10.2	7.6	11.4
S2	7.4	10.2	3.8	6.4	4.1	7.4
S3	2.5	15.2	7.6	10.2	8.4	12.2
S4	7.4	23.5	5.1	5.7	2.4	6.9
S5	2.5	19.1	10.8	15.2	9.1	15.5
S6	7.4	45.7	8.9	20.3	8.4	25.4
C1	0	14.0	34.9	33.0	42.7	31.0
C2	0	8.9	15.9	12.1	12.7	15.5
C3	0	14.0	10.2	11.4	10.7	14.0

Large fluctuations in the total number species occurred in the grazed plots between years (Table 4.3). However, these did not appear to show any relationship to the grazing regime. The effects of grazing are, to some extent, masked by the large numbers of species occurring at very low frequency, especially annuals whose numbers fluctuate greatly. Significantly fewer species were recorded in the unmanaged controls in all years. In terms of species richness, the ungrazed controls contained the fewest species. There was little difference in the number of species found on the 'light' and 'heavily' grazed treatments after 9 years.

Grasses formed more than 80% of the total vegetation cover in all plots. The actual proportion of the different grass species varied between plots on response to factors such as soil depth and fertility, and land use history. *Arrhenatherum elatius* was especially frequent on the deeper soils at the foot of the slopes. This was probably due to the ploughing of this area in 1900 and scrub clearance prior to the beginning of the experiment. It was often intermingled with another coarse grass species *Brachypodium sylvaticum*.

Festuca rubra, together with lesser quantites of *F. ovina*, were the most abundant species in all plots with typical frequencies of 100% (Table 4.3). These showed little response to grazing regime. In contrast, *Arrhenatherum elatius* was greatly reduced in the heavily grazed plots from a tall (30 - 50 cm) stand with a large quantity of litter to small tufts 2 - 4 cm tall in a *Festuca* - dominated turf. However, frequency of this species still remained high. *A. elatius* increased significantly in the unmanaged controls. *Brachypodium sylvaticum* increased in all of the plots, although the increase was greatest in the less intensively grazed plots. This species is extremely unpalatable to sheep and it was only eaten when stocking rates were highest. Conversely, *Dactylis glomerata* is extremely palatable to sheep and also increased in all plots, despite heavy grazing. *Holcus lanatus* increased in all plots, although the increase was significantly greater in the heavily grazed plots. Finally, the sedge *Carex flacca* appeared to flourish under conditions of heavy or light grazing, whereas *C. caryophyllea* fluctuated greatly in abundance between years with no clear pattern in relation to grazing. Other grass and sedge species occurred at too low a frequency for any relationship to grazing intensity to be established.

Table 4.3 Mean root frequency of species recorded at Aston Rowant 1964 - 1993 (* = not recorded in that year)

Treatment	Ungrazed control		light grazed S1,S3,S5		heavy grazed S2,S4,S6		
Date	1964 - 1973	1964 - 1973	1978	1993	1964 - 1973	1978	1993
Agrostis stolonifera	19.0	30.8	24.5	55.5	30.8	27.5	61
Arrhenatherum elatius	60.1	48.4	76	41.5	53.2	48	55.5
Avenula pratense	15.7	12.4	24	30.5	8.5	27	16.5
Avenula pubescens	21.5	12.1	17	28	11.5	19.5	33
Brachypodium sylvaticum	32.4	34.0	46.5	91.5	48.2	33	66.5
Briza media	10.0	12.0	9	41.5	10.8	16.5	69.5
Bromus erecta						2	11
Cynosurus cristatus						1	
Dactylis glomerata	20.7	13.7	27	86	12.7	32.5	72.5
Festuca ovina/rubra	94.5	95.5		28	96.5		67
Festuca rubra			93	100		97.5	100
Holcus lanatus	22.0	43.2	38.5	80.5	35.8	34.5	64
Koeleria macrantha	22.0	17.3	14	50	15.5	11.5	30.5
Phleum bertolonii			10.5	61		6.5	24
Poa angustifolia							11
Poa pratensis	14.5	9.8	5	41.5	14.7	4.5	39
Trisetum flavescens			23	41.5		37	44.5
Carex caryophyllea	11.3	6.2	5	11	8.1	7	11
Carex flacca	53.6	61.5	65.5	100	59.0	72	100
Achillea millefolium	65.9	52.0	76.5		54.4	79	94
Agrimonia eupatoria			4	16.5			5
Anthriscus sylvestris			1				
Arabis hirsuta							5
Arenaria serpyllifolia			1				5
Asperula cynanchica			7	25		12	44.5
Bellis perennis						2	
Blackstonia perfoliata			1	5		2	16
Campanula glomerata			6	42		12.5	50
Campanula rotundifolia	15.7	18.0	31	94.5	21.2	65.5	94
Carlina vulgaris			1	5		2	5
Centaurea nigra			2.5	27.5		2.5	44.5
Centaurea scabiosa							5
Cerastium fontanum			2	24.5		8.5	11
Cirsium acaule	18.8	6.5	4	38.5	6.4	25	50.5
Cirsium arvense			2.5	22		1	83
Cirsium palustre				11			
Cirsium vulgare	44.8	30.8	3.5	22	35.7	6.5	5
Coeloglossum viride						1	16.5
Cornus sanguinea			3.5	8		8	39
Corylus avellana							11
Clinopodium vulgare			71.5	91.5		68.5	88.5
Crataegus monogyna			4	33.5		2.5	28
Crepis capillaris	8.0	12.9	33.5	77.5	20.2	64	16.5
Daucus carota				19.5		1	38
Euphrasia nemorosa	10.3	7.4	22	72.5	25.7	64.5	72
Filipendula vulgaris			1	5		1	11
Fragaria vesca	19.4	13.8	6.5	8	11.5	8	
Fraxinus excelsior				5			5
Galium aparine			2				
Galium mollugo			9	41.5		13	25
Galium verum	31.9	41.0	66.5	94	33.2	73.5	97
Gentianella amarella	8.0	2.7	4.5	39	7.8	65.5	50
Geranium robertianum			1			1	
Glechoma hederacea			1.5				
Helianthemum nummularium	28.4	20.7	18	41.5	20.0	22.5	50
H. pilosella	10.2	6.2			8.8		
Hippocrepis comosa				5			11
Hypericum perforatum			5.5	44.5		3	30.5

Table 4.3 cont	Ungrazed control	light grazed S1,S3,S5			heavy grazed S2,S4,S6		
	1964 - 1973	1964 - 1973	1978	1993	1964 - 1973	1978	1993
Iberis amara	5.7	6.2	6	11	4.1		
Lathyrus pratensis			5	5		2	8
Leontodon autumnalis			3.5			7	
Leontodon hispidus	30.9	24.6	29	58.5	18.7	85	97
Leontodon saxatilis				77.5			69.5
Leucanthemum vulgare			1				
Ligustrum vulgare			4.5	22		1	11
Linaria repens			3	22		4	
Linum catharticum	11.4	9.5	21	86	17.2	74	89
Lotus corniculatus	40.3	43.2	45	83	30.9	66.5	100
Medicago lupulina	9.6	10.2	3	44.5	11.3	6	19
Myosotis arvensis			2			1	
Origanum vulgare	14.4	6.3	2	28	12.8	1	28
Pastinaca sativa	14.1	11.6	35.5	28	19.0	12	5
Picris hieracioides			11	16		7	42.5
Pilosella officinarum			2	14		21	22
Pimpinella saxifraga			10.5	66.5		8	66.5
Plantago lanceolata	38.1	43.4	73.5	100	45.8	92	97
Plantago media			3	5		5	33
Polygala vulgaris	5.9	2.3	2	14	2.9	4.5	16.5
Potentilla anserina			3	11		2	
Potentilla reptans	20.1	21.8	25.5	39	27.9	11.5	13.5
Prunella vulgaris	13.7	11.6	28.5	86	15.4	57.5	86
Prunus spinosa				17			
Ranunculus bulbosus	6.7	3.2	18.5	33.5	4.5	17	24.5
Ranunculus repens				5			
Reseda lutea			1.5	8		6	11
Rhamnus catharica				5			5
Rhinanthus minor			16	5			50
Rosa canina			3.5	16.5		1.5	5
Rubus fruticosus			10.5	33		8	5
Sanguisorba minor	65.1	63.0	73.5	91.5	53.2	56.5	94.5
Scabiosa columbaria	14.9	8.9	15	91.5	12.0	50.5	100
Senecio jacobaea	7.3	5.1	8	25	9.8	13	44.5
Sonchus spp			3	11		8	
Succisa pratensis				5			
Taraxacum agg.				11		2.5	
Thymus polytrichus	25.6	18.1	22	58	20.5	40.5	55.5
Thymus pulegioides			4.5			13.5	
Tragopogon pratensis							5
Trifolium pratense			2.5	25		5	66.5
Trifolium repens			4.5	5		9	5
Valeriana officinalis			1				
Veronica chamaedrys	23.6	31.3	54	38.5	29.6	22	11
Veronica officinalis			1				
Viburnum lantana			7.5			3.5	8
Viola hirta	10.2	6.3	9.5	47	6.4	4.5	44.5
Calliergon cuspidatum	19.9	15.5	•	61	20.4	•	80.5
Campylium chrysophyllum			•	5		•	5
Ctenidium molluscum			•	5		•	11
Dicranum scoparium			•	5		•	
Fissidens sp.			•	22.5		•	41.5
Plagiomnium undulatum			•			•	5
Pseudoscleropodium purum	52.8	41.3	•	97	48.7	•	83
Rhytidiadelphus squarrosus	11.3	7.5	•	55	10.7	•	5
Rhytidiadelphus triquetrus			•	11		•	
Weissia microstoma			•	5		•	
Mean no. species	41.3	58.5	75	76	63.1	71	74

The perennial forbs *Prunella vulgaris, Thymus polytrichus* and *Galium verum* increased in all of the grazed plots compared to the unmanaged controls. Similarly, *Campanula glomerata* and *Medicago lupulina* were significantly

more abundant in the heavily grazed plots compared to the lightly grazed plots and the controls. These species all have a prostrate growth habit, much of which is below the bite of sheep. Also, *T. polytrichus* is unpalatable to sheep and *M. lupulina* is a short-lived perennial which can spread rapidly by seed into the gaps created by heavy grazing. Other species, such as *Clinopodium vulgare, Helianthmum nummularium, Potentilla reptans, Plantago lanceolata, Sanguisorba minor,* and *Lotus corniculatus* fluctuated greatly between years, but showed no apparent pattern in response to grazing regime. These species were, however, significantly less abundant in the controls.

Table 4.4 Summary of changes observed in species during first five years of grazing experiment.

* Large change ** Very large change *** Extremely large change

Species	1 sheep acre (S1 & S3)	3 sheep acre (S2 & S4)	Control (C1 - C3)
Agrostis stolonifera	decrease	no change	decrease
Arrhenatherum elatius	increase *	increase	increase
Brachypodium sylvaticum	increase	increase	increase
Dactylis glomerata	increase	increase	increase
Festuca rubra / ovina	increase	increase	increase
Holcus lanatus	increase *	increase *	increase
Poa pratensis	increase *	increase *	increase
Clinopodium vulgare	decrease	no change	no change
Campanula rotundifolia	increase	increase *	increase
Cirsium acaule	no change	increase	decrease
Crepis capillaris	increase	increase **	no change
Euphrasia nemorosa	increase	increase ***	decrease
Galium verum	increase *	increase *	no change
Gentianella amarella	decrease	no change	decrease
Iberis amara	decrease	decrease	decrease
Leontodon hispidus	no change	decrease	no change
Linum catharticum	decrease	increase	decrease
Lotus corniculatus	increase	increase	no change
Plantago lanceolata	no change	increase	decrease
Prunella vulgaris	increase	increase	decrease
Thymus polytrichus	no change	increase	decrease
Veronica chamaedrys	increase	increase *	increase
Pseudoscleropodium purum	no change	increase	decrease

Only three annual forb species were present in large numbers in the experimental plots. The response of these species to grazing management was the most interesting finding of the experiment. In the control plots *Euphrasia nemorosa* and *Linum catharticum* both significantly decreased in abundance with time, although localised rabbit activity in 1965 and 1966 enabled small numbers of these species to be maintained. Only small numbers of *Crepis capillaris* occurred in the control plots throughtout the experiment. All three species spread and increased in abundance within the grazed plots. This can be explained by grazing maintaining a short, open sward and providing

areas of bare ground which are critcal for the long term survival of annual species. Finally the rare annual species, *Iberis amara* increased in frequency in all of the grazed plots in the first year. However, in subsequent years the species declined. The most likely explanation for this is that grazing provides suitable germination sites, but the species is highly palatable to sheep and is selectively grazed.

Effects of management on floristic composition 1974 - 1993

The wholescale changes in the management of the plots which took place after 1974 make it difficult to interpret the composition of the vegetation in subsequent years. Any trends that might have been specifically related either to 'light' or to 'heavy' grazing during the first eight years of the study have since been obscured. There is very little evidence of species decreasing - indeed by 1993, only *Fragaria vesca* had declined in a majority of plots, and the apparent declines observed in some plots in both *Potentilla reptans* and *Veronica chamaedrys* could not be convincingly related to past grazing regime. About half the species recorded (58 of 123) within plots S1-S4 increased in apparent frequency between 1964 and 1993. In 1964 (and 1978) fifty 20cm quadrats were recorded, a total area within each plot of $2m^2$, whereas in 1993 $18m^2$ were recorded. Although the total area from which data were gathered increased, the random scattering of the quadrats means it is unlikely that this should account for anything more than a small proportion of the marked changes in species frequency observed. There is little pattern in the taxonomy or growth-form of the species which have increased: grasses, sedges, shrubs, annuals, chamaephytes, rosette and semi-rosette hemicryptophytes.

The vegetation in all the plots comprised a short grassland, generally ≤6 cm tall, but toward the foot of the slope on deeper soils, it was somewhat taller (c. 10 cm). The sward was relatively even and compact, except around rabbit warrens and where scrub management had occurred. The turf was species-rich, with an average of 34 species per quadrat (25-46 species per m^2) and showed no marked pattern in diversity in relation to plot or position on the slope. The community was dominated by *Festuca rubra* and *Carex flacca*, with scattered tufts of *Brachypodium sylvaticum*, in a forb-rich turf where *Plantago lanceolata, Sanguisorba minor, Scabiosa columbaria* and *Leontodon* species were especially prominent. Although ten bryophyte species were noted, only *Calliergon cuspidatum* and particularly *Pseudoscleropodium purum* had significant cover.

Amongst the less widespread chalk-grassland forbs present were *Asperula cynanchica, Blackstonia perfoliata, Coeloglossum viride, Filipendula vulgaris* and *Hippocrepis comosa.* At least 40 spikes of *C. viride* were present in both plots S3 and S4, especially in the middle and upper parts of the slope. Two species more typical of disturbed chalk habitats had important populations in the plots, growing near rabbit warrens and along fence lines: *Iberis amara*, a nationally scarce species, was frequent on rubble by rabbit-scrapes in plot S1, whilst *Linaria repens* was most common in coarser grassland near the foot of the slope, occurring only sporadically elsewhere.

4.1.1.4 Conclusions

The continuation of sheep grazing over thirty years, admittedly with varying intensity, can be considered to have been successful in conserving the majority of species originally present within the sward, as well as producing what is evidently a more species-rich composition by 1993. The background grazing from rabbits and, where necessary, the suppression of scrub invasion may also have contributed to this success. The persistence of an uncommon grassland community (CG6a) on Beacon Hill for at least 20 years is also of some interest. The survival of *Iberis amara* (and *Linaria repens*) in this area may depend on the continued presence of significant rabbit populations.

4.1.2 Parsonage Down, Wiltshire

4.1.2.1 Study site

Parsonage Down National Nature Reserve (grid ref. 42 / 040413) comprises some 276 ha of gently undulating downland lying to the east of the Iron Age camp site known as Yarnbury Castle. The site is highly valued as one of Britain's finest calcareous grasslands. It has been managed by a mixture of cattle and sheep grazing at low densities for at least the last 53 years. The site is divided into three areas for the purposes of management:

(1) Old Downland

Some 147 ha of unimproved chalk grassland supporting an exceptionally diverse flora and fauna.

(2) New Downland

Two areas of old downland, known as '100 acres' and Parsonage Down, covering some 40 ha which were compulsorily ploughed during World War Two. These were returned to pasture in 1946, but even today differ considerably in floristic composition from the adjacent old downland (Wells *et al* 1994).

(3) Back-up land

Eight fields, accounting for about 89 ha of the reserve have been sown with leys to which fertilisers are applied and are used as pasture or for hay production. These fields play an essential role in the overall farm management, allowing livestock to be moved on and off the floristically rich downland when herbage is in short supply or when conditions are not favourable for grazing.

4.1.2.2 Grazing management

The diverse chalk grassland community has been produced and is maintained by long term livestock grazing (Box

4.1). Stocking levels have being carefully adjusted so that grassland is neither under or overgrazed. The sward is kept short, usually less than 5 cm high, often only 1cm in height. Poaching is kept to a minimum and agricultural weeds such as thistles and ragwort are at very low levels. Apart from a small amount of chain harrowing, used to keep the sward open and prevent the build up of litter, the old downland is managed solely by grazing. No fertilisers are applied to the old downland. Both cattle and sheep graze all the year round, hay and straw are fed in winter, and care is taken to use less species-rich areas as feeding points.

Stocking levels are such that cattle contribute about 80% of the grazing and sheep 20% . Stocking levels on the old downland are 0.25 dairy cow equivalents per acre (0.6 Livestock Units LU per ha^{-1}), 0.4 diary cow equivalents on the new downland (1.0 LU ha^{-1}).

Box 4.1 Management of Parsonage Down:

Cattle: Between the 1930s - 1972 the Down was grazed by a mixture of Aberdeen Angus, Belted Galloways and Blue Greys being ranched over more than 1000 acres (400 ha). Between 1973 and the present the site has been grazed by 330 - 350 beef cattle including 90 breeding cows. As these remain out in winter and calve on the open down, hardy breeds are used: Hereford crosses pre-dominate, while characteristics are also derived from Longhorn, Angus and British White. The cows are served by a Charolais bull which produces a quick growing calf suitable for market at all times of the year. Calves are typically produced in spring, weaned and taken to the stocking yards in January. There is also a small herd of Longhorn cattle.

Sheep: The flock consists of 430 Scotch half-bred ewes, crossed with Suffolk rams for fat and ewe lamb production. Lambing occurs in fields close to the farm and ewes and lambs are put out into all the fields. Ewes with twin lambs are put on the down in April and lambs are sold from May to October. The rams are put with the ewes from December until March when all the sheep come off the down. Winter feeding occurs from December until April, the winter feed areas being harrowed in May. All lambs are sold by late October.

4.1.2.3 Botanical recording

The floristic composition and structure of the old downland was described from four transects in May 1970. Two transects were 34 m long and a further two were 18 m long. The position of each transect was surveyed and marked with a peg. The cover abundance of all higher plants and mosses was estimated using the Domin scale in 20 cm quadrats placed at 1 m intervals along each transect. The same transects were re-located and recorded in August 1990 to investigate changes in the vegetation over a twenty year period of apparently stable management.

4.1.2.4 Results and discussion

(a) Visual appearance and structure of the old downland in 1970 and 1990

In 1970, the outstanding feature of the Down was considered to be the uniformity in structure, comprising turf 3 - 5 cm high. Over considerable areas the floristic composition was remarkably constant, with *Festuca ovina* the most abundant grass with smaller quantities of *Agrostis stolonifera, Briza media, Cynosurus cristatus, Dactylis glomerata, Avenula pratensis, A. pubescens, Koeleria macrantha* and *Trisetum flavescens*. *Carex flacca* and *C. caryophyllea* were constant associates of the grasses. Of great interest was the abundance of the nationally scarce sedge *Carex humilis*. This species has a western distribution in England, and is known from about only 35 sites in England. It is usually associated with old, species-rich grassland which is subjected to stable a management regime.

The grassland contained a wide variety of forb species, the most abundant of which were *Campanula rotundifolia, Centaurea nigra, Cirsium acaulon, Filipendula vulgaris, Galium verum, Leontodon hispidus, Plantago lanceolata, Sanguisorba minor, Succisa pratensis* and *Trifolium pratense*. *Polygala calcarea*, an uncommon species of the Oceanic Southern climate, was widespread on the down, as were many orchid species, especially *Orchis morio* and *O. ustulata*. Other scarce species worthy of mention included: *Spiranthes spiralis, Anacamptis pyramidalis, Cynoglossum officinale, Gentianella anglica, Ononis spinosa, Ophrys apifera, Saxifraga tridactylites* and *Erophila verna*. Mosses were generally scarce and only *Pseudoscleropodium purum* and *Camptothecium lutescens* are widespread.

In 1990, Parsonage Down had much the same appearance as it had in 1970. The turf had retained its 'fine grained' appearance consisting of a mosaic of small, closely grazed forbs and grasses. There were no signs of the grasses becoming dominant. Despite the drought (which was severe in 1989 and 1990), the turf was green and uniform in structure. It had been closely grazed, the mean height being 2 cm (range 1 - 3 cm); in May 1970 the turf had been slightly longer, mean height 3.6 cm (range 1 - 7 cm). The site manager controlled the vegetation height by increasing stocking levels on the down when vegetation growth was greatest in the spring and reducing them in the autumn and winter.

(b) Species composition of the grassland, 1970 and 1990

The species composition of the site changed very little between 1970 and 1990. Sixty-eight species were recorded in May 1970. Sixty-one species were recorded in August 1990. The twelve species recorded in 1970 but not in 1990 were all of low frequency. They can be divided into 3 groups: (a) those which would have no above ground leaves in August, and so would not be recorded: *Crepis capillaris, Orchis morio, O. ustulata*, (b) mosses which had dried up by August: *Acrocladium cuspidatum, Mnium spp., Rhytidiadelphus squarrosus* and (c) other species of low frequency and therefore easily overlooked: *Bellis perennis, Ligustrum vulgare, Spiranthes spiralis, Trifolium campestre, Veronica chamaedrys* and *Bromus erectus*. All of these species were seen and noted in grassland near

to the quadrats, so were still present on the site. These were *Achillea millefolium, Fissidens spp., Gentianella amarella, Lolium perenne* and *Trisetum flavescens*. We have accordingly focused on the dynamics of the more common and abundant species.

The mean number of species per quadrat in transects 2 and 3 was remarkably similar in 1970 and 1990 (22.1 and 21.5 in transect 2; 22.1 and 22.3 in transect 3; Table 4.5). In transect 1, the mean number of species per quadrat declined from 23.8 to 20.8 (significant at $P \leq 0.001$); in transect 4 the mean number of species per quadrat also declined from 26.05 in 1970 to 19.2 in 1990 (sign. at $P \leq 0.001$). Possible reasons for this might include localised disturbance caused by rabbit activity or livestock poaching.

Table 4.5 Changes in the vegetation composition of Parsonage Down 1970 - 1990

	Year	Transect No.				
		1	2	3	4	overall
Mean height (cm)	1970	3.8	3.7	4.2	2.8	3.6
	1990	2.1	1.9	2.3	1.9	2.1
No. of species per quadrat	1970	23.8	22.1	22.1	26.1	23.5
	1990	20.8	21.5	22.3	19.2	21.0
No. of Grasses	1970	10	9	8	9	9.0
	1990	8	9	11	10	9.5
No. of Sedges	1970	3	3	3	3	3.0
	1990	3	3	3	3	3.0
No. of Forbs	1970	38	39	34	39	37.5
	1990	35	37	32	35	34.8
No. of Mosses	1970	5	5	4	3	4.3
	1990	4	2	2	2	2.5

Table 4.6 shows the changes in species composition for each transect, highlighting the fact that transects apparently may gain or lose species without changing the mean number of species per quadrat of per transect. Most of the species which appear to be lost or gained are those with low frequencies (1 - 10) or short-lived species which are replaced regularly by seed, for example *Campanula glomerata* and *Leontodon autumnalis* and which therefore could be expected to fluctuate more in response to climatic or the availability of gaps in the sward.

Table 4.6 Changes in species composition of each transect

Transect No.	Species present 1970, absent in 1990 (with frequency)	Species present 1990, absent in1970 (with frequency)
1	*Acrocladium cuspidatum (3)*	*Cirsium arvense (3)*
	Crepis capillaris (3)	*Fissidens spp. (3)*
n=38	*Hippocrepis comosa (10)*	*Picris hieracioides (8)*
	Luzula campestris (3)	
	Orchis morio (3)	
	Phleum bertolonii (3)	
	Rhyt. squarrosus (3)	
	Thymus drucei (5)	
	Bromus erecta (3)	
2	*Acrocladium cuspidatum (1)*	*Achillea millefolium (3)*
	Asperula cynanchica (14)	*Anthyllis vulneraria (6)*
n=35	*Crepis capillaris (3)*	*Cirsium arvense (6)*
	Hieracium pilosella (3)	*Gentianella amarella (3)*
	Ligustrum vulgare (3)	*Ononis spinosa (6)*
	Mnium sp. (3)	*Polygala calcarea (3)*
	Orchis morio (6)	*Senecio jacobaea (9)*
	Rhytid. squarrosus (9)	
	Thymus drucei (3)	
	Tragopogon pratense (3)	
	Trifolium campestre (3)	
	Veronica chamaedrys (3)	
3	*Acrocladium cuspidutum (10)*	*Anthyllis vulneraria (6)*
	Bellis perennis (5)	*Cirsium arvense (19)*
n=21	*Crepis capillaris (5)*	*Leucanthemum vulgare (10)*
	Luzula campestris (14)	*Lolium perenne (5)*
	Picris hieracioides (33)	*Ononis spinosa (19)*
	Polygala calcarea (10)	*Phleum bertolonii (19)*
	Rhytid. squarrosus (14)	*Taraxacum laevigatum (19)*
	Senecio jacobaea (5)	*Trisetum flavescens (5)*
	Spiranthes spiralis (5)	
4	*Asperula cynanchica (10)*	*Gentianella amarella (5)*
	Campanula glomerata (19)	*Leontodon autumnalis (33)*
n=21	*Crepis capillaris (5)*	*Leucanthemum vulgare (5)*
	Hieracium pilosella (14)	*Lolium perenne (10)*
	Orchis ustulata (10)	*Thymus polytrichis (5)*
	Pseudoscleropodium purum (28)	
	Spiranthes spiralis (5)	
	Taraxacum laevigatum (10)	
	Trifolium campestre (10)	

4.1.2.5 Conclusions

The results show that a stable, extensive grazing regime is effective in maintaining the structure and floristic composition of calcareous grassland for over 20 years. The fluctuations in species abundance between quadrats and transects serves to emphasise the dynamic nature of grassland ecosystems at different scales, even when undergoing apparently stable managment practices. These small scale differences might reasonably be ascribed to external factors, such as changes in plant performance due to climate or micro-climate fluctuation. Finally, this study emphasises the importance of close by, productive grassland to support the conservation management of the downland.

4.1.3 WYLYE DOWN, WILTSHIRE

4.1.3.1 Study site

Wylye Down NNR (grid ref. SU0036) occupies and area of some 45 ha (111 acres). It consists of ancient and uniformly high quality calcareous grassland on the west- and east-facing slopes of the Wiltshire Downs (Plate 3). The site is considered to be one of the oldest grassland ecosystems in England and is of both outstanding ecological and archaeological interest. The site was in private ownership up till 1991 when it was purchased by English Nature.

4.1.3.2 Management

For the last 45 years and possibly for the last 70 years, the site has been grazed all year by a herd of 20 - 30 Ayreshire dairy cattle (0.4 - 0.7 LU ha^{-1}) together with variable numbers of sheep (Plates 3 & 4).

4.1.3.3 Botanical recording

In July of 1965, the botanical characteristics of the site were recorded by surveyors from ITE Monks Wood as part of the Nature Conservation Review (Ratcliffe 1977). A species list for the whole site was complied and the sward described by two 1 m x 1 m quadrats on the west-facing scarp slope. The site was re-surveyed in early September 1994 following the same methodology.

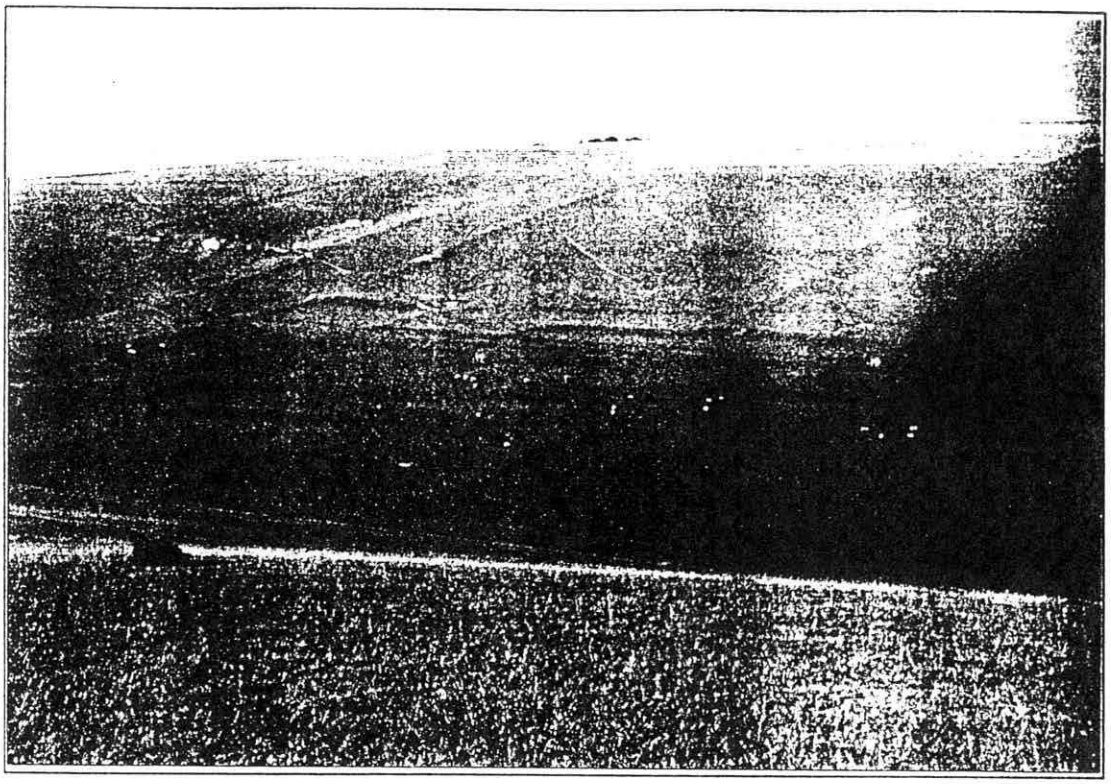


Plate 3. Wylye Down, Wiltshire (September 1994)

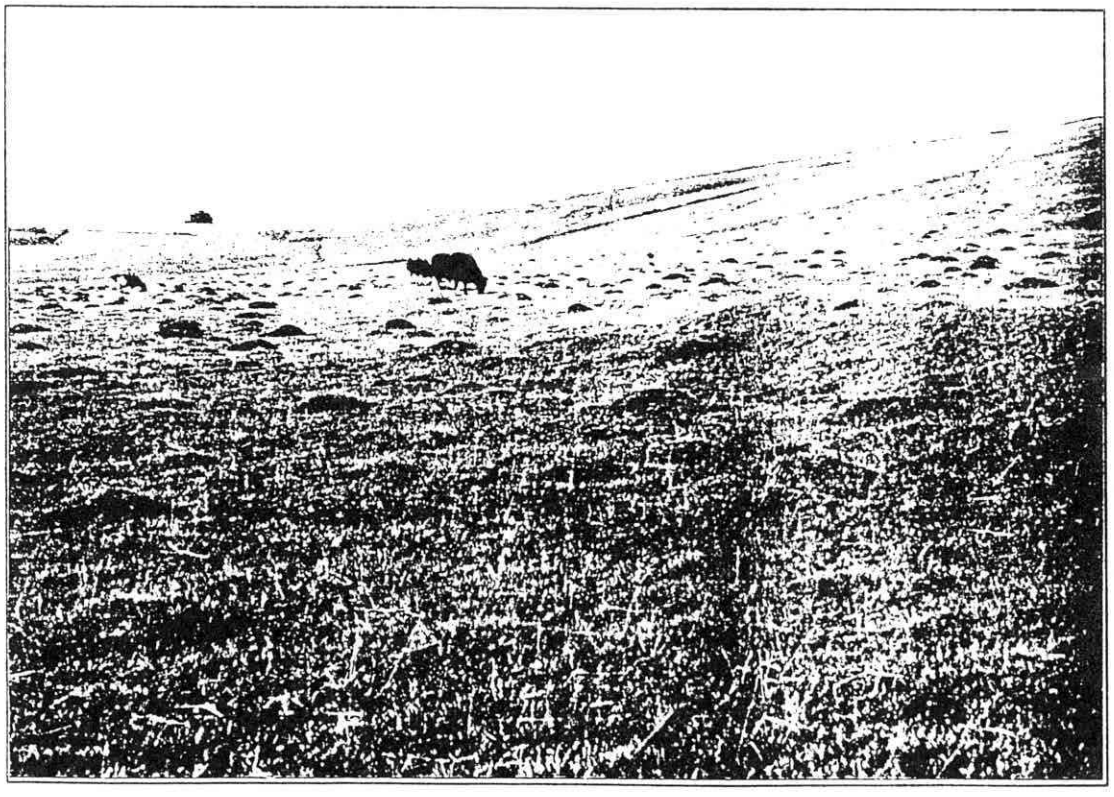


Plate 4. The closely grazed, diverse sward of Wylye Down maintained by cattle and sheep grazing.

4.1.3.4 Results and discussion

Comparison of the composition and structure of the downland 1965 - 1990

In 1965, the turf was 7 - 8 cm high and had outstanding floristic richness, typically with 40 - 45 species m^{-2}. The species list for the whole site contained 50 forb species alone. The sward was dominated by the nationally rare sedge, *Carex humilis* (Table 4.7). Lesser amounts of *Carex flacca, Festuca ovina, Briza media* and eight other species of grass were also recorded. Large numbers of associated forbs were present, including species of restricted distribution such as *Coeloglossum viride, Hippocrepis comosa, Serratula tinctoria* and *Thesium humifusum.*

Despite the relatively few quadrats recorded, the vegetation closely resembled (71%) ,the *Succisa pratensis - Leucanthemum vulgare* sub-community of the *Festuca ovina - Avenula pratensis* grassland (CG2b) described in the National Vegetation Classification (NVC; Rodwell 1992). This is probably the most diverse of the calcareous grassland communities described in the NVC and is usually associated with sites which are closely grazed by sheep or cattle, and have remained undisturbed for many years or even centuries. Despite variation on a local scale, the outstanding feature of this grassland is the unusual structural and floristic uniformity over the whole site.

In 1994, the turf was tightly grazed to an average height of 2.5 cm (Plate 4). On the whole the composition of the grassland had changed very little in the last 30 years, although there had been a small decline in floristic diversity (37 - 35 species m^{-2}). The most likely explanation for this is the later recording date of the second survey. The grass *Festuca ovina* had replaced the rare sedge *Carex humilis* as the most dominant species, although the latter was still an important component of the sward (Table 4.7). The relative abundance of forb species has changed little with rare species such as *Pimpinella saxifraga, Helianthemum nummularium, Serratula tinctoria* and *Thesium humifusum* still abundant. After 29 years of stable livestock grazing, the grassland community was still a good fit (68%) to the *Succisa pratensis - Leucanthemum vulgare* sub-community of the *Festuca ovina - Avenula pratensis* grassland (CG2b) described in the NVC (Rodwell 1992).

Comparison of grazed vs. ungrazed downland

Immediately adjacent to Wylye Down NNR, on the same west-facing scarp, is an area of downland than has only been sporadically grazed by low numbers of livestock in recent years. The 1965 survey described this area as 'rough grassland', suggesting it was ungrazed or occasionally grazed at this time. The vegetation of this site was described in 1994 from four 1 m x 1 m quadrats placed at random. There was considerable encroachment of the downland by Hawthorn scrub. The grass sward was much taller (12 - 20 cm) and there was a deep litter layer. Coarser, tussock forming grasses such as *Dactylis glomerata* and *Festuca arundinacea* were dominant (Table 4.8). Smaller, mat-forming forb species, such as *Hippocrepis comosa* and *Thymus polytrichis*, were either greatly reduced in abundance or absent. However, the taller forb species, such as *Succisa pratensis* and *Sanguisorba minor* were still

important components of the turf. In 1965 the site was noted to contain a large population of the nationally rare Tuberous Thistle (*Cirsium tuberosum*). This species was still common on the site in 1994 with large numbers of individuals in flower and seed. The vegetation of the site corresponded to the *Avenula pubescens* grassland community (MG6) described in the NVC (Rodwell 1992). This type of grassland is associated with sites which have a history of infrequent disturbance, such as ploughing or fire, but receive little of no grazing.

4.1.3.5 Conclusions

As at Parsonage Down, relatively low stocking rates of cattle (0.4 - 0.7 LU ha^{-1}) and sheep appear to maintain much of the floristic and structural diversity of such ancient calcareous grassland over periods of at least 30 years. The apparent differences in the vegetation between the surveys is likely to reflect differences in sampling effort and the time of year. Evidence from adjacent sites suggests that the lack of grazing is associated with a loss of structural and floristic diversity of the grassland.

Table 4.7 Vegetation of Wylye Down in 1965 and 1990. 'Adj' = species adjacent but not present within the quadrat.

	1965		1994			1965		1994	
Species	%freq	max Domin	%freq	max Domin		%freq	max Domin	%freq	max Domin
Agrostis capillaris	25	2			*Hippocrepis comosa*	adj	adj	100	4
Agrostis stolonifera	88	3	50	1	*Hypochaeris radicata*			adj	adj
Avenula pratense	100	3	100	4	*Juniperus communis*			adj	adj
Avenula pubescens	50	2	50	2	*Leontodon autumnalis*	25	2	adj	adj
Briza media	88	3	50	4	*Leontodon hispidus*	50	3	100	4
Cynosurus cristatus	100	4	adj	adj	*Leontodon taraxacoides*	50	2	adj	adj
Dactylis glomerata	100	3	100	1	*Leucanthemum vulgare*			50	1
Danthonia decumbens	12	2	50	1	*Linum catharticum*	37	1	100	1
Festuca arundinacea			adj	adj	*Lotus corniculatus*	100	2	100	2
Festuca ovina	100	6	100	5	*Medicago lupulina*	25	2	50	1
Festuca rubra	37	2	adj	adj	*Picris hieracioides*			adj	adj
Koeleria macrantha	100	3	50	2	*Pimpinella saxifraga*	adj	adj	adj	adj
Lolium perenne			adj	adj	*Plantago lanceolata*	100	4	100	3
Phleum bertolonii	50	2	adj	adj	*Plantago media*	100	4	100	4
Poa pratensis			adj	adj	*Polygala vulgaris*	50	3	adj	adj
Trisetum flavescens	adj	adj	adj	adj	*Polygala calcarea*	12	2	adj	adj
					Potentilla erecta			adj	adj
Luzula campestris	50	2	adj	adj	*Primula veris*	63	2	adj	adj
Carex caryophyllea	50	2	adj	adj	*Prunella vulgaris*	88	2	50	1
Carex flacca	100	4	100	4	*Prunus spinosa*	12	0.01		
Carex humilis	63	3	100	8	*Ranunculus bulbosus*	100	2	adj	adj
					Sanguisorba minor	100	4	100	3
Achillea millefolium	12	2	adj	adj	*Scabiosa columbaria*	88	3	100	3
Anthyllis vulneraria			50	1	*Senecio jacobaea*	25	1	adj	adj
Asperula cynanchica	12	1	100	3	*Serratula tinctoria*	37	3	50	1
Bellis perennis			adj	adj	*Stachys officinalis*	25	4	50	1
Campanula glomerata	50	2	adj	adj	*Succisa pratensis*	100	4	100	5
Campanula rotundifolia			50	1	*Taraxacum officinale*	12	2	adj	adj
Carlina vulgaris			adj	adj	*Thesium humifusum*	adj	adj	adj	adj
Centaurea nigra			50	1	*Thymus polytrichis*	25	3	100	2
Cerastium fontanum	25	1	adj	adj	*Trifolium pratense*	100	3	adj	adj
Cirsium acaulon	100	3	100	4	*Trifolium repens*	63	2	50	2
Cirsium vulgare			adj	adj	*Viburnum lantana*			adj	adj
Crepis capillaris	37	2			*Viola hirta*	25	2	50	2
Coeloglossum viride			50	1					
Euphrasia nemorosa	88	2	50	1	*Acrocladium cuspidatum*	63	2	adj	adj
Euphrasia pseudokerneri			adj	adj	*Brachythecium rutabulum*			adj	adj
Filipendula vulgaris	88	4	50	1	*Homalothecium lutescens*	25	2	adj	adj
Galium verum	88	2	50	2	*Fissidens sp.*	12	0.01	50	2
Gallium mollugo			adj	adj	*Pseudoscleropodium purum*	100	3	50	2
Genista tinctoria			adj	adj	*Rhytidiadelphus squarrosus*	12	2	adj	adj
Gentianella amarella	adj	adj	50	1					
Helianthemum nummularium	100	4	50	1	**No. species in quadrat**	**34**			**29**
Hieracium pilosella	50	3	50	1	**Total no. species**	**36**			**42**

Table 4.8 The vegetation of the infreqently grazed downland adjacent to Wylye Down. 'Adj' = species adjacent but not present within the quadrat.

Species	%freq	max Domin	Species	%freq	max Domin
Agrostis stolonifera	20	2	*Galium verum*	50	3
Briza media	100	3	*Gentianella amarella*	adj	adj
Dactylis glomerata	100	5	*Helianthemum nummularium*	100	4
Festuca arundinacea	50	3	*Hypericum perforatum*	50	3
Festuca ovina	100	5	*Leontodon autumnalis*	adj	adj
Festuca rubra	100	5	*Leontodon hispidus*	75	3
Avenula pratense	75	4	*Leontodon taraxacoides*	50	3
Avenula pubescens	100	4	*Lotus corniculatus*	50	3
Holcus lanatus	adj	adj	*Picris hieracioides*	20	1
Koeleria macrantha	100	2	*Pimpinella saxifraga*	100	3
Phleum bertolonii	20	1	*Plantago lanceolata*	100	3
Poa pratensis	20	1	*Plantago media*	20	3
Danthonia decumbens	75	3	*Sanguisorba minor*	100	4
			Primula veris	75	3
Carex flacca	100	4	*Prunella vulgaris*	20	2
Carex humilis	100	3	*Rhamnus catharticus*	20	2
			Serratula tinctoria	100	5
Achillea millefolium	20	2	*Silene vulgaris*	50	2
Campanula glomerata	20	2	*Stachys officinalis*	100	3
Campanula rotundifolia	100	2	*Succisa pratensis*	100	4
Centaurea nigra	100	3	*Thymus polytrichis*	20	0.01
Cerastium fontanum	20	1	*Trifolium pratense*	20	1
Cirsium acaulon	50	2	*Viburnum lantana*	50	4
Cirsium tuberosum	adj	adj	*Viola hirta*	50	2
Clinopodium vulgare	20	2			
Crataegus monogyna	20	3	*Acrocladium cuspidatum*	20	3
Daucus carota	20	2	*Pseudoscleropodium purum*	100	3
Euphrasia nemorosa	20	2			
Euphrasia pseudokerneri	20	0.01			
Filipendula vulgaris	50	4	**No. species in quadrat**		33
Galium mollugo	20	0.01	**Total no. species**		36

4.1.4 BARTON HILLS, BEDFORDSHIRE

4.1.4.1 Study site

Barton Hills National Nature Reserve (grid ref. 52 090297) occupies some 73 ha and contains 44.5 ha of chalk grassland. The remainder of the site supports a semi-natural beech woodland and scrub communities which have invaded the site. The site consists of a series of steep south, south-west and north-facing slopes, separated by flat-bottomed dry valleys.

4.1.4.2 Management

The management of the grassland has varied considerably throughout the last two centuries (Box 4.2). This illustrates the problem of trying to attribute simple cause and effect to individual management practices. In recent years the main aim of the grazing has been to maintain and enhance floristic diversity through the control of the dominant grass, *Bromus erectus*, and prevent the further invasion of hawthorn scrub.

Box 4.2 Management of Barton Hills

1778 Tithe Award Map: common grazing.

1814 Enclosure Award Map: common grazing.

1890 - 1910: grazed by Dorset Horn sheep, animals folded on adjacent arable land at night.

1920s: agricultural depression, Hills not grazed. However, rabbits were plentiful in this period, and a full-time rabbit catcher was employed. Photographic evidence from 1924 shows that the coarse grass *Bromus erectus* grew to about 60 cm and invasion by hawthorn scrub was considerable.

1932 - 1934: grazed by about 100 sheep.

1935 - 1953: no sheep grazing; *Bromus erectus* dominant, forming a dense sward.

1954: site burnt.

1954 - 1970: Border-Leicester x Cheviot sheep grazed the Hills at about 7.4 sheep per ha (c. 0.6 LU ha^{-1}) for roughly 9 months of the year.

1970s: grazing by 20-30 cattle (c. 0.4 - 0.7 LU ha^{-1}).

1980 - 1983: no livestock grazing.

1983 - 85: site divided intograzing licence allowing 100 sheep to graze from 1 March to 30 June (2.25 sheep ha^{-1}; 0.18 LU ha^{-1}) and up to 200 sheep for eight weeks from 1 September to 1 December (4.5 sheep ha^{-1}; 0.36 LU ha^{-1}).

Fig. 4.2 shows the details of the grazing regime for paddock 1 (19.8 ha) between 1987 and 1994. The area was grazed was by Border-Leicester x Cheviot sheep and took place at any time of the year, although there was a tendency for grazing to be concentrated in the summer and late autumn. The numbers of sheep grazing varied from year to year, with more than 200 sheep (10.1 ha^{-1}) being present between October and November 1989, whereas in other years numbers rarely exceeded 100 (5.05 ha^{-1}).

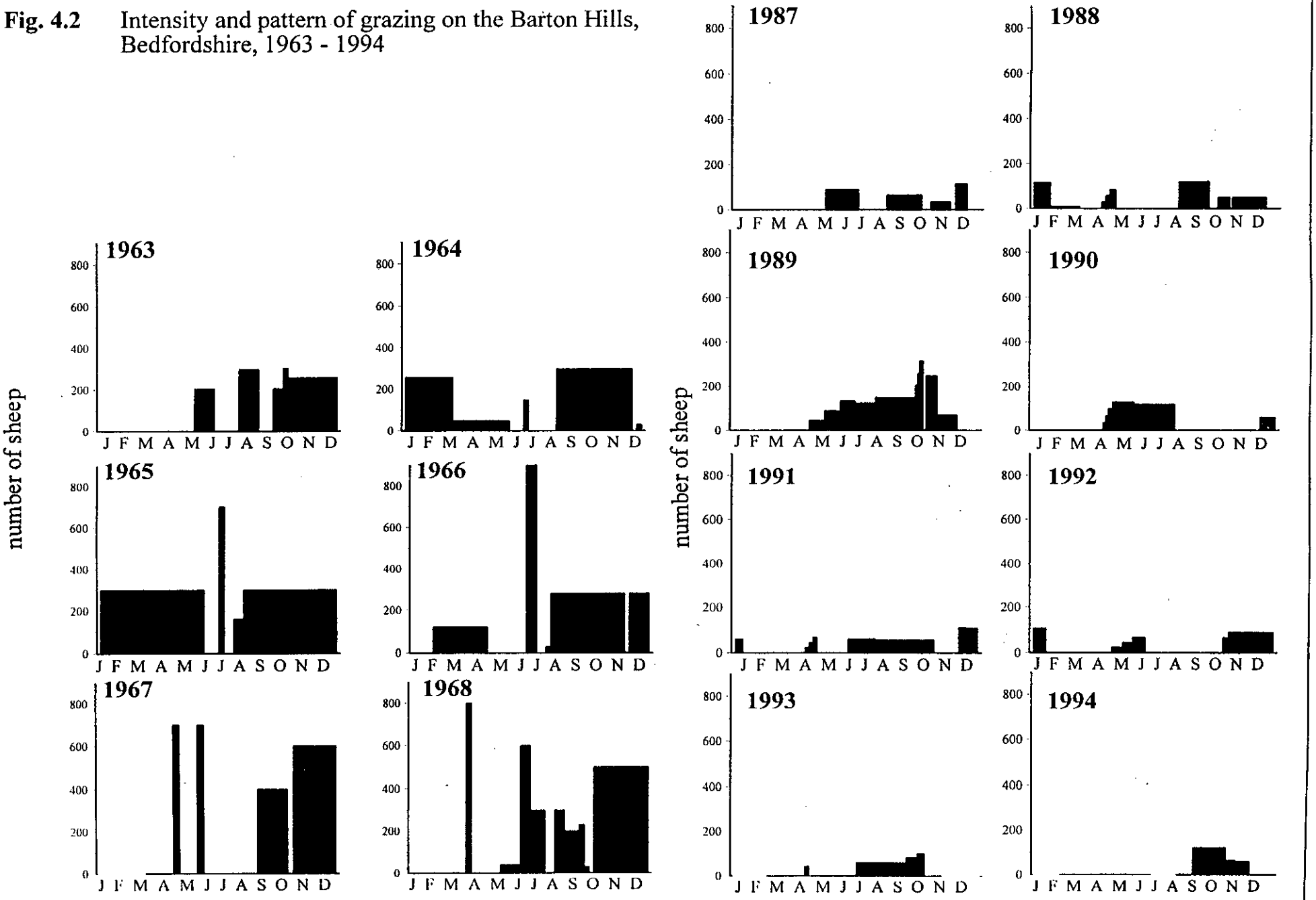
4.1.4.3 Botanical recording

In the spring of 1964 - 1967, eighteen 1 m x 1 m were placed at random on Plum Pudding Hill (Plate 5) and the vegetation recorded using the Domin scale. In September 1993, identical quadrats were recorded from the same locations;

4.1.4.4. Results and discussion

The structure of the vegetation in 1993 was very similar to that described in 1964. On both occasions the sward consisted of a short, fine-textured grassland in which the dominant grasses (*Bromus erectus, Festuca ovina and Briza media*) were of low stature (< 10cm) and did not form large competitive tufts (Plate 6). Simialrly, the composition of the grassland had changed little over the 30 years of recording (Table 4.9). Forty of the 52 species recorded were present in all yeras. As at Parsonge Down, any differences can largely be explained by the different times of recording. Thus, species such as *Asperula cynanchica, Pimpinella saxifraga, Scabiosa columbaria* and *Succisa pratensis*, which produce their maximum leaf area in late summer had higher cover values in 1993 than in 1964 or 1967. Conversely, early flowering species such as *Primula veris* were more conspicuous when recorded in the spring of 1964 than in the late summer of 1993. Other differences were largely confined to species with low frequencies (Domin values + or 1). Many of these species are annuals whose numbers fluctuate greatly every year (e.g. *Gentianella amarella* and *Euphrasia nemorosa*), or species which are associated with transient patches of distubance (e.g. *Picris hieracioides*).

Fig. 4.2 Intensity and pattern of grazing on the Barton Hills, Bedfordshire, 1963 - 1994



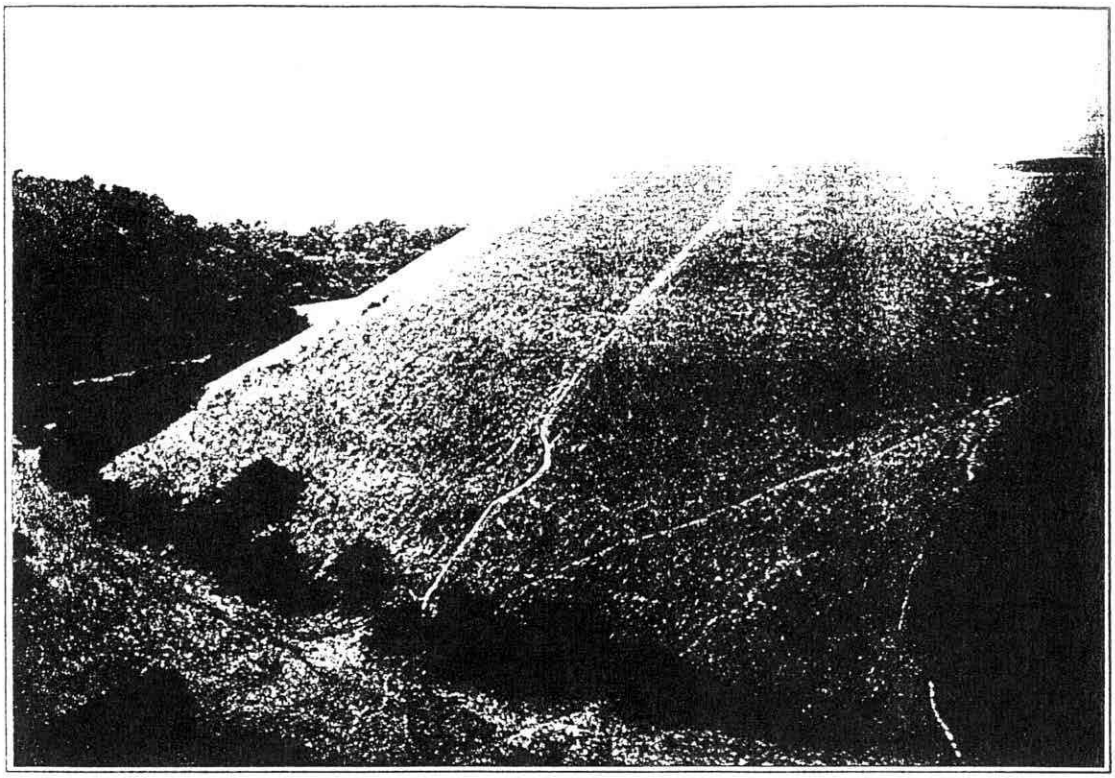


Plate 5. Barton Hills, Bedfordshire (September 1993).

Plate 6. The open and diverse structure of the turf at Barton Hills.

Table 4.9 Vegetation composition of Plum Pudding Hill 1964-1993

	1964 (n = 2)		1967 (n = 5)		1993 (n = 18)	
Species	% Freq.	Max Domin	% Freq.	Max Domin	% Freq.	Max Domin
Grasses & sedges						
Avenula pratensis	100	2	80	3	22.2	2
Briza media	50	3	100	3	100.0	4
Bromus erectus	100	7	100	8	100.0	8
Dactylis glomerata	50	1			11.1	2
Festuca ovina	100	3	100	6	100.0	7
Koeleria macrantha	100	3	100	2	55.6	3
Poa pratensis	50	+				
Carex caryophyllea	100	3	80	3	5.6	1
Carex flacca	100	4	100	4	100.0	6
Forbs						
Achillea millefolium					5.6	0
Asperula cynanchica	50	1	20	1	50.0	3
Campanula glomerata	50	1			11.1	3
C. rotundifolia	100	4	80	3	94.4	3
Carlina vulgaris	100	2	40	+	33.3	2
Centaurea nigra	100	4	100	3	38.9	2
Cirsium acaulon	100	4	100	3	66.7	3
Crataegus monogyna	100	+			61.1	4
Euphrasia nemorosa					44.4	3
Filipendula vulgaris	100	4	80	3	94.4	4
Galium verum					5.6	1
Gentianella amarella			20	1	88.9	2
Gymnadenia conopsea	50	+				
Helianthemum nummularium	100	5	100	4	100.0	5
Hieracium pilosella			100	4	27.8	3
Hippocrepis comosa	100	3	60	2	88.9	4
Leontodon hispidus	100	2	100	3	72.2	2
Linum catharticum	100	3	40	1	88.9	2
Lotus corniculatus	50	1	60	1	44.4	2
Picris hieracioides					22.2	3
Pimpinella saxifraga	100	1			77.8	3
Plantago lanceolata	100	3	60	2	66.7	3
Plantago media	50	+				
Polygala vulgaris	100	2	40	2	38.9	1
Primula veris	100	+	20	1		
Prunella vulgaris			40	3	38.9	3
Pulsatilla vulgaris	50	4	80	5	72.2	3
Ranunculus bulbosus			20	1	22.2	2
Rosa canina					5.6	+
Sanguisorba minor	100	5	100	4	100.0	5
Scabiosa columbaria			20	3	50.0	4
Senecio integrifolius	50	4	40	1	50.0	4

Table 4.9 cont.	1964 (n = 2)		1967 (n = 5)		1993 (n = 18)	
Species	% Freq.	Max Domin	% Freq.	Max Domin	% Freq.	Max Domin
Succisa pratensis	50	1	20	3	55.6	3
Thymus praecox	50	4	20	2	94.4	3
Viola hirta			40	1	100.0	3
Mosses						
Camptothecium lutescens	50	5	40	1	5.6	1
Campylium chrysophyllum	50	3	40	5	44.4	1
Ctenidium molluscum			80	4	22.2	2
Fissidens sp.	100	2	20	3	50.0	2
Pseudoscleropodium purum					33.3	3
Neckera complanata					72.2	3
Weissia sp.						
Eurhynchium praelongum					5.6	+
No. of species		26		21.4		24.9
Vegetation ht (cm)		3		1.2		9.4
Aspect (o)		235		224		210

4.1.4.5 Conclusion

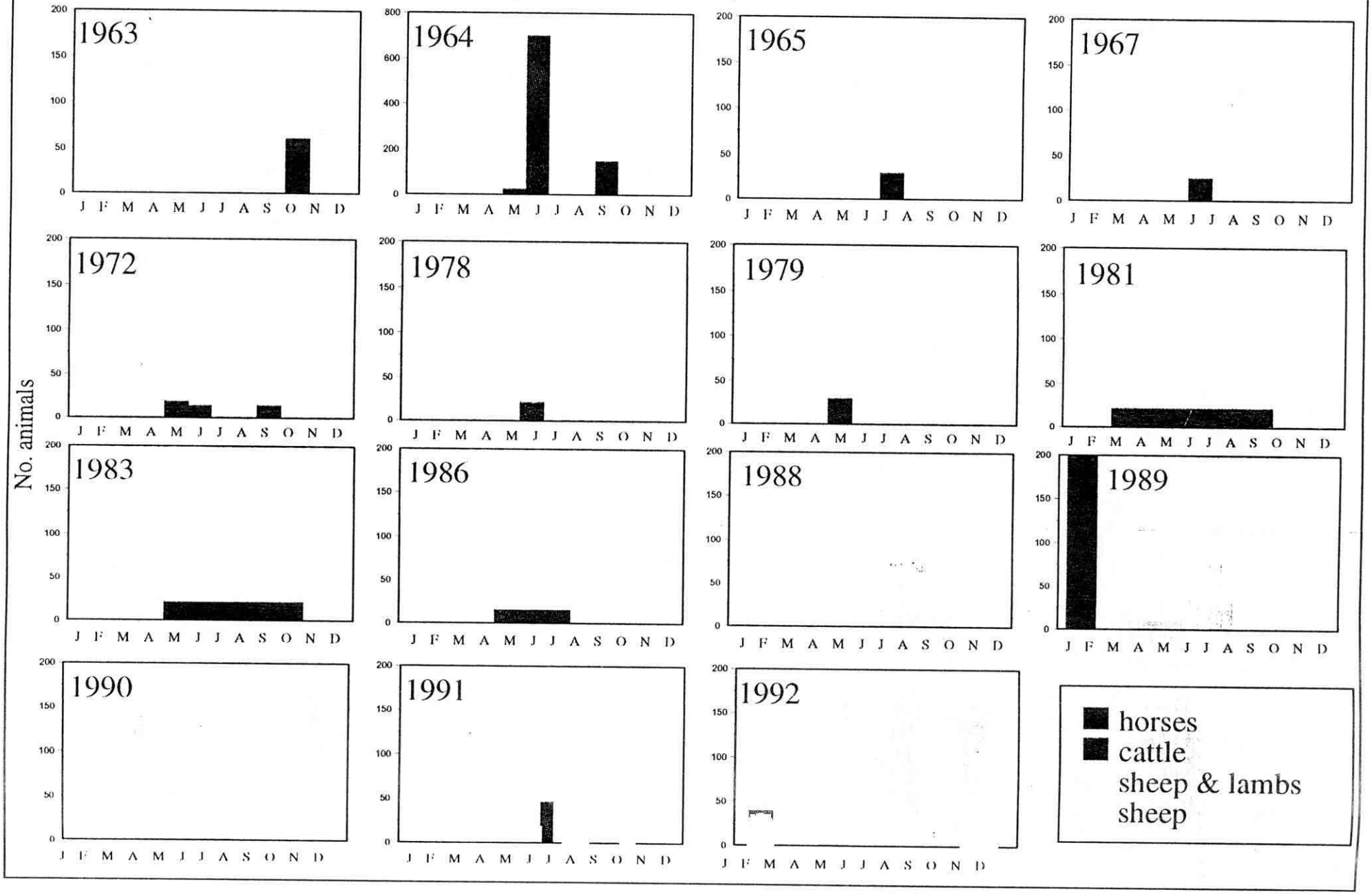
As with the sites in Wiltshire, the vegetation of Barton Hills had apparently changed little over 30 years. However, this site had been subjected to a far more varied management regime. It is likely that this reflects a degree of resilience to change in the same way that the composition of the grassland at Aston Rowant took a long time to respond to the different grazing management.

4.1.5 KNOCKING HOE, BEDFORDSHIRE

4.1.5.1 Study site

Knocking Hoe is the smallest National Nature Reserve (grid ref. 52 / 131308) on the chalk and contains about 8.9 ha of grassland, of which only 4.85 ha is floristically diverse downland. This is one of the few remnants of a much larger area of downland known as Pegsdon Hills, most of which has beeen converted to arable agriculture in the last 40 years. The most prominent features of the reserve are the steep-sided, flat bottomed dry valley which runs in a northwesterly direction, and the Hoe (or knoll) which rises steeply from the flat chalk marl plain on the western side of the reserve. The soils of the slopes are mostly shallow rendzinas, with deeper, calcimorphic loams in the valleys. Soil creep occurs on the steeper slopes.

Fig. 4.3 Intensity and pattern of grazing at Knocking Hoe NNR, Bedfordshire, 1963 - 1992



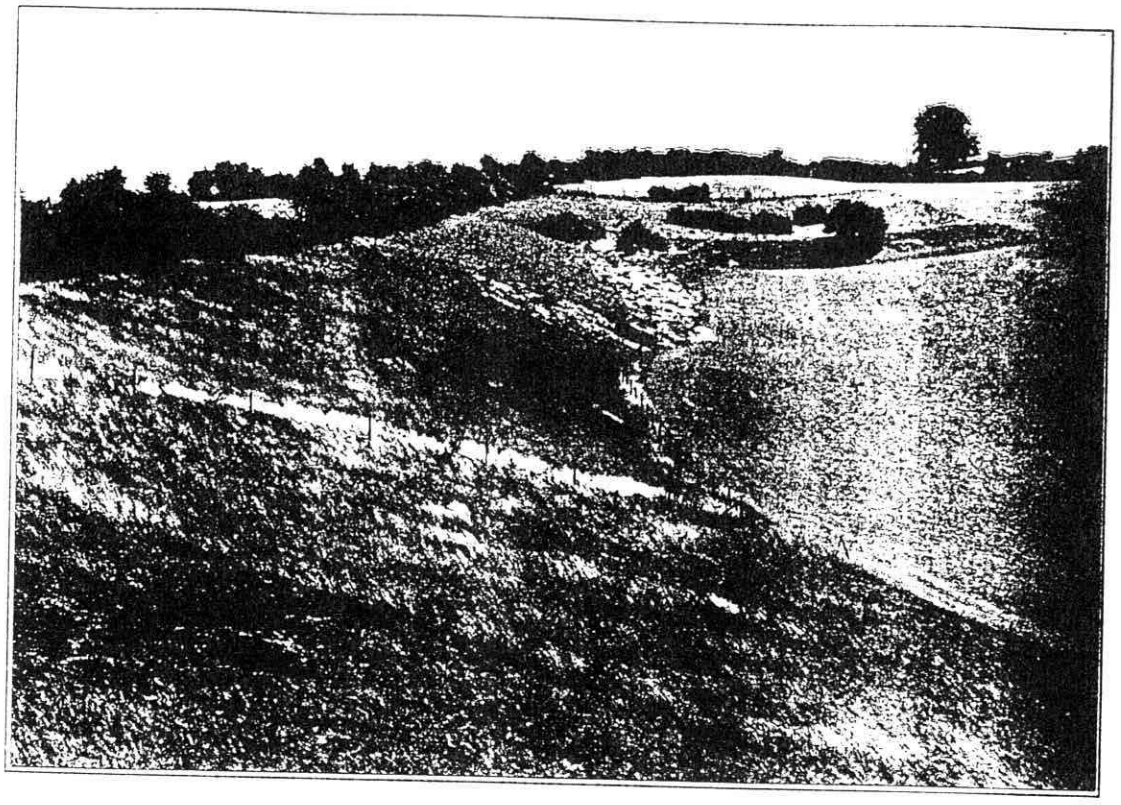


Plate 7. The '*Spiranthes*' Bank, Knocking Hoe, Bedfordshire.

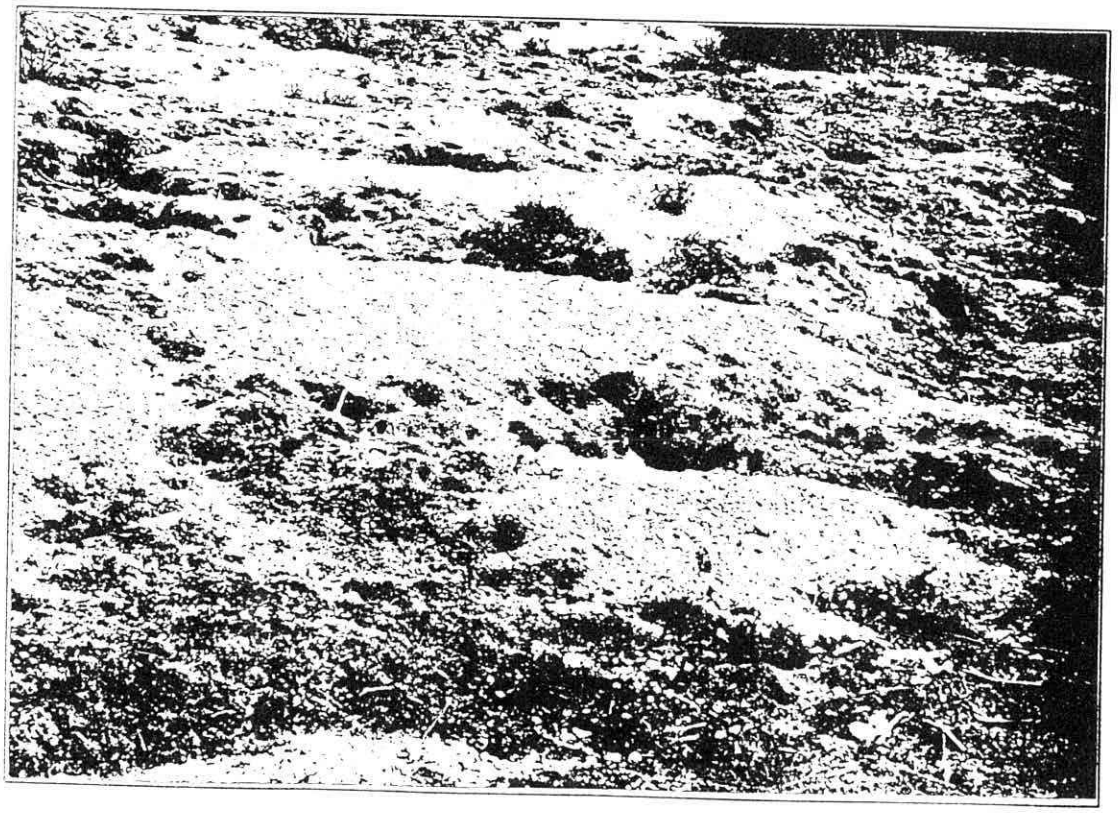


Plate 8. Rabbit damage at Knocking Hoe.

The grasslands on the Reserve are of three main types:

(1) a Cocksfoot (*Dactylis glomerata*) ley, sown in the early 1960s, which has since been invaded by *Agrostis stolonifera, Festuca rubra* and a variety of other species, including notable chalk grassland species, such as *Sanguisorba minor* and *Senecio integrifolius;*

(2) a short springy grassland containing a large number of forbs, classified as a CG2 grassland in the NVC (Rodwell 1992). This type of grassland is best developed on the Hoe but was also widespread elsewhere on the Reserve in earlier times;

(3) A taller grassland dominated by *Bromus erectus* (CG3) on the flatter areas such as the "Spiranthes bank" and the steep sides of the flat bottomed valley (Plate 7). The latter area being named so because of the abundance of the rare orchid species Autumn Lady's tresses (*Spiranthes spiralis*).

4.1.5.2 Management

The Reserve is small in extent and isolated, and has all of the management problems associated with trying to maintain floristically diverse grassland in a farming system in which grazing animals are either not on the farm or are only obtainable at times of the year which are not ideal for managing for wildlife.The management history of Knocking Hoe is both complex and varied, like so many other sites on the chalk (Box 4.3; Fig. 4.3). This is further complicated by the fact that rabbits have been an important grazing animal at various times in the history of the Reserve. By 1990 they had become a serious pest, damaging the turf and creating new burrow systems in previously unbroken turf (Plate 8). By the end of 1992, rabbits numbers were so great that vegetation for sheep was so scarce that sheep grazing ceased. The rabbit population in 1994 on the 8.9 ha Reserve was estimated at more than 1000 and is now clearly the most important "management" problem.

Box 4.3 Management of Knocking Hoe

1924: photograph showing the site to have a uniformly short turf, little scrub and be grazed by some 161 sheep.
1931: grazing of Chiltern Hills ceased due to economic reason.
1949: intensive grazing by rabbits checking the growth of *Bromus erectus*.
1963: c.60 sheep grazed site for 4 weeks in October.
1964: 25 sheep grazed the site in May; 700 sheep grazed the site, together with adjacent improved grassland for 4 weeks in June; 150 sheep grazed site in September.
1966, 1968, 1971, 1973-78: grazed by 20-30 store cattle between March-October.
May 1970, July and December 1971, October and November 1973, October 1974, October 1975, February and August 1977, March 1982, July and August 1986 to 1988 cutting of the floristically diverse areas, especially "Spiranthes bank" and the Hoe.
1988-present: site sheep grazed, largely by Blackface x Border-Leicester (mules), Border-Leicester x Cheviot, Suffolk and Suffolk crosses, Llwyn crosses (Fig. 4.3)

4.1.5.3 Botanical recording

Changes in the structure and composition of the vegetation were assessed at four points in time between 1949 and 1993:

1. a list of species made within a circle of 5 yards diameter (area 65.7 m^{-2}), together with a subjective estimate of frequency made in 1949 (Dony 1953);
2. 1 m^{-2} quadrats recorded using the Domin cover scale in May 1967 and 1971 and September 1993.

4.1.5.4 Results and discussion

Changes in the overall species richness of the vegetation between 1949 and 1993 have been relatively small (Table 4.10). Dony (1953) recorded 4 species which were not recorded in later surveys (*Euphrasia pseudokerneri, Fagus sylvatica* (seedling), *Orchis ustulata* and *Anacamptis pyramidalis*). All of these species were still present outside of the quadrats at Knocking Hoe in 1993. Fifteen species were recorded in the later surveys but not by Dony. This was probably because Dony's sample was confined to the Hoe whereas later surveys also included areas in the valley bottom.

Table 4.10 Vegetation of Knocking Hoe 1949-1993

	1949 (Hoe)	1967	1971	1993 (Hoe)	1993 (*Spiranthes* bank)
Area sampled:	65.7 m^{-2}	4 m^{-2}	3 m^{-2}	12 m^{-2}	12 m^{-2}
Grasses	5	5	6	7	7
Sedges	2	2	2	2	2
Forbs	38	36	30	37	38
Mosses	4	5	5	2	5
Total	49	48	43	48	52

Significant changes in relative abundance appeared to have occurred for only a few species between 1967 and 1993 (Table 4.11). Most of these species were either grasses or sedges. *Bromus erectus* and *Carex flacca* were noted as rare by Dony on the Hoe whereas in later surveys they appeared to be increasing in abundance, with cover values of between Domin value 5 (16.4%) and 33% respecitively. Observation suggested that patches of both species have spread on the Hoe, especially those of *Bromus erectus*. This probably reflects the relaxation of livestock grazing during the mid-1960 and early 1970s. However, high densities of sheep in 1989 and 1990 (Fig. 4.3) have effected some degree of control on the performance of this species. Tufts and tussocks of *Bromus erectus* were reduced from an average height of more than 20 cm to less than 1 cm and the general appearance of the vegetation was that of a short grassland with locally at least, an abundance of forbs. Small hawthorn bushes were also severely damaged by grazing. *Avenula pratensis* and *Koeleria macrantha*, recorded by Dony as rare and occasional were present in all samples taken in 1967 and 1971 but appeared to have declined since then. As at many of the other sites in this review, most of the apparent 'losses and gains' to the plant communtiy were either rare or of low frequency and hence readily underestimated.

Most forbs seem to have remarkably stable populations after allowance is made for seasonal differences. Furthermore, there is no evidence that the nationally scarce and rare species for which Knocking Hoe is famous, namely *Hypochaeris maculata*, *Pulsatilla vulgaris* and *Seseli libanotis*, have declined greatly. There is, however, strong evidence that the population of *Spiranthes spiralis* has declined significantly, probably as a result of competition with *Bromus erectus* during the period when the reserve was grazed by small numbers of store cattle in the 1970s.

The most notable change on the Reserve has been the increase in scrub, especially from boundary hedges and it is clear that grazing alone is not able to control the ingress of shrubs under the present management regime.

Table 4.11 Changes in the floristic composition of Knocking Hoe NNR 1967 - 1993

Species	1967 (n = 4)		1971 (n = 3)		Hoe 1993 (n = 12)		*Spiranthes* Bank 1993 (n = 11)	
	% Freq.	Max domin	% Freq.	Max domin	% Freq.	Max domin	% Freq.	Max domin
Grasses & sedges								
Agrostis stolonifera	-	-	-	-	8.3	2	-	-
Avenula pratensis	100.0	3	100.0	3	8.3	1	-	-
Briza media	100.0	3	100.0	3	75.0	3	54.5	3
Bromus erectus	100.0	5	100.0	5	100.0	7	100.0	6
Dactylis glomerata	-	-	-	-	16.7	3	54.5	4
Festuca ovina	100.0	9	100.0	7	100.0	8	100.0	7
Koeleria macrantha	100.0	3	100.0	3	33.3	2	9.1	+
Poa angustifolia	-	-	-	-	-	-	18.2	+
Danthonia decumbens	-	-	33.3	1	-	-	-	-
Carex caryophyllea	100.0	3	100.0	3	8.3	1	9.1	2
Carex flacca	100.0	5	100.0	4	100.0	6	100.0	7
Forbs								
Asperula cynanchica	75.0	2	100.0	1	58.3	2	72.7	3
Blackstonia perfoliata	25.0	1	-	-	-	-	72.7	2
Campanula glomerata	50.0	1	66.7	2	83.3	3	100.0	4
Campanula rotundifolia	-	-	66.7	1	100.0	2	100.0	3
Carlina vulgaris	75.0	3	-	-	-	-	-	-
Centaurea nigra	75.0	4	100.0	3	83.3	2	45.5	3
Centaurea scabiosa	25.0	1	33.3	+	75.0	3	9.1	1
Cirsium acaulon	100.0	4	100.0	5	100.0	7	100.0	5
Crataegus monogyna	-	-	66.7	+	8.3	1	36.4	1
Daucus carota	-	-	33.3	1	-	-	-	-
Euphrasia nemorosa	50.0	1	66.7	1	8.3	1	-	-
Filipendula vulgaris	100.0	3	66.7	3	100.0	3	63.6	3
Galium verum	50.0	2	-	-	16.7	2	54.5	3
Gentianella amarella	25.0	+	33.3	+	25.0	1	27.3	+
Gymnadenia conopsea	25.0	+	-	-	-	-	-	-
Helianthemum chamaecistus	100.0	4	100.0	3	100.0	4	36.4	4
Hieracium pilosella	75.0	3	66.7	2	33.3	2	27.3	3
Hippocrepis comosa	75.0	2	33.3	3	50.0	3	90.9	3
Hypochaeris maculata	100.0	3	100.0	2	25.0	+	-	-
Leontodon hispidus	75.0	3	66.7	3	91.7	4	100.0	4
Leucanthemum vulgare	25.0	1	33.3	1	33.3	2	36.4	1
Linum catharticum	75.0	1	100.0	1	100.0	3	100.0	1
Lotus corniculatus	100.0	3	100.0	4	75.0	3	100.0	2
Medicago lupulina	-	-	33.3	0	8.3	+	18.2	1
Onobrychis viciifolia	25.0	3	66.7	2	-	-	18.2	1
Picris hieracioides	25.0	+	-	-	66.7	3	-	-
Pimpinella saxifraga	25.0	+	66.7	1	41.7	+	36.4	2
Plantago lanceolata	100.0	2	100.0	4	100.0	4	90.9	3
Plantago media	100.0	3	100.0	4	91.7	3	90.9	3
Polygala vulgaris	75.0	1	33.3	0	16.7	1	27.3	1
Primula veris	75.0	1	66.7	3	25.0	3	36.4	1
Prunella vulgaris	25.0	2	100.0	4	50.0	2	81.8	2
Pulsatilla vulgaris	100.0	2	66.7	2	58.3	2	45.5	2
Ranunculus bulbosus	50.0	1	66.7	1	33.3	2	63.6	2
Sanguisorba minor	100.0	4	100.0	3	100.0	4	100.0	4
Scabiosa columbaria	75.0	1	100.0	2	75.0	3	90.9	3
Senecio jacobaea	-	-	-	-	8.3	+	54.5	1
Senecio integrifolius	100.0	2	33.3	3	66.7	2	18.2	1
Seseli libanotis	25.0	4	-	-	41.7	3	-	-
Spiranthes spiralis	-	-	-	-	-	-	9.1	+

Table 4.11 cont.	1967 (n = 4)		1971 (n = 3)		Hoe 1993 (n = 12)		*Spiranthes* Bank 1993 (n = 11)	
Species	% Freq.	Max domin	% Freq.	Max domin	% Freq.	Max domin	% Freq.	Max domin
Succisa pratensis	50.0	1	33.3	2	41.7	3	54.5	2
Thymus pulegioides	75.0	3	100.0	3	100.0	4	100.0	3
Trifolium pratense	-	-	-	-	-	-	45.5	2
Veronica chamaedrys	-	-	-	-	8.3	1	18.2	2
Viola hirta	25.0	+	-	-	8.3	1	27.3	2
Mosses								
Homalothecium lutescens	50.0	+	-	-	-	-	9.1	=
Campylium chrysophyllum	25.0	+	33.3	1	16.7	0	36.4	+
Ctenidium molluscum	25.0	+	33.3	2	-	-	-	-
Fissidens sp.	50.0	2	66.7	2	25.0	1	36.4	+
Pseudoscleropodium purum	100.0	3	33.3	4	-	-	72.7	2
Neckera complanata	-	-	-	-	-	-	-	-
Weissia sp.	25.0	1	33.3	1	-	-	18.2	+
Mean no species		33.3		33.3		26.0		28.2
Vegetation ht (cm)		2.25		3.0		7.8		4.9
Aspect (o)		180		230		180		240

4.1.5.5 Conclusions

This study proves that it is possible to maintain floristically diverse grassland on small, isolated sites outside the farming system. Despite the great variety of different types and intensities of management, the composition of the grassland has remained relatively stable.

4.1.6 BARNACK HILLS AND HOLES, CAMBRIDGESHIRE

4.1.6.1 Study site

Barnack Hills and Holes (grid ref. 53 076047) comprises an area of 22.3 ha (55 acres) of undulating grassland, scrub and incipient woodland situated on the site of medieval stone quarries. The quarries were believed to have been worked out by about 1500. Topographically the site is exceedingly irregular and consists of a series of mounds and troughs formed from the old quarry workings and the piles of waste debris. The area lies entirely on Jurassic strata and the highly calcareous soils are derived from the Inferior Oolite and the Upper Estuarine beds of the Great Oolite.

4.1.6.2 Management

As with other calcareous grasslands, the management history of this site is complex (Box 4.4). It seems likely that the site has been largely unmanaged for much of this century, only being grazed in a systematic way from 1978 onwards. The thin, stony soils and uneven relief have prevented the area from ever being brought into intensive agricultural use.

Box 4.4 Management of Barnack Hills and Holes

The area was considered 'waste ground' for the first half of this century, with the only management being occasional burning in autumn to control scrub.

1939-1941: site used for tank training.

1964-1977: south-western quarter of the site (paddock 1; 6.4 ha) fenced and occasionally grazed by sheep in the winter. Scrub was also removed.

1978-present: site divided into four paddocks and sheep grazed between October and December. In addition, a systematic program of scrub clearance (especially Oak (*Quercus cerris*)) was initiated.

Grazing management 1978-present

The main objectives of management are the control of coarse grass and scrub species. The Barnack site supports very large populations of rare species, including *Aceras anthropophorum*, *Anacamptis pyramidalis* and *Pulsatilla vulgaris*. Spring or summer grazing would reduce the ability of these species to flower and set seed.This means that autumn and winter grazing are the only option. Like the Knocking Hoe site, Barnack occupies a small area and is outside the predominantly arable farming system. This puts constraints on the availability of livestock.These considerations make a relatively short period of intesive grazing between early October to the end of December the preferred management option (Plate 9; Table 4.12). Relatively high numbers of sheep (3.2 - 6.0 LU ha^{-1}) are put into the paddocks until they have grazed the sward down to about 2 cm. This typically takes between 2-4 weeks. The actual number of sheep varies from year to year, depending on grass growth and livestock availability. The sheep are mostly Swaydale x Border Leicester mules which ahave proved particularly good at eating really coarse vegetation.

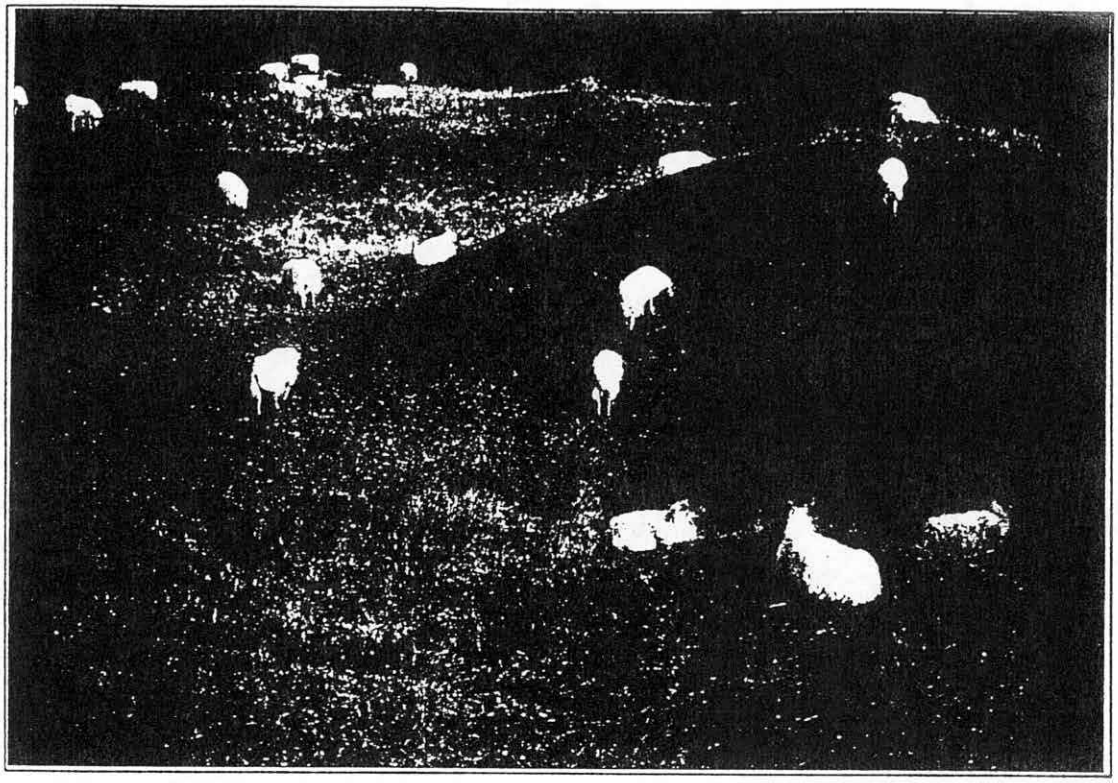


Plate 9. High densities of sheep grazing *Brachypodium* in the winter at Barnack, Cambs

Table 4.12 Sheep grazing management at Barnack Hills and Holes 1978-1993

	Paddock 1 (5.5 ha)				Paddock 2 (4.8 ha)			
year	total sheep wks	sheep wks ha^{-1}	No sheep ha^{-1} for 4 wks	LU ha^{-1}	total sheep wks	sheep wks ha^{-1}	No sheep ha^{-1} for 4 wks	LU ha^{-1}
1978	1118	203	51	7.65	902	188	47	7.05
1979	972	178	44	6.6	837	174	44	6.6
1980	850	154	39	5.85	962	200	50	7.5
1981	452	82	21	3.15	661	138	35	5.25
1982	972	177	44	6.6	881	184	46	6.9
1983	781	142	36	5.4	566	118	30	4.5
1984	691	126	32	4.8	578	120	30	4.5
1985	614	112	28	4.2	614	128	32	4.8
1986	600	109	27	4.05	600	125	31	4.65
1987	686	125	31	4.65	557	116	29	4.35
1988	772	140	35	5.25	772	161	40	6
1989	1550	282	70	10.5	800	167	42	6.3
1990	406	74	19	2.85	428	89	22	3.3
1991	1050	191	48	7.2	700	146	37	5.55
1992	804	146	37	5.55	600	125	31	4.65
1993	687	137	35	5.25	927	217	54	8.1
average	812.8	148.6	37.3	5.6	711.6	149.8	37.5	5.6

	Paddock 3 (4.35 ha)				Paddock 4 (5.76 ha)			
year	total sheep wks	sheep wks ha^{-1}	No sheep ha^{-1} for 4 wks	LU ha^{-1}	total sheep wks	sheep wks ha^{-1}	No sheep ha^{-1} for 4 wks	LU ha^{-1}
1978								
1979								
1980								
1981	375	86	21	3.15				
1982	871	200	50	7.5				
1983	818	188	47	7.05				
1984	703	161	40	6	564	99	25	3.75
1985	614	141	35	5.25	614	108	27	4.05
1986	600	138	35	5.25	600	106	27	4.05
1987	771	177	44	6.6	557	98	25	3.75
1988	772	177	44	6.6	600	106	27	4.05
1989	950	218	55	8.25	500	88	22	3.3
1990	385	88	22	3.3	0	0	0	0
1991	700	161	40	6	700	123	31	4.65
1992	685	157	39	5.85	300	53	13	1.95
1993	857	199	50	7.5	360	63	16	2.4
average	700.1	160.8	40.2	6	479.5	84.4	21.3	3.2

4.1.6.3 Botanical recording

In the summer of 1942 the vegetation was described from fifty 1 foot square (0.093m^2) quadrats at random over the whole area (Hepburn 1942). The presence of species was recorded in each quadrat and the percentage frequency of occurrence calculated. In addition, a full list of plant species was made for the site and surrounding areas. In September 1994, the vegetation was recorded in five 1 m x 1 m quadrats placed at random over the whole site. The cover of plant species was assessed using the Domin scale. These data was also supplemented by a species list for

the whole site.

4.1.7.4 Results and discussion

Structure and composition of the unmanaged grassland in 1942

Photographs taken at the time of the 1942 survey clearly show the northern end of the site as covered with coarse grassland, but with no scrub. The southern end of the site shows the same type of grassland being invaded by the scrub species *Quercus cerris*. The vegetation was both taller and more lush in the 'holes', with an average height of between 25 cm - 31 cm. This was thought to be due to the deeper, more humic soils. The sward on the slopes and hill tops was considerably more diverse and open, with a mean height of 13 cm. The quadrat data suggested that the vegetation was dominated by the coarse tussock grasses *Bromus erectus* and *Brachypodium pinnatum* in a coarse-grained mosaic (Table 4.13). *B. erectus* appeared to be prominent on the 'hills' and *B. pinnatum* more abundant in the 'holes' (Hepburn 1942). The finer-leaved grasses, such as *Festuca ovina,* and the forbs species associated with calcareous grassland (e.g. *Helianthemum nummularium, Hieracium pilosella* and *Sanguisorba minor*) also had high frequencies of occurrence. The vegetation also contained a large number of species more typical of mesotrophic grasslands and disturbed habitats. This probably explains the relatively poor fit (50%) to the plant communities described in the National Vegetation Classification.

Table 4.13. The frequency of occurrence of species recorded in 1942

Species	% frequency	Species	% frequency
Avenula pubescens	16	*Filipendula vulgaris*	6
Brachypodium pinnatum	76	*Galium verum*	24
Briza media	12	*Helianthemum nummularium*	68
Bromus erecta	90	*Hieracium pilosella*	50
Festuca ovina	34	*Hippocrepis comosa*	2
Koeleria macrantha	6	*Lathyrus pratensis*	4
Phleum bertolonii	2	*Leontodon hispidus*	4
Anthoxantum odoratum	6	*Linum catharticum*	20
		Lotus corniculatus	42
Aceras anthropophorum	2	*Pimpinella saxifraga*	24
Achillea millefolium	2	*Plantago lanceolata*	4
Alopecurus myosuroides	2	*Plantago media*	8
Anacamptis pyramidalis	10	*Primula veris*	4
Arabis hirsuta	2	*Pulsatilla vulgaris*	2
Asperula cynanchica	14	*Ranunculus bulbosus*	2
Astragalus danicus	4	*Rumex acetosa*	4
Campanula glomerata	2	*Sanguisorba minor*	88
Carlina vulgaris	2	*Thymus polytrichis*	10
Centaurea nigra	2	*Tragopogon pratensis*	2
Cerastium fontanum	2	*Trifolium pratense*	2
Cirsium acaulon	40		
		Species no.	43

Structure and composition of the grazed grassland in 1994

The findings of the 1994 vegetation survey suggest that the sward was much a more uniform, open calcareous grassland with an intimate matrix of tussock grasses and prostrate forb species. The vegetation in the hollows was shorter (perhaps 5-10 cm) and less distinctly different from that of the ancient quarry slopes. Here, the sward was very short (2-4 cm) and open with up to 10% bareground. The community comprised a fine scale mosaic of many species (Table 4.14). Small tussocks of *Bromus erectus* and *Brachypodium pinnatum* were still co-dominant, but these were being effectively controlled by grazing. The sedge *Carex flacca* and the rosette hemicryptophytes forbs were prominent, especially *Cirsium acaulon, Thymus polytrichis, Helianthemum nummularium, Hieracium pilosella* and *Hippocreppis comosa.* The latter often formed dense patches. This community was a good fit (72%) to the CG5 *Bromus erectus - Brachypodium pinnatum* grassland described in the NVC (Rodwell 1992).

Table 4.14 The frequency and % cover of species recorded in 1994

Species	% frequency	Max domin	Species	% frequency	Max domin
Avenula pubescens	60	2	*Inula conyza*	20	2
Brachypodium pinnatum	100	5	*Knautia arvensis*	20	2
Briza media	100	4	*Leontodon hispidus*	80	7
Bromus erectus	100	7	*Leontodon taraxacoides*	20	3
Dactylis glomerata	20	2	*Linum catharticum*	80	2
Festuca ovina	100	3	*Lotus corniculatus*	20	1
Koeleria macrantha	40	2	*Medicago lupulina*	20	1
			Pimpinella saxifraga	60	1
Carex caryophyllea	80	3	*Plantago lanceolata*	100	2
Carex flacca	80	4	*Plantago media*	40	3
			Pulsatilla vulgaris	60	3
Achillea millefolium	20	3	*Ranunculus bulbosus*	20	1
Antennaria dioica	20	3	*Sanguisorba minor*	100	3
Arabis hirsuta	60	2	*Scabiosa columbaria*	80	3
Asperula cynanchica	60	3	*Thymus polytrichis*	80	5
Campanula glomerata	20	2	*Trifolium pratense*	20	1
Campanula rotundifolia	60	3	*Viola hirta*	20	2
Carlina vulgaris	20	1			
Cirsium acaulon	80	4	*Acrocladium cuspidatum*	40	4
Euphrasia nemorosa	40	2	*Campylium chrysophyllum*	20	3
Filipendula vulgaris	20	2	*Cladonia sp.*	20	3
Galium verum	40	2	*Ctenidium molluscum*	80	5
Gentianella amarella	40	2	*Fissidens sp.*	100	2
Gymnadenia conopsea	20	1	*Homalothecium lutescens*	60	4
Helianthemum nummularium	80	4	*Pseudoscleropodium purum*	60	3
Hieracium pilosella	80	4	*Weissia microstoma*	100	4
Hippocreppis comosa	60	4			
			Species no.	50	

Changes in the vegetation as a result of grazing

The overall effect of winter grazing has been to control the growth of coarse grasses, especially *Brachypodium*

pinnatum and *Bromus erectus* which has provided space for less competitive grasses and forbs. Scrub, especially young hawthorn and privet have also been controlled. Species which have apparently been lost since the 1942 survey fall into the following categories (Table 4.15):

1. species of disturbed habitats, both of agricultural origin (e.g. *Rumex obtusifolius* and *Alopecurus myosuroides*) and typical of disturbed calcareous grassland (e.g. *Reseda luteola, Sonchus oleraceus* and *Silene vulgaris*). These could have colonised from the adjacent farmland and may have been associated with the disturbance and compaction of the soil caused by tank training during the time of the 1942 survey;
2. species typical of more mesotrophic grasslands. These include grasses such as *Alopecurus pratensis* and *Lolium perenne*, large umbellifers (e.g. *Anthriscus sylvestris*) and sprawling legumes (e.g. *Vicia cracca* and *Lathyrus pratensis*).

In the absence of fire, such vegetation would have rapidly accumulate a large amount of dead material, reducing the bryophytes to a few pleourocarpus species. Such communities would have been rapidly invaded by scrub.

Species which have apparently colonised the site since the 1942 survey include the rare *Antennaria dioica, Carex ericetorum* and *Coeloglossum viride*. Some species, such as *Carex flacca* and *C. caryophyllea* were almost certainly missed in the original survey. Rare species which have significantly increased in abundance and are now present in there thousands include *Aceras anthropophorum, Anacamptis pyramidalis* and *Pulsatilla vulgaris*.

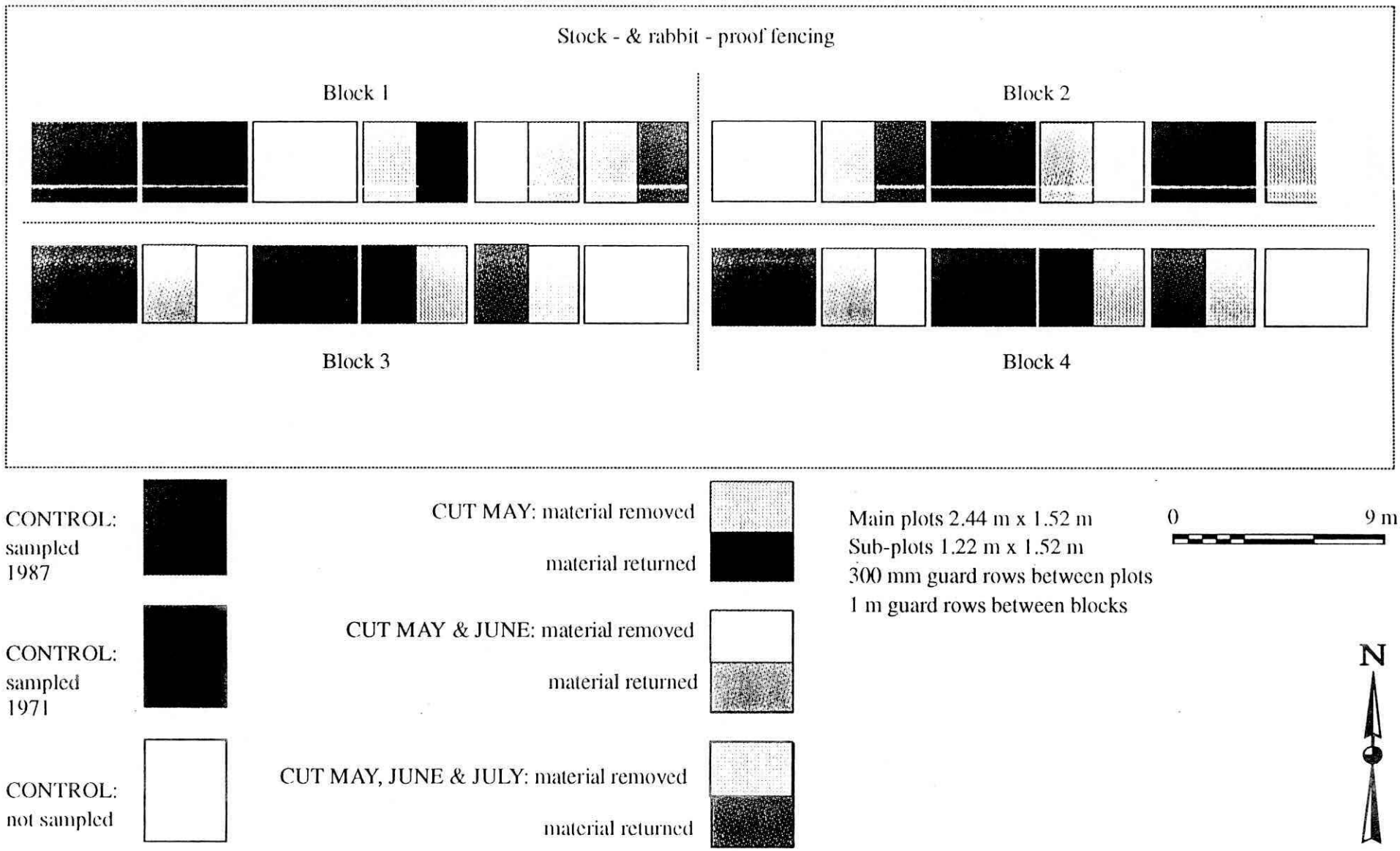
Table 4.15 Change in the composition of the vegetation at Barnack 1942 - 1994

Species apparently lost 1942 - 1994		**Species apparently gained 1942 - 1994**
Grasses & sedges	Forbs (cont/)	Grasses & sedges
Alopecurus myosuroides	*Lathyrus pratensis*	*Carex caryophyllea*
Alopecurus pratensis	*Lepidium campestre*	*Carex flacca*
Cynosurus cristatus	*Origanum vulgare*	*Carex ericetorum*
Lolium perenne	*Pimpinella saxifraga*	
Poa pratensis	*Polygala calcarea*	
Trisetum flavescens	*Reseda luteola*	
	Rumex obtusifolius	
Forbs	*Saxifraga tridactylites*	Forbs
Anthriscus sylvestris	*Silene latifolia*	*Cerastium fontanum*
Anthyllis vulneraria	*Silene vulgaris*	*Coeloglossum viride*
Astragalus glycyphllos	*Sonchus oleraceus*	*Dactylorhiza fuchsii*
Centaurea scabiosa	*Stellaria holostea*	*Inula conyza*
Cerastium arvense	*Stellaria media*	*Picris hieraciodies*
Cerastium semidecandrum	*Trifolium pratense*	*Pimpinella saxifraga*
Coeloglossum verde	*Verbascum nigrum*	*Viola hirta*
Crepis mollis	*Vicia cracca*	*Antennaria dioica*
Erophila verna		*Arabis hirsuta*
Galium mollugo	Scrub	
Geranium pusillum	*Betula pendula*	
Heracleum sphondylium	*Verbena officinalis*	
Hypericum pulchrum		
	Total species: 42	Total species: 9

4.1.6.4 Conclusions

The main lesson to be learnt from this study is that it is possible to control the competitive ability of coarse grasses such as *Brachypodium pinnatum* and *Bromus erectus* by grazing with hardy breeds of sheep during the winter months. By using high stocking rates for short periods (25-50 sheep ha^{-1} for 2-4 weeks) the animals are forced to eat the coarser vegetation and also to disturb the litter layer. This in turn provides germination sites for a variety of annuals and perennials thereby maintaining a diverse and rich flora. A combination of mechanical removal and grazing is also effective in controlling scrub species.

Fig. 4.4 Cutting experiment at Knocking Hoe NNR, Bedfordshire



In addition, the cut plots were sub-divided at random: from one half the cut material was removed and from the other half the cut material was returned as finely ground plant material. The plots were cut with hand shears as close to the ground as possible (< 1 cm). The cut material removed from the plots was dried for 48 hrs at 85°C in a fan oven and weighed to constant weight. The plant material which was returned to the plots was ground in a rotary mill to a fine powder and scattered evenly over the plots 2 - 3 days after cutting. Sub-samples of the dried and ground material were taken for chemical analyses from the samples which were not returned to the plots.

4.2.1.3 Botanical recording

Assessments were made of the effects of the different cutting treatments on floristic composition of the plots in June 1971 and 1987, after seven and twenty three years respectively. All of the plots which had been cut annually since 1965 were cut to ground level. In addition, the four control plots which had been cut in 1971 to determine their botanical composition were sampled again to determine the effects of infrequent cutting. These were compared to four uncut controls. The cut material was stored at - 20°C and sorted into individual species. Each component was oven-dried at 85°C for 48 hours and its dry weight determined. From this the species diversity and species richness of each plot was also measured.

In addition, the effects of cutting management on the reproductive performance of *Bromus erectus* was determined by making counts of the flowers of this species in May of 1987 and 1988. Flower production of other species was estimated by counting the inflorescence of 18 and 23 species in May and August 1988 respectively

After appropriate transformations, all data was subjected to analysis of variance (ANOVA).

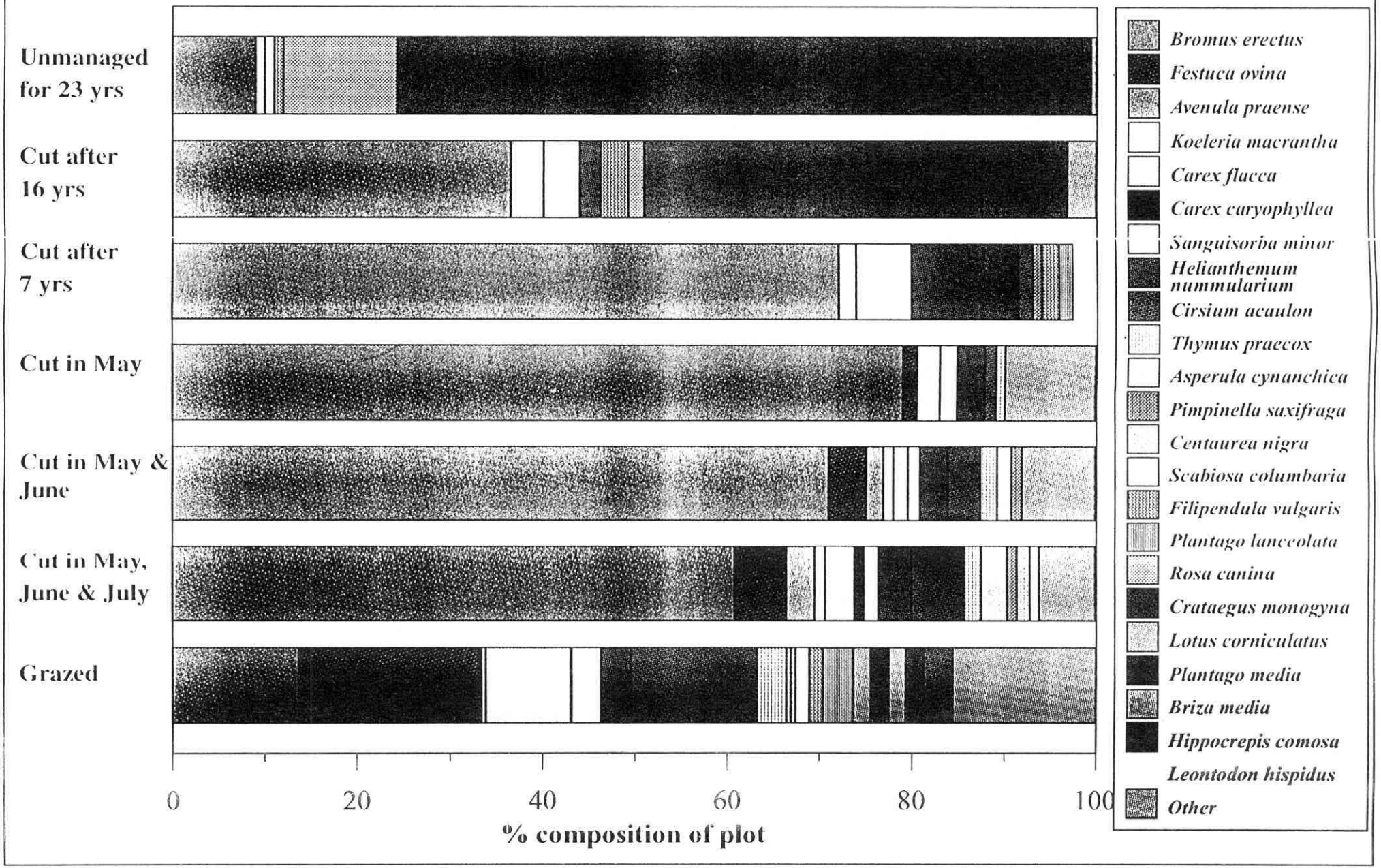
4.2.1.4 Results and discussion

Structure and composition of the vegetation

Unmanaged plots

The composition of the plots which had not been managed for 23 years was very variable, reflecting the effects of scrub invasion. The structure of the vegetation was that of tall rank grassland with scattered, mature woody shrubs. The shrub *Crataegus monogyna* was the dominant species, accounting for an average of 75.1% of the above ground biomss (Fig. 4.5), with the shrub *Rosa canina* also prominant (12.3%). The grass *Bromus erectus* formed large tussocks between the scrub, accounting for 9.0% of the total biomass. These three species accounted for 96.5% of the total biomass of the plots. Nevertheless, 28 other species were recorded, although all were present in small quantities. The most successful forb species able to survive in the coarse, shrubby grassland were *Sanguisorba*

Fig. 4.5 Effects of management on the composition of chalk grassland at Knocking Hoe



minor, Carex flacca, Filipendula vulgaris, Helianthemum nummularium and *Viola hirta.*

Plots not cut for 17 years

These plots were also highly variable in appearance. They were described as coarse, tussocky *Bromus erectus* grassland up to 500 mm high with woody shrub species *Crataegus monogyna, Rosa canina* and *Rhamnus carthartica* up to 1.7m high. Occasional tufts of the other coarse grass species *Brachypodium sylvaticum* were recorded in some plots. There was a thick layer of grass litter, with a dense carpet of mosses, mostly *Pseudoscleropodium purum*. The forb species *Sanguisorba minor, Carex flacca, Helianthemum nummularium* and *Filipendula vulgaris* were also relatively frequent. Interestingly, the nationally scarce chalk species *Pulsatilla vulgaris* was able to survive on some of the plots under this infrequent cutting regime. *Crataegus monogyna* accounted for 45.9% of the live biomass and *Bromus erectus* for 36.5% (Fig. 4.5). Other important forb species were *Sanguisorba minor* (3.9%), *Carex flacca* (3.6%), *Filipendula vulgaris* (3.0%), *Helianthemum nummularium* (2.2%) and the shrub *Rosa canina* (1.7%). Of the other 29 species recorded in the plots, none contributed more than 1% to the total live biomass.

Plots not cut for 7 years

At the end of May 1971, the live above ground biomass was dominated by *Bromus erectus* (Fig. 4.5). The forb species which contributed to > 1% of the biomass were, *Helianthemum nummularium, Sanguisorba minor, Filipendula vulgaris, Cirsium acaulon, Plantago lanceolata,* and *Pimpinella saxifraga. Crataegus monogyna* was the most frequent shrub present in all plots, either as seedlings or small plants < 0.5 m high.

Plots cut once a year in May

The grass sward was 130 mm to 200 mm high with inflorescences of *Bromus erectus* reaching 800 mm. Structurally, the vegetation was comprised of small tufts and tussocks of *B. erectus* in a matrix of other grasses and forbs. Mosses were abundant and there was a small amount of dead plant material present at the base of the sward. *B. erectus* was the dominant species, accounting for 79% of the above ground biomass on average (Fig. 4.5). The forb *Helianthemum nummularium* was the next most abundant species (3.0%) followed by the sedge *Carex flacca* (2.5%), *Sanguisorba minor* (1.9%), *Festuca ovina* (1.5%), *Cirsium acaulon* (1.2%) and *Thymus praecox* (1%). These seven species accounted for 91% of the above ground biomass. A further 46 species were present in very small amounts, each contributing to less than 1% of the total biomass. This decline in the contribution of individual species to the total biomass is accompanied by a large increase in species richness.

Plots cut twice a year in May and June

In May 1987 the vegetation was 100 mm to 150 mm tall with infloescences of *Bromus erectus* reaching up to 750 mm. The structure of the sward was much more open than the plots cut once a year, with diverse patches of forbs

in a matrix of fine-leaved grasses such as *Festuca ovina* and *Koeleria macrantha*. *Bromus erectus* accounted for less (71%) of the above ground biomass than in the single cut treatment (Fig. 4.5). Substantial contributions were made by the following species: *Festuca ovina* (4%), *Cirsium acaulon* (3.6%), *Helianthemum nummularium* (3%), *Avenula pratensis* (1.9%), *Thymus praecox* (1.8%), *Asperula cynanchica* (1.6%), *Carex flacca* (1.6%), *Sanguisorba minor* (1.3%), *Pimpinella saxifraga* (1.1%) and *Koeleria macrantha* (1.1%). These 11 species accounted for 92 % of the total biomass. Twenty nine other species were recorded on the plots, but none contributed more than 1% of the biomass. The nationally rare species *Hypochaeris maculata* and nationally scarce species *Pulsatilla vulgaris* occurred in some plots and were in flower.

Plots cut three times a year in May, June & July

The sward produced by this management regime was similar in structure to that of the adjacent, sheep-grazed downland. The short (20 mm to 60 mm) turf had a fine-grained texture with an intimate mosaic of grasses and forb species. Inflorescence of grasses were relatively scarce in comparison to the turf produced by the other cutting treatments. *Bromus erectus* still accounted for the highest proportion of the above ground biomass (60.8%; Fig. 4.5), but was present as isolated tillers and did not form tufts or tussocks typical of the other treatments. The proportion of other species increased with the following making considerable contributions: *Cirsium acaulon* (5.7%), *Festuca ovina* (5.6%), *Helianthemum nummularium* (3.6%), *Carex flacca* (3.2%), *Avenula pratensis* (3.1%), *Asperula cynanchica* (2.8%), *Thymus praecox* (1.9%), *Sanguisorba minor* (1.6%), *Centaurea nigra* (1.4%), *Koeleria macrantha* (1.1%), *Pimpinella saxifraga* (1.1%), *Scabiosa columbaria* (1%) and *Carex caryophyllea* (1%). These 14 species accounted for 94% of the biomass, with 26 other species accounting for the remainder.

Adjacent, sheep-grazed downland

The surrounding chalk downland at Knocking Hoe has been grazed by livestock for many centuaries. Compared to the cut grassland, the grazed downland has a markedly different composition and structure (section 4.1.5). The differential effects of grazing have created a habitat with a much more open and diverse structure, including many microsites for germination and establishment. This is reflected in the greater species richness and the lack of domiance of the vegetation by any one species (Fig. 4.5).

Species richness

Of the 53 species recorded from the samples, 45 were recorded in both 1971 and 1987, four species (*Festuca arundinacea, Gentianella amarella, Senecio integriflorus* and *Trifolium pratense*) were only recorded in 1971, while four species (*Centauria scabiosa, Lolium perenne, Rhamnus cathartica* and *Sonchus oleraceus*) were only found in 1987. All were only present in very small quantities and many of them (e.g. *Gentianella* and *Sonchus*) were short-lived annuals.

In 1971, seven years after the beginning of the experiment, the control plots (not cut) had significantly ($P \leq 0.05$) fewer species than plots which were cut (19 compared to 30.4), but there were no significant differences in the number of species in plots cut once, twice or three times a year (29.0, 30.6 and 29.4 respectively). By 1987, twenty three years after the experiment began, the number of species in the control plots had fallen to 15.3, whereas the number of species in the cut plots remained much the same as they had 16 years previously (27 to 37 species per plot, mean 29.6; Fig. 4.5). Despite frequent, annual cutting, the species richess of the cut plots was still lower than that of the adjacent downland which was sheep grazed (Fig. 4.5). The cut grasslands are dominated by a single species of coarse grass (*Bromus erectus*), whereas in the grazed sward no one species is dominant.

Effects of cutting management on individual species

The ecological effects of cutting can be direct: species which are not suitably adapted will disappear or be reduced in number and size. This will also have indirect effects on floristic composition as other, adapted species are able to expand to fill the vacant niches. Some twenty four species were significantly affected by cutting management in 1971 and thirty five species in 1987. Twenty one species were significantly different in both years. Responses of individual species can be classified as follows (Boxes 4.5 & 4.6). Frequent and very frequent annual cutting caused a significant increase in the greatest of forb and grass species characteristic of calcareous grassland. These tended to be small, fine-leaved grasses (e.g *Koeleria macrantha*) and forb species with a prostrate growth habit (e.g. *Hippocrepis comosa* and *Thymus polytrichis*) which are likely to lose less herbage by cutting compared to species with a more erect growth form. Taller, competitve forb species and coarse, tussocky grasses were significantly more abundant on the infequently cut plots (e.g.*Centaurea nigra, Brachypodium sylvaticum, Bromus erectus*). Finally, scrub species, especially *Crataegus monogyna*, increased significantly under no management as the succession to woodland begins to take place.

Box 4.5 Effects of frequent cutting management on floristic composition

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING UNDER CUTTING MANAGEMENT IN GENERAL:

Grasses:
*Avenula pratensis, Koeleria macrantha, Danthonia decumbens**

Sedges:
Carex caryophyllea

Forbs:
*Hieracium pilosella**, *Linum catharticum, Pimpinella saxifraga, Polygala vulgaris, Scabiosa columbaria, Sonchus oleraceus**, *Succisa pratensis*

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING UNDER CUTTING ANNUALLY IN MAY:

Forbs:
Galium verum, Leontodon hispidus

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING UNDER FREQUENT ANNUAL CUTTING IN MAY & JUNE:

Grasses:
Avenula pratensis, Briza media, Festuca ovina, Koeleria macrantha

Forbs:
Campanula glomerata, Cirsium acaulon, Hippocrepis comosa, Leontodon hispidus, Prunella vulgaris†, Ranunculus bulbosus, Thymus polytrichis

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING UNDER VERY FREQUENT ANNUAL CUTTING IN MAY, JUNE & JULY:

Grasses:
Briza media, Festuca ovina, Koeleria macrantha

Forbs:
*Asperula cynanchica, Campanula glomerata, Cirsium acaulon, Hippocrepis comosa, Leucanthemum vulgare**, *Plantago media, Prunella vulgaris†, Ranunculus bulbosus, Thymus polytrichis*

* only present in small amounts in plots; † not significant after 23 years

Box 4.6 Effects of infrequent cutting management on floristic composition

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING UNDER INFREQUENT CUTTING MANAGEMENT (ONCE IN 7 YEARS):

Grasses:
Bromus erectus

Sedges:
Carex flacca

Forbs:
Centaurea nigra, Centaurea scabiosa, Galium verum, Helianthemum nummularium, Sanguisorba minor, Viola hirta subsp. hirta

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING UNDER VERY INFREQUENT CUTTING MANAGEMENT (ONCE IN 17 YEARS):

Grasses:
Brachypodium sylvaticum, Bromus erectus

Sedges:
Carex flacca

Forbs:
Centaurea nigra, Centaurea scabiosa, Galium verum, Helianthemum nummularium, Sanguisorba minor, Viola hirta subsp. hirta

Scrub:
Crataegus monogyna, Rosa canina

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING UNDER NO MANAGEMENT FOR 23 YEARS:

Grasses:
Bromus erectus

Sedges:
Carex flacca

Forbs:
Centaurea scabiosa, Helianthemum nummularium, Sanguisorba minor, Primula veris

Scrub:
Crataegus monogyna, Rhamnus cathartica, Rosa canina

SPECIES DOING EQUALLY WELL UNDER CUTTING AND NO CUTTING MANAGEMENT:

Forbs:
Lotus corniculatus, Plantago lanceolata,

Effects of cutting management on flowering performance

The effects of management on the flowering performance of plant species has important implications for the long term survival of plant population, as well as many invertebrate species which are associated with them. Cutting management appeared to cause a significant increase in the flowering performance of predominantly mat-forming forbs (Box 4.7). Such species are ecologically adaped to produce flowers despite defoliation, and there is evidence to suggest that this stimulates the process. As expected, the lack of cutting caused a significant increase in flowering for a number of tall forb species.

Box 4.7 Effects of cutting on flowering performance

SPECIES WITH SIGNIFICANTLY (P≤0.05) MORE INFLORESCENCES IN PLOTS CUT ANNUALLY IN MAY:

Sedges:

Carex caryophyllea

Forbs:

Hieracium pilosella, Hippocrepis comosa, Leucanthemum vulgare, Ploygala vulgaris, Ranunculus bulbosus, Senecio integrifolius, Campanula glomerata, Campanula rotundifolia, Leontodon hispidus, Lotus corniculatus, Picris hieracioides, Plantago lanceolata, Scabiosa columbaria, Sochus asper

SPECIES WITH SIGNIFICANTLY (P≤0.001) MORE INFLORESCENCES IN PLOTS UNMANAGED FOR 23 YEARS:

Sedges:

Carex flacca

Forbs:

Filipendula vulgaris, Sanguisorba minor, Centaurea nigra, Helianthemum nummularium

Effects of return or removal of cut material on individual species

Cutting and removal of the vegetation will gradually deplete the relatively small nutrient resources of the ecosystem. However, if the cut material is left in place it may form a mat over the grassland and prevent some species from germinating and flowering. Some 16 species were found to show a significant response to the return or removal of cut material from the plots (Box 4.8). Species which significantly increased after 23 years of returning the cut material tended to be tall, competitve species which could respond well to nutrient addition (e.g. *Plantago lanceolata*). Species which were promoted under the removal of cut material were leguminous species (e.g. *Lotus*

corniculatus) which have the ability to fix nitrogen, species of low competitve ability which are able to tolerate a lack of nutrients (e.g. *Asperula cynanchica*), and late flowering species (e.g. *Succisa pratensis*) which would otherwise set their seed into a mulch of cut grass.

Box 4.8 Effects of removal and addition of cut material on vegetation

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING IN RESPONSE TO THE RETURN OF CUT MATERIAL FOR 7 YEARS:

Forbs:
Galium verum

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING IN RESPONSE TO THE RETURN OF CUT MATERIAL FOR 23 YEARS:

Grasses:
Bromus erectus

Sedges:
Carex caryophyllea, Carex flacca

Forbs:
Campanula glomerata, Campanula rotundifolia, Centaurea nigra, Leontodon hispidus, Pimpinella saxifraga, Plantago lanceolata

SPECIES SIGNIFICANTLY (P≤0.05) INCREASING IN RESPONSE TO THE REMOVAL OF CUT MATERIAL FOR 23 YEARS:

Grasses:
Festuca ovina

Forbs:
Asperula cynanchica, Linum catharticum, Lotus corniculatus, Onobrychis viciifolia, Scabiosa columbaria, Succisa pratensis

4.2.1.5 Conclusions

This experiment clearly demonstrates that if calcareous grasslands are left unmanaged they are invaded by coarse grass and scrub species. This degradation is intially a relatively slow process, with coarse grasses such as *Bromus erectus* increasing and seedlings of scrub species becoming established after 7 years. Scrub species eventually dominated the grassland after 17 - 23 years of no management. However, some chalk grass species are able to persist. These included tall, competitve forb species, such as *Centaurea scabiosa*, and those species which grow and flower early in the year, thus avoiding much of the shading and competition (e.g. *Primula veris*). There was a large reduction in plant species richness associated with the lack of management. The structure of the grassland

was also fundamentally altered with a mature scrub layer, tall tussocks of grass, deep litter and few gaps.

Cutting once a year prevents the invasion of scrub species. Cutting more frequently will effective restrict the competitve ability of the dominant coarse grass species *Bromus erectus*. Cutting three times a year caused a decline in the amount of *B. erectus* from c. 80% to 60% compared to the plots cut once a year (Fig. 4.5). At the same time there was an increase in overall species richness. The species benefiting the most from very frequent cutting (3 times per year) were those with a low - growing, mat forming habit (e.g. *Asperula cynanchica, Cirsium acaulon, Hippocrepis comosa* and *Thymus polytrichis*). Such species typically have low competitve ability and cannot compete with the coarse grass species, but are able to withstand the considerable stresses of low nutrient status, droughts and regular defoliation typical of calcareous grassland. There is also evidence to suggest that some of these low-growing species flowered more frequently in response to cutting, possibly reflecting this increase in stress. Finally, frequent cutting creates an open, short turf which is visually similar to that of grazed downland.

Cutting is not a substitute for the traditional livestock grazing management of calcareous grassland. However, frequent cutting may be of value for the short term maintenance of species richness on sites where grazing is either impractical or unecomonic.

4.2.2 THE RADCOT CUTTING AND GRAZING EXPERIMENT

4.2.2.1 Introduction

The Knocking Hoe cutting experiment demonstrated that frequent cutting of previously grazed chalk grassland could maintain some of the original floristic composition and structure over a 23 year period. A similar experiment was established on a site in the Upper Thames Tributaries ESA to determine if such alternative management treatments could maintain floristic diversity on deeper, more fertile calcareous soils.

4.2.2.2 Study site

The management experiment was established at Radcot, Oxfordshire (grid ref. SP 284998) by Mr Marek Nowakowski of Willmot Pertee Ltd in August 1987. The site was situated on a flat river terrace adjacent to the river Thames. The soils type was a fertile, freely drained calcareous loam over riverine gravels. The site was fenced to prevent livestock gaining access.

4.2.2.3 Experimental design

The experiment comprised four replicate blocks within which the following treatments were fully randomised (Fig. 4.6):

1. Control (no management);

2. Single hay cut 1st week of July and hay removed;

3. Single hay cut 1st week of July and hay left *in situ*;

4. Double hay cut last week of April and 2nd week of August, hay left *in situ;*

5. Vegetation sprayed with the grass retardant Mowchem at a rate of 1.66 ltr ha^{-1}, hay cut two weeks later;

6. July hay cut and removal followed by aftermath grazing.

Each treatment plot measured 9 m by 12 m. The grass retardant treatment plots (5.) were divided in two and one half was cut two weeks after the application of the chemical. Only these latter plots were recorded. In addition, four 9 m by 12 m plots were situated at random in the surrounding meadow which was cut for hay in July and aftermath grazed by sheep and cattle. This gave a sixth treatment. These plots were situated at least 20 m from the experiment. This was to reduce the effects of livestock tracking along the fence line.

4.2.2.4 Botanical recording

Prior to establishing the experiment, the site supported a floristically diverse calcareous meadow community. This was a product of the fertile calcareous soils and a long history of summer hay cutting followed by aftermath grazing. The floristic composition of the meadow was recorded in July 1995 (Table 4.16). The plant community corresponded to that of the *Galium verum* sub-community of the *Cynosurus cristatus - Centaurea nigra* hay meadow (MG5c) described by the National Vegetation Classification (NVC; Rodwell 1992). The floristic composition of this sub-community closely resembles that of the *Festuca ovina - Avenula pratensis* grassland (CG2) found on the chalk. However, the deeper, more fertile soils, and the cutting and grazing management produce a longer, less open sward structure.

Fig. 4.6 Grassland management experiment at Radcot, Oxfordshire

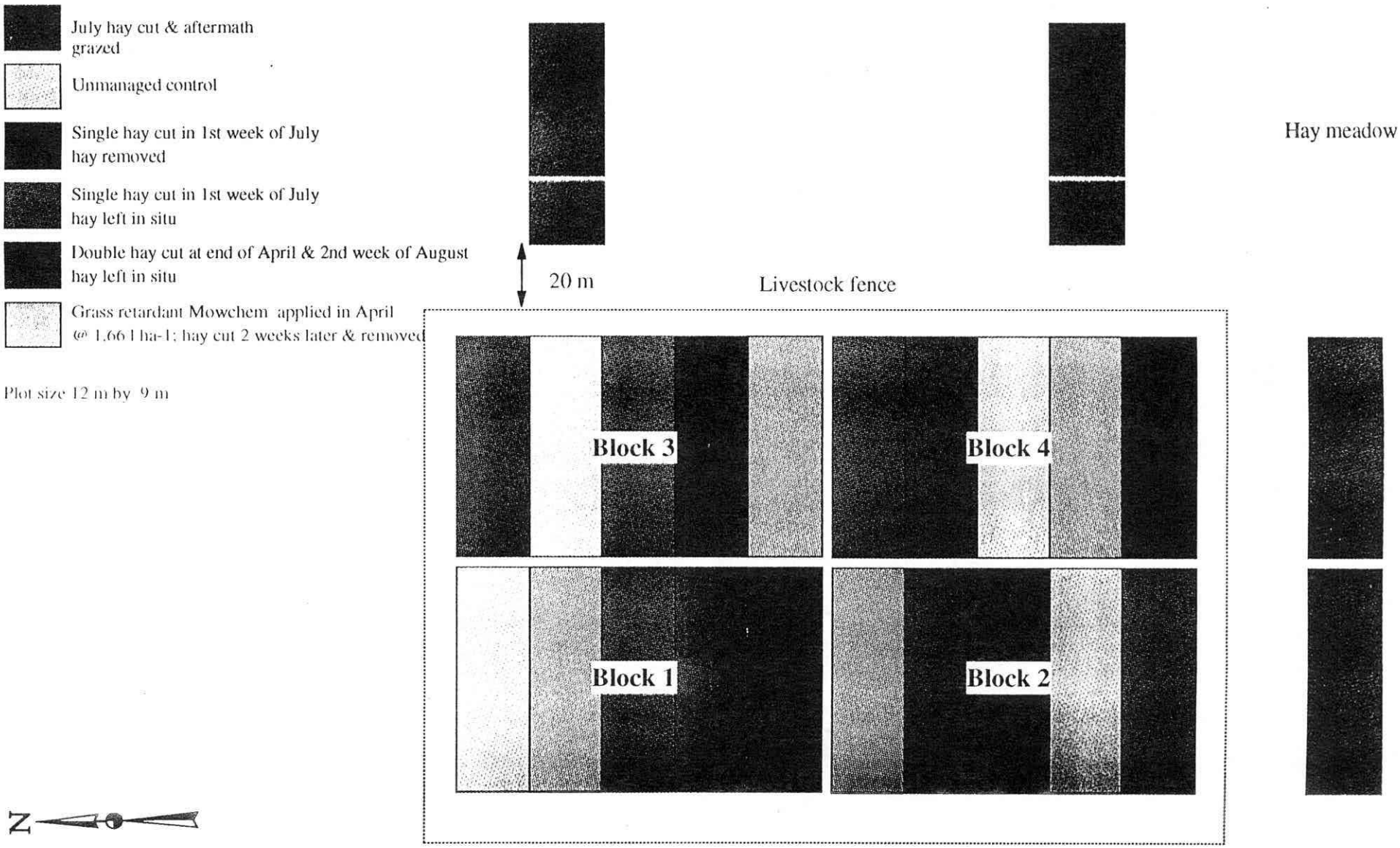


Table 4.16 Species list for the meadow at Radcot

Agrostis capillaris	*Glechoma hederacea*
Agrostis stolonifera	*Lathyrus pratensis*
Alopecurus pratensis	*Leontodon autumnalis*
Anthoxanthum odoratum	*Lotus corniculatus*
Dactylis glomerata	*Lysimachia nummularia*
Deschampsia caespitosa	*Plantago lanceolata*
Festuca arandun.	*Plantago major*
Festua rubra	*Potentilla anserina*
Festuca ovina	*Potentilla reptans*
Festuca pratensis	*Ranunculus acris*
Holcus lanatus	*Rumex acetosa*
Hordeum secalinum	*Senecio vulgare*
Phleum pratense	*Silaum silaus*
Lolium perenne	*Stellaria graminea*
Poa pratensis	*Stellaria media*
Poa trivialis	
Carex hirta	
Carex riparia	
Achillea millefolium	*Brachythecium rutabulum*
Centaurea nigra	*Eurynchium praelongum*
Cerastium fontanum	
Cirsium arvense	
Filipendula ulmaria	

In July 1995, five 50 cm by 50 cm quadrats were placed at random within each treatment plot, including those within the meadow. The quadrats were sub-divided into twenty five 10 cm by 10 cm cells and the presence or absence of plant and bryophyte species was recorded in each. This gave a rooted frequency score for each species. Plant species diversity was estimated as the Simpson's Index.

The frequency data was arcsine transformed to stablise sample variance and subjected to analysis of variance (ANOVA).

4.2.2.5 Results and discussion

The different management treatments resulted in markedly different vegetation structure. The control (1.) was dominated by tall, tussock grasses, especially *Arrehantherum elatius* and *Festuca arudinacaea* up to 100 cm. Climbing forb species, such as *Galium aparine* were abundant in these plots. There was a deep litter layer (3-5 cm) and the understorey was starved of light, resulting in very few species being present. Overall, the vegetation had the appearance of an unmanaged roadside verge. The single cut and removal of hay in July (2.) reduced the abundance of the tall, tussock grasses and epiphytic forbs. These were replaced by a uniform sward of competitve

grass species, such as *Holcus lanatus*. A slightly greater number of forb species were also present, relecting the more open nature of the vegetation. Leaving the cut material *in situ* (3.) appeared to have a detrimental effect on the sward. On fertile sites such as this, productivity is high and the cut material can form a dead mat over the vegetation. This caused the supression of the fine - leaved grasses, such as *Festuca rubra*, and some of the forb species present in treatment 2. The dual hay cut in April and August probably produced the most open and diversely structured sward of all of the cutting and chemical treatments. The application of grass retardant (5.) caused the dominance of the coarse tussock grass species *Deschampsia caespitosa*, with very few other species present. The adjacent, grazed meadow had a relatively uniform appearance (30-40 cm). However, there were a considerable number of gaps in the sward which were due to patches of animal urine and dung, as well as the activities of moles.

There were significant ($P \leq 0.05$) differences in species richness between the management treatments. The cut and grazed meadow (treatment 6.) and the dual hay cutting treatment (4.) contained nearly twice the number of plant species than the other treatments. Similarly, there were significant ($P \leq 0.05$) differences in overall species diversity as estimated by the Simpson's diversity idex, with treatments 6. and 4. being the most diverse.

The response of individual species to the different management treatments is classified in Box 4.9. Other species which only occurred in the hay cut and grazed plots were *Anthoxanthum odoratum*, *Achillea millefolium*, *Leontodon hispidus, Plantago lanceolata,* and *P. media*. Species which totally excluded by grazing included *Arrhenatherum elatius, Poa trivialis* and *Carex hirta*.

Box 4.9: Effects of management on floristic composition

SPECIES SIGNIFICANTLY (P ≤0.05) MORE ABUNDANT UNDER A HAY CUTTING AND GRAZING REGIME

Grasses:
Agrostis capillaris, Agrostis stolonifera, Lolium perenne, Holcus lanatus

Forbs:
Cerastium fontanum, Ranunculus acris, Taraxicum officinale

SPECIES SIGNIFICANTLY (P ≤0.05) MORE ABUNDANT UNDER CUTTING MANAGEMENT

Cutting once

Alopecurus pratensis, Holcus lanatus

Cutting twice (April and August)

Arrehantheum elatius, Festuca rubra

SPECIES SIGNIFICANTLY (P ≤0.05) MORE ABUNDANT AFTER APPLICATION OF GRASS RETARDANT

Deschampsia caespitosa

SPECIES SIGNIFICANTLY (P ≤0.05) LESS ABUNDANT AFTER APPLICATION OF GRASS RETARDANT

Phleum pratense, Poa pratensis, Poa trivialis

4.2.2.6 Conclusions

Cutting management, a combination opf cutting and the use of grass retardant chemicals is unable to maintain the floristic diversity of calcareous meadow vegetation on deeper, more fertile substrata. Single or double cuts cannot exercise sufficient control over the tall, competitve grass species which rapidly dominate the vegetation. The major ecological effect of livestock grazing are likely to be the creation of gaps in the sward through dunging and poaching which allow the persistence of smaller, less competitve forb species. Cutting has a more uniform effect and creates fewer gaps.

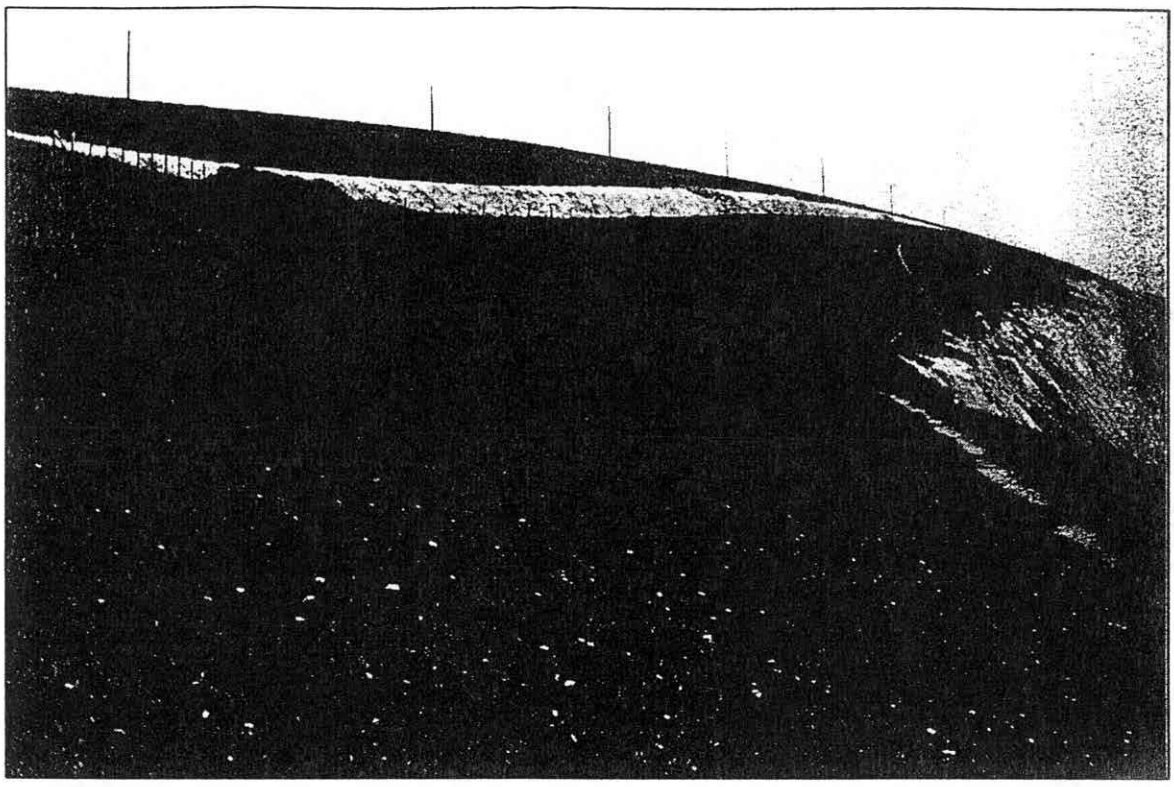


Plate 10. Calcareous grassland maintained by the maritime influence at Afton Down, I.O.W. (May 1968)

Plate 11. Afton Down in July 1994.

Plate 12. The rare chalk heathcommunity of calcareous grassland at Tennyson Down, I.O.W..

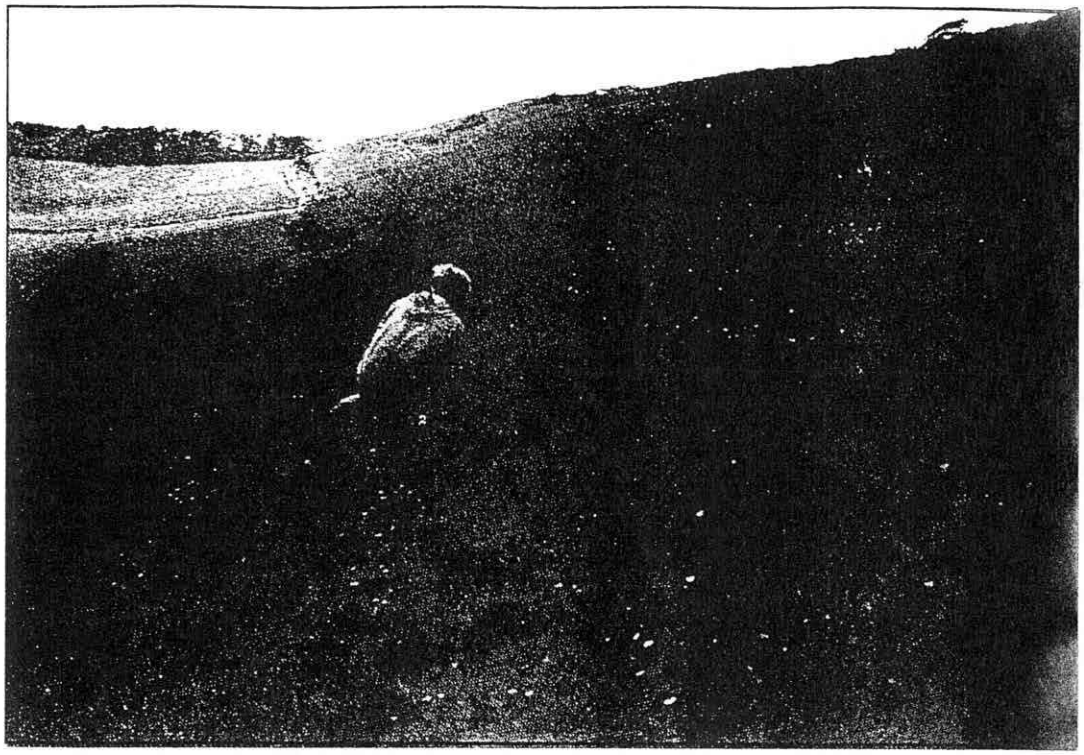


Plate 13. The effects of cattle grazing at Mottistone Down I.O.W. (May 1968)

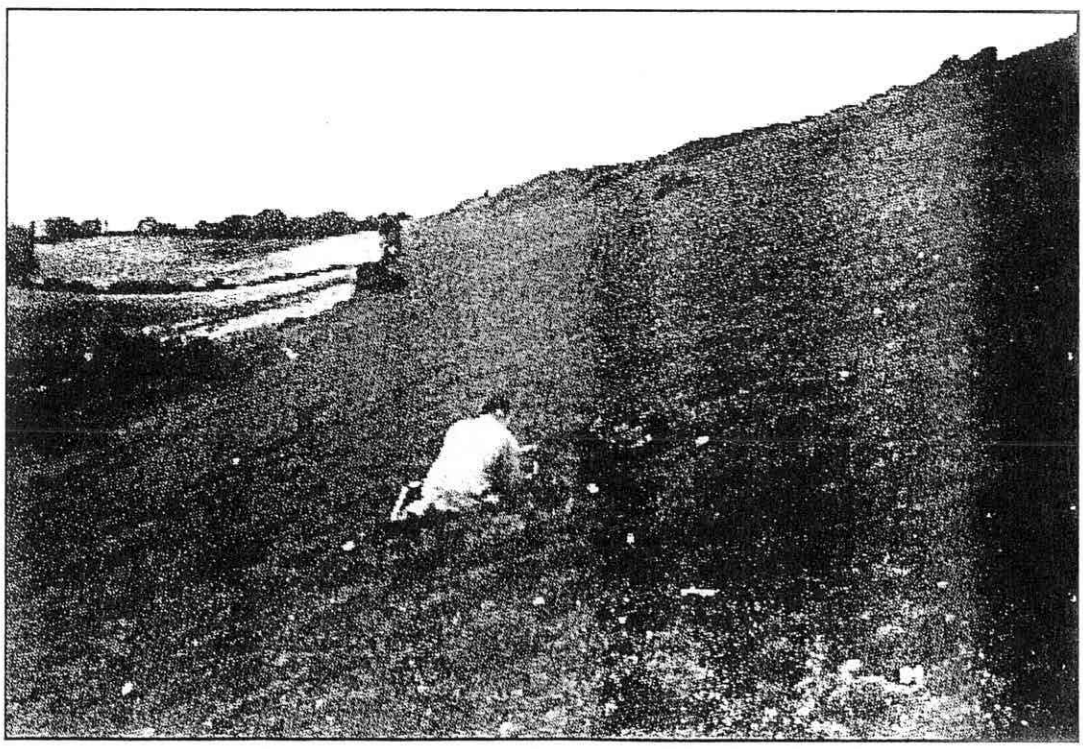


Plate 14. Mottistone Down I.O.W. (July1994)

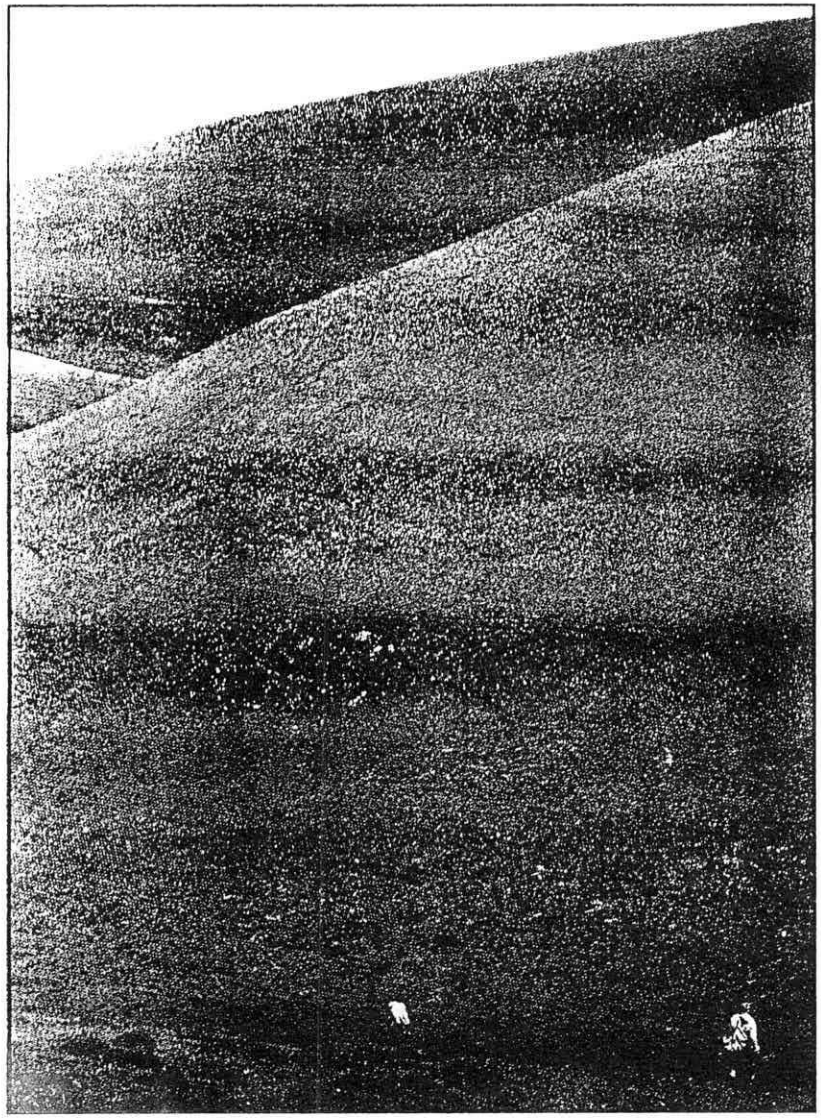


Plate 15. Effects of sheep grazing at Garstons Down, I.O.W. (May 1968). Note the uniformly short turf with ant hills in the foreground.

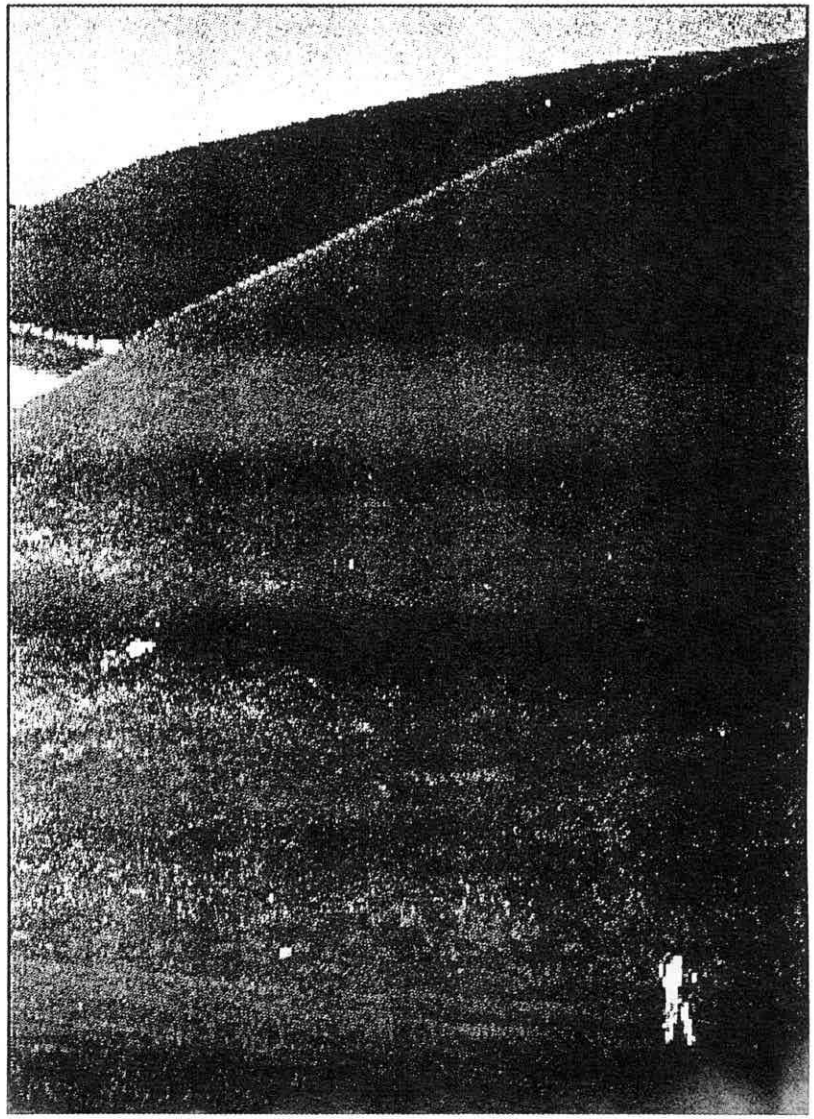


Plate 16. Garstons Down, I.O.W. (July 1994)

5.0 RECOMMENDATIONS FOR THE MANAGEMENT OF CALCAREOUS GRASSLANDS

This section summarises the findings of the Review and derives a series of recommendations for the conservation management of existing calcareous grasslands. These are compared to current management guideline in the ESA and Countryside Stewardship schemes. Other useful sources of information on the management of grassland include :

Crofts & Jefferson (1994), Bakker (1989), Duffey *et al.* (1974) and Rorison & Hunt (1980).

5.1 OBJECTIVES OF GRASSLAND MANAGEMENT

- conserve and promote the characteristic assemblages of plant and animal species associated with calcareous grassland;
- maintain the structure and function of the ecosystem;
- prevent unwanted successional changes;
- provide an economic return.

5.2 GRAZING MANAGEMENT

Livestock grazing is the traditional and preferred management for the conservation and enhancement of calcareous grasslands. It is the only management option which will produce an economic return. Cutting is not an adequate replacement for this in the long term.

5.2.1 Ecological impacts of grazing on vegetation

These studies have shown that grazing has three important ecological impacts on the calcareous grassland ecosystem: defoliation, trampling, and nutrient cycling (Box 5.1). These are the largely responsible for the increase in biodiversity often associated with grazing.

Box 5.1 Ecological impacts of grazing

Selective defoliation: preferential selection of different plant species by livestock can be an important determinant of grassland structure and composition. Low stocking rates also cause the more gradual removal of herbage compared to cutting and allow invertebrate populations to recover.

Tampling: moderate trampling breaks up the litter layer, crushes tall vegetation, and creates gaps for germination and establishment. This is especially important for annual species and the bare ground is habitat for some invertebrates.

Nutrient cycling: grazing promotes nutrient cycling. Traditionally, livestock were moved off the downs at night, thus removing nutrients and maintaining the low fertility of the system. Deposition of dung and urine also create gaps in the sward.

Plant growth: grazing promotes tillering in grasses and favours rosette forming plants with underground storage organs. This helps maintain the compact structure of the sward in which no one species is dominant and prevents the invasions by weed species. Species characteristic of calcareous grassland are often ecologically adapted to withstand grazing.

5.2.2 Conservation management within the farm system

Calcareous grasslands are of lower productivity and produce less digestible herbage than improved grasslands. Integration of the management of such semi-natural habitats within the modern, intensive farming system presents several problems. This review has shown that the following grazing systems are most suitable for conservation management and are the preferred agronomic options:

- **Extensive beef grazing:** suckler calf production, and store cattle, bullock and heifers for beef production.
- **Extensive sheep grazing:** mature wethers, barren ewes, or lambs (fattened on better quality grassland elsewhere)

There is no reason why both systems cannot be combined on larger sites, such as at Wylye Down. The case study of Parsonage Down has shown the value of areas of high productivity 'back-up' grassland close to the nature reserve.

5.2.3 Grazing management regime

Before producing a management regime, it is important to evaluate the site in order to identify and determine the extent the species and habitats that would benefit from management. Once this has been achieved it is possible to set clear targets or objectives for management. Past management regimes which were responsible for conservation interest of a site should be resurrected or maintained.

Management regimes to achieve the conservation objectives need to be **flexible** and depend on the manipulation of the following variables:

- Livestock type, breed and age
- Timing of grazing
- Duration and intensity of grazing
- Supplementary feeding

Livestock type, breed and age

Brief accounts of the characteristics and effects of individual species are given here. Combinations of animals and breeds may be required to achieve the desired conservation objectives.

Sheep are widely available and relatively cheap. They graze by nibbling to produce a relatively uniform, short sward. They are lighter and more agile than cattle. Lowland breeds of sheep (e.g. Suffolk, Mules, Dorset Horn and South Down) may provide an economic return from extensive grazing systems, but are considered unsuitable for coarse, problematic vegetation and scrub. Such breeds are best suited to maintaining existing, good quality grassland. Hardy breeds (e.g. Hebridean and Beulah) are consider 'hard mouthed' being able to eat unpalatable species and utilise herbage of poor nutritional quality. However, they are generally more difficult to obtain and handle, and provide a lower agronomic return. Crossing hardy and lowland breeds has proved a successful compromise at sites such as Parsonage Down.

Cattle differ greatly in their ecological effects compared to sheep. They tear the vegetation unevenly and eat with a rasping tongue. They also trample the sward to a greater extent and create more gaps. Cattle are especially adept at browsing and knocking down tall, dense scrub and readily eat rank grass. They are not worried by dogs. However, they are more expensive to buy and keep, and overstocking in winter will lead to poaching and subsequent weed infestations. Smaller, lighter cattle are generally better suited to conservation management. Charolais x, Aberdeen Angus, Dexters and Belted Galloways have all been used with great effect on the Isle of Wight and at Parsonage Down. Cattle may be beneficial for the initial, restoration management of degraded sites. They can then be replaced by at a later date by sheep grazing to maintain the site and provide a greater return.

Goats have been used successfully to control invasive scrub species at a variety of sites (section 4.3, including Boniface Down, Isle of Wight). They are not worried by dogs and require little care. However, they are wild and provide virtually no economic return. Non-domestic grazing animals, most notably rabbits, have a significant, but variable effect on many calcareous grasslands. They are highly selective grazers and create patches of bare ground. Moderate densities can be very beneficial, although high densities favour a narrow spectrum of plant species and reduce overall diversity. They have become a management problem at many sites including Knocking Hoe and Mottistone Down, Isle of Wight. It is important to consider the potential impact of non-domestic grazers on the grassland when devising the grazing management regime as they can significantly reduce the amounts of herbage available.

Finally, it is important to consider the age of the domestic livestock. Grazing preferences and ability differ considerably with age. In general, mature animals are preferred over young or aged stock because of the poor palatability and nutritional quality of much semi-natural herbage.

Time of grazing

Grazing should aim to remove most of that year's herbage either during the spring and summer growth period, or during the winter. In the latter case the herbage will be less palatable. Flexibility in approach is required to allow for between year variations in productivity. Also, the timing of grazing should be co-ordinated to avoid damage to sensitive plant and invertebrate species. This requires some understanding of the biology of the species of conservation interest at a given site. Spring grazing is useful for the control of scrub and unpalatable species (e.g. Ragwort). Summer grazing removes herbage as it is produced, although high stocking rates will reduce the visual attractiveness of the site as flower heads are removed. This may also be potentially damaging to invertebrates as potential nectar sources are reduced. Winter grazing has the advantage that moderate trampling serves to break up the litter layer and create gaps for plant colonisation. However, there is the inherent danger of soil poaching. Larger sites will enable rotational grazing management regimes to be employed. These are likely to be the most advantageous for conservation.

Duration and intensity of grazing

It may take several years for the effects of changes in grazing management to become apparent. The Barton Hills grazing experiment (4.1.1) suggested that grazing initially effects the structure of the sward and it make take several years for the composition of the perennial species to alter. However, the number of annuals and short-lived perennials were almost immediately increased by grazing.

It is difficult to derive exact rules for grazing management because of local variation in soil fertility, climate, productivity and palatability. The duration and intensity of grazing should aim to achieve the relevant conservation objectives, whilst at the same time not compromising the welfare of the livestock. Short periods (weeks) of intense grazing may appropriate on small sites where stock is of limited availability or there are sensitive plant species. This type of regime has proved effective at eliminating problem species (e.g. *Brachypodium pinnatum* at Barnack 4.1.5). However, such management may be detrimental to invertebrates, although the effects may well be lessened if the site is first divided into compartments, each being grazed systematically. Similarly, long grazing periods (all year) by relatively small numbers of animals may well be ineffective in controlling the growth of grass and is a difficult regime for making adjustments. In general, a moderate grazing intensity over a longer period (16 - 20 weeks) is preferred.

English Nature have produced a guide to livestock stocking rates for the conservation management of calcareous grassland (Crofts & Jefferson 1994). The results of this Review are, in part, derived from case studies of English Nature reserves and we are in general agreement with their recommendations (Table 5.1). Stocking rates should, ideally, range from 8 - 12 sheep ha^{-1} and 2 - 3 beef cattle ha^{-1} for between 10-16 weeks. **It must be stressed that these figures are only a guide to stocking rates. They are very much dependant on the factors stated above. We recommend that they are used in conjunction with simple sward measurements carried out at regular intervals.** Target sward structure and heights should be determined after an initial site assessment to determine conservation management objectives.

Table 5.1 A guide to livestock stocking rates for conservation management of calcareous grassland (adapted after Crofts & Jefferson 1994)

Duration of grazing (weeks)	Sheep			Cattle		
	density ha^{-1}	LU ha^{-1} (growing animals)	LU ha^{-1} (mature animals)	density ha^{-1}	LU ha^{-1} (growing animals)	LU ha^{-1} (mature animals)
2	60	3.60	6.00	15	5.70	10.20
4	30	1.80	3.00	8	3.04	5.44
6	20	1.20	2.00	5	1.90	3.40
8	15	0.90	1.50	4	1.52	2.72
10	12	0.72	1.2	3	1.14	2.04
12	10	0.60	1.00	2.5	0.95	1.70
14	8.5	0.51	0.85	2	0.76	1.36
16	7.5	0.45	0.75	2	0.76	1.36
20	6	0.36	0.60	1.5	0.57	1.02
24	5	0.30	0.50	1	0.38	0.68
36	3.5	0.21	0.35	1	0.38	0.68
52	2.5	0.15	0.25	0.5	0.19	0.34
Grazing pressure (animal weeks/ ha^{-1}/yr^{-1})	120			30		

Supplementary feeding

Supplementary should be avoided where ever possible. It is likely that seed of weed species will be introduced with the feed and the stock may well eat the more palatable feed in preference to the natural herbage. The main impact of this will be physical damage, poaching, around the feeding areas. Additional feeding is sometimes inevitable, especially during severe weather. Experience at Parsonge Down suggests that the feed should be spread in areas of relatively low conservation importance, and that the location of these sites should be varied.

5.2.4 Monitoring

Careful monitoring of the ecological impacts of a given grazing regime is essential. It allows adjustments to be made to the duration and intensity of grazing in order to achieve the conservation objectives. This could take the form of relatively simple sward height measurements.

5.3 CUTTING MANAGEMENT

Cutting of calcareous grasslands is unlikely to achieve the overall objectives of conservation management (5.1) in the longer term. However, as a management technique, it has the potential to arrest the processes of succession and to maintain at least some of the biodiversity of a site. In some situations it is neither economic or practical to maintain grazing animals outside the farming system. This is often the case for arable farms with small areas of grazing land, inaccessible sites, and those on the urban fringe. In such cases, cutting management is the only alternative to grazing.

5.3.1 Ecological impacts of cutting on vegetation

Cutting has markedly different effects on the ecology of grassland compared to grazing. Mowing causes an immediate and uniformly drastic alteration in the structure of the sward. It is non-selective and does not create the valuable mosaic of gaps in the sward associated with livestock trampling. Removal of hay also causes a gradual nutrients depletion and loss of productivity. Finally, the timing of cutting will strongly influence the eventual composition of the sward as some species are prevented from setting seed. Cutting of a whole site on one date could have very damaging impacts on the associated invertebrate fauna as much of their habitat will be removed.

5.3.2 Cutting regime

The study at Knocking Hoe (section 5.2.1) has demonstrated that cutting and immediate removal of the vegetation was more beneficial to species of conservation interest that leaving the cut material in place. However, leaving the cut material on the ground for a few days prior to removal may allow some species to shed their seed. This will depend upon the time of cutting. It is important that the time of cutting is carefully co-ordinated so as not to prevent desirable species from setting seed. Rotational cutting of larger sites is preferred. More frequent cutting (2 or 3 times in a summer) has been shown to be effective in controlling the competitive ability of coarse grass species. Close cutting and 'scalping' of small areas may be beneficial in the creation of gaps for germination.

5.4 EXISTING ESA AND COUNTRYSIDE STEWARDSHIP GUIDELINES

ESA guidelines

South Wessex Downs ESA (Tier 1) does not give any guidance as to stocking rates, duration of grazing or target sward heights. Farmers are simply advised not to overgraze or under-graze the land. The Cotswolds ESA (Tier 1C) recommends that stocking rates do not exceed 0.75 LU per hectare between April and May and supplementary feeding areas are agree with the Project Officer in advance. Tier 1 of the South Downs ESA suggests that sward height is best guide to correct grazing management. Managers are required to aim for a height of 3-10 cm, with the majority of the sward being kept in the upper part of the range between April to July to enable species to set seed. Annual stocking densities of between 0.5-1.5 LU ha^{-1} are recommended to achieve this. Supplementary feeding areas have to be agreed with the Project Officer in advance.

Countryside Stewardship guidelines

Countryside Stewardship (CS) guidelines recommend that chalk grasslands are managed by light sheep and / or cattle grazing for at least 10 weeks in each year without damaging the sward. The aim is to remove the year's grass growth and to achieve an average sward height of about 75 mm by the end of the summer. Stocking should not normally exceed 0.75 livestock units per ha.

Several criticisms can be made of these guidelines:

In the context of this review, the objectives of calcareous grassland management are too general, lack flexibility and are not focused on individual species and site requirements. The guidelines provided for the South Wessex Downs and Cotswolds ESAs rely on stocking rates alone . This is unsatisfactory as it takes no account of between year and site variations. Guidelines for the South Downs and CS are an improvement, relying on sward heights and stocking rates, but still lack the necessary flexibility in approach to management. Guidelines need reflect different climate,

geology, soils and farming systems which created these semi-natural habitats the scheme seeks to protect and enhance. Site specific management prescriptions may well be required. The use of Livestock Units (LU) to define stocking densities is not precise and does not reflect relative intake of herbage by different types of livestock. Finally, none of these schemes require regular monitoring of the impacts of grazing, even at a simplistic level.

5.3 RECOMMENDATIONS

An integrated approach to calcareous grassland management is recommended:

1. Each site should be **evaluated** to:
   - identify the species and habitats which require management in order to conserve them;
   - determine if either **restoration** or **maintenance** management is required (in the former case, a different management regime and higher initial payments may be required);

2. From this clear **ecological management objectives** should be derived:
   - whether to conserve or promote a given species (it is important to strike a balance between management for the main component species of a site and locally or nationally rare species);
   - these will depend on the requirements of species and communities;

3. These must be balanced with what is **realistically achievable**:
   - with the **resources available** (e.g. livestock, skills & machinery);
   - **local constraints** (e.g. topography, soils and access);
   - other management considerations (e.g. culture, heritage and landscape).

4. From this **operational management objectives** can be derived:
   - these must be **flexible** (e.g. allowing for between year variation);
   - should encourage **rotational grazing management**;
   - **rigorous, sward height objectives** should be developed;
   - these should be **underpinned** by guidance on stocking rates in more **appropriate units** (e.g. Utilized Metabolisable Energy Output);

5. This should provide the farmer with a suite of **viable management options** specially tailored to a given site.

6. **Frequent monitoring** is important in order to review management policy and make the necessary adjustments to achieve the conservation objectives. This could take the form of simple, standardized sward measurements.

6.0 INTRODUCTION TO LOWLAND HEATHS

6.1 Definitions

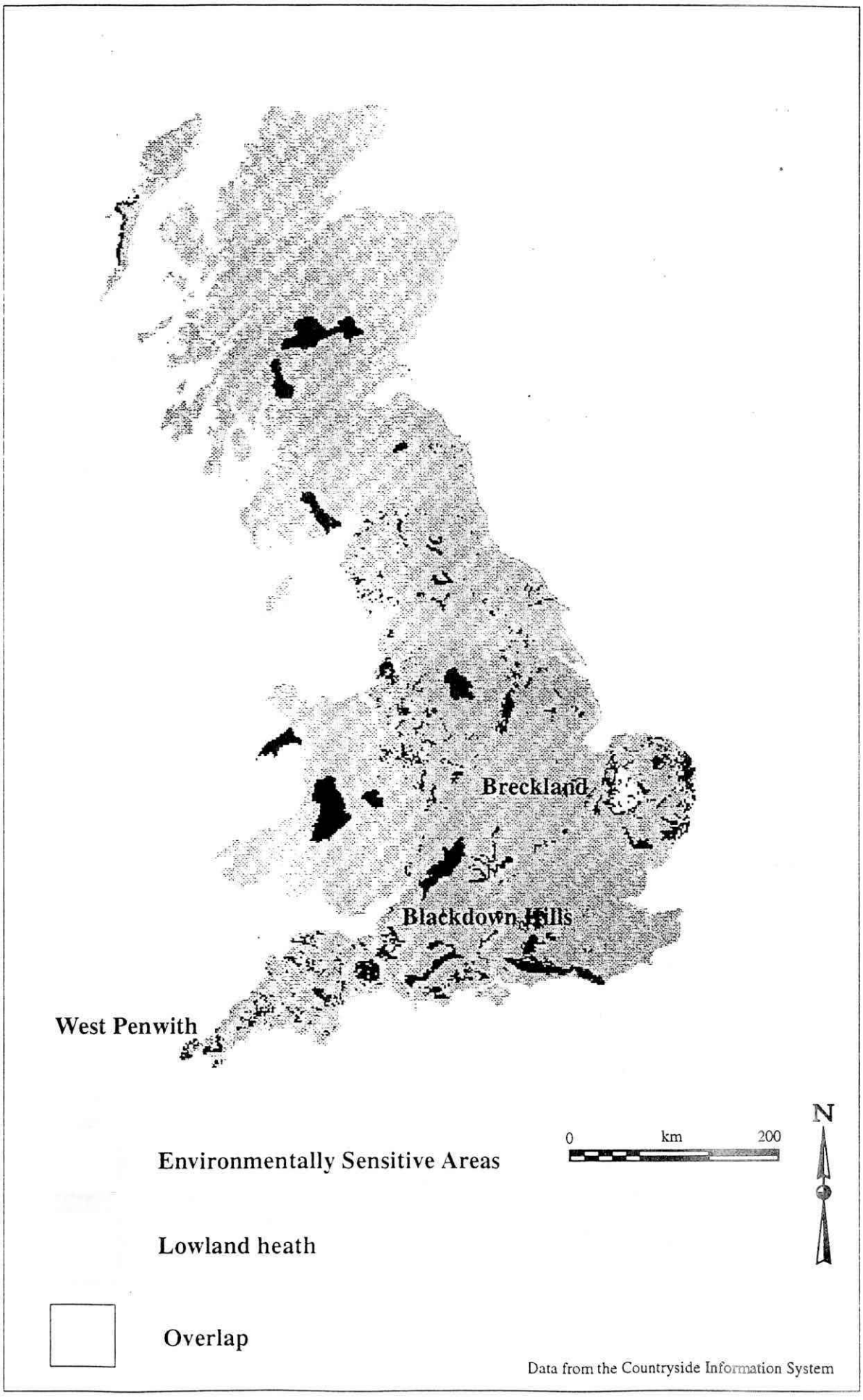
Lowland heaths are defined as plant communities dominated by ericaceous dwarf-shrubs (heathers) growing below 250 m O.D. (Webb 1986). The distribution of lowland heaths is shown in Fig. 6.1. Like calcareous grasslands, trees and tall shrubs are usually absent or sparsely scattered. Heather dominated heaths typically intergrade with acidic grasslands and mire communities in which heather species no longer dominate. For the purposes of this review, we have extended the definition of heath to include these closely related communities types, including acid grassland and mires.

6.2 History and development

The distribution of heathlands in Northwest Europe reflects the climatic requirements of the dominant plant species - Common Heather or Ling (*Calluna vulgaris*). This species performs best in areas with mild, moist winters, though it can tolerate low nutrient levels, high acidity and a high degree of drought. However, it is not particularly tolerant of frost and this prevents its dominance in more continental areas.

Most heathlands, like calcareous grasslands are a product of human intervention. Formerly, 'natural' heathlands would have only occurred on exposed coastal cliffs and in sub-Arctic conditions above the treeline, or more commonly as a glade plant of woodland on impoverished, acid substrata. Pollen analysis suggests that the majority of heathlands were formerly covered by forests. Replacement of the forest by heath was not a sudden event, but took place progressively over an extended period, starting sometime in the Neolithic period (c. 3000 BC) and continuing up to the 18th century. Several human activities are likely to have brought about the development of lowland heaths, including the long term grazing of the woodlands and small-scale clearance for arable cultivation. These actions would have combined to gradually reduce natural regeneration of woodland. This latter path was typical of the pattern of shifting agriculture in regions such as Breckland. Both practices would have resulted in the loss of nutrients from the already impoverished soils, so that suitably adapted species (calcifuges), including heather, were able to spread and dominate the vegetation. Regeneration of the tree cover would have been prevented by the low nutrient status, removal of seedlings by grazing animals as well as continual disturbance by agriculture, in the form of turf stripping for fuel or burning to promote new growth. Hence heathland systems are, in the main, plagioclimax communities maintained within their present state by some form of disturbance, and ultimately will be replaced by woodland unless management is continued.

Fig. 6.1 Extent of lowland heath and ESAs within Britain



6.3 The heathland environment

Heathlands soils are typically sandy and acidic (pH 3 - 4.5), with extremely low levels of major plant nutrients. The acidity of heathland soils is partly due to the base-poor nature of the substrata. This has been accentuated by the acidity of heather litter. The very low pH of these soils excludes virtually all of the soil burrowing macrofauna, such as earthworms, which are responsible for the decomposition of organic matter and mixing the soil. Without these animals, acid litter accumulates on the surface of the soil, and as a consequence percolating water is itself acidified and leaches minerals (especially iron and aluminium) from the underlying soil. Thus heathland soils are characteristically podsolised: with well defined organic and eluviated or 'bleached' horizons above layers of humic and almost pure sand.

6.4 Lowland heath types

Compared to calcareous grasslands, the plant communities of many heathlands are characterised by the relatively low numbers of vascular plants and a relatively higher diversity of lichen and bryophyte species. As with the calcareous grassland ecosystem, it is important to consider the different types of heathland as merely a continuum of variation in response to local climatic, topographic and hydrological factors. However, for management purposes, we often need to talk in terms of the requirements of single vegetation types. At the broadest level, lowland heaths can be split into dry, and wet heaths, and closely related acid grasslands. This continuum has been more systematically broken up into discrete communities in the National Vegetation Classification (NVC: Rodwell 1991). This describes five discrete lowland heath communities, two closely related acidic grassland communities and the most common wet heath or mire community (Boxes 6.1 & 6.2)

Box 6.1 Lowland heath communities defined by the National Vegetation Classification

Dry lowland heaths
Typically occur on freely drained, light, sandy soils which are extremely low in nutrients:

H1 *Calluna vulgaris - Festuca ovina* heath
Occurs in the more continental climate of Eastern England (Breckland, Norfolk, Suffolk, Sussex and Lincolnshire). This community has the lowest diversity of vascular plants, but is rich in lichen, and to some extent mosses. Often forms a matrix with acidic (U1) grassland. A product of sheep and rabbit grazing, as well as shifting patterns of short term cultivation.

H2 *Calluna vulgaris - Ulex minor* heath
Occurs in more oceanic climate of the central parts of southern England. The characteristic community of the Weald of Kent, the Hampshire and eastern Dorset Basins, Surrey and Sussex. The diversity of vascular plants is increased slightly, with *Erica cinerea* and *Ulex minor* widespread. A product of rotational burning and more extensive livestock grazing by horses and cattle.

H8 *Calluna vulgaris - Ulex gallii* heath
Occurs in the warmer, most oceanic climate of western Britain. An intimate mixture of heathers and gorsewith *Ulex minor* being replaced as a dominant species by the more oceanic *Ulex gallii*. Once again, maintained by burning and rotational livestock grazing.

Acid grasslands
Transition to acidic grassland: Where grazing is more intense or patchily distributed then heather dominated communities intergrade with those dominated by grasses.

U1 *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland
This vegetation occurs widely over freely draining soils in eastern and southern England, often in association with stands of H1, which takes over if grazing or disturbance is reduced.

U2 *Deschampsia flexuosa* grassland
This again occurs on freely draining soils, replacing heathland after the abandonment of burning, grazing and other traditional treatments such as bracken and gorse cutting. Large areas of this habitat are rarely found in the drier parts of Britain. The transition of heathland to *Deschampsia flexuosa* grassland has also been attributed to increased nitrogen deposition (e.g. Heil & Deimont 1983), the evidence for which is, however, equivocal and is reviewed by Marrs (1993).

Wet heaths and mires
On oligotrophic mineral soils and peats which are subjected to seasonal and permanent waterlogging.

M16 *Erica tetralix - Sphagnum compactum* wet heath
Widespread throughout central and southern lowland Britain where it forms a transition between the drier heath types and bogs. The diversity of vascular plants and bryophytes is relative high. *Calluna vulgaris* is co-dominant with various combinations of *Erica tetralix* and *Molinia caerulea. Eriophorum vaginatum, E. angustifolium and Drosera* spp. are common. *Sphagnum compactum, S. tenellum* and other *Sphagnum* species also become prominent.

Box 6.2 Other communities NVC communities associated with lowland heaths

A range of communities are often associated with heathland, usually as a result of successional change. These include those dominated by bracken as well as a range of woodland communities.

U20 *Pteridium aquilinum - Galium saxatile* community

A common community associated with grassland, heathland and woodland on neutral and acidic soils.

W25 *Pteridium aquilinum - Rubus fruticosus* agg. community

This community is found in similar situations but on deeper and richer soils.

6.5 The dynamics of heathland plant communities

Like grasslands, heathlands are semi-natural man-made habitats. They usually occur where conditions of soil and climate combine to favour the development of stable or climax woodland. In the absence of continued use and management, scrub and tree species will gradually establish themselves and take over the site. This process of succession will tend to take place more rapidly on grasslands where the soils are less acidic and more fertile.

In addition, the dominant plant of most lowland heaths, *Calluna vulgaris*, has a series of growth stages (Box 6.3). *Calluna* bushes typically becomes degenerate and die off after 30 - 40 years, or as little as 13 years in the drier climate of the Breck in East Anglia. The gaps in the degenerate heathland canopy are invaded by lichens and bryophytes, as well as other heathland plant species including *Erica cinerea* or *Agrostis curtisii*. Plant diversity probably reaches its maxima at this stage of dry heathland development. These gaps also provide ideal sites for the germination and establishment of a next generation of *Calluna* seedlings which will grow and eventually replace the other species. Thus the cycle will begin again. However, heathland in the degenerate stage is also susceptible to the invasion of tree and scrub species if suitable sources of seed are available. These will persist if grazing animals are not present to defoliate and kill the seedlings. Conversely, over grazing will allow the persistence and spread of grass species such as *Molinia caerulea* and *Festuca ovina*. The action of traditional heathland management (burning, cutting and grazing) continually rejuvenates *Calluna* and prevents it from reaching the degenerate state.

Box 6.3 The four stages of *Calluna* growth (Gimingham 1972)

Pioneer stage (0 - 6 years)
Calluna plants establish either from seed, or from stem bases which have survived a fire. The plants usually flower in the second season and gradually develop a bushy habit. The vegetation is open, with sometimes large gaps between bushes and there is often little leaf litter. Tree species, especially Birch, can invade at this stage.

Building (up to 10 - 15 years)
Vigorous, radiating growth gives rise to compact, hemi-spheric bushes. The individual bushes merge to form a dense canopy which allows little light to penetrate and the litter layer begins to accumulate. Heathland is often at its most productive and palatable to livestock at this stage.

Mature (up to 20 - 25 years)
Growth slows and becomes more woody. The canopy thins, becomes more irregular and gaps appear.

Degenerate (30 - 40 years)
The central branches of the bushes die off and the gaps increase in size and join, although the outer branches may remain alive for some time. Heathland species, including *Calluna*, as well as woodland species often invade the gaps in the canopy and establish.

6.6 Heathland management

The reasons for the continued existence of heathland in lowland Britain over hundreds or even thousands of years must therefore be explained by their exploitation and management by man. Traditionally, heathlands provided useful grazing land and were able to sustain short periods of arable cropping. In addition, they were used for other activities, such as the gathering of fuel (Box 6.4 & Table 6.1).

These management practices served to :

- **periodically remove nutrients from the ecosystem;**
- **prevent tree and scrub encroachment;**
- **maintain the dominance of heather in a vigourous state of growth.**

The unregulated application of these techniques led to a diverse matrix of habitats types within the heathland, ranging from bareground to mature heath. However, many of these management practices have declined or ceased in the last two hundred years or so. Advances in agricultural technology have removed the limitations of deficiency on heathland soils. This has allowed the conversion of heathland to pasture and arable land, and negated their value as extensive grazing land. Similarly, the heaths are no longer required for fuel. The present day appearance of many lowland heaths bares little relationship to their former state. Today, many lowland heaths are virtual monocultures

of even-age *Calluna* bushes with serious encroachment of woodland, scrub or Bracken. This is both a product of the cessation of many of the traditional uses and the increase in catastrophic summer burns which can affect whole blocks of heath. It is therefore essential that these traditional forms of management processes and cycles, or something like them, are reinstated to the heaths of lowland Britain.

Box 6.4 Traditional management of lowland heath

Grazing
Heaths provided useful grazing on relatively infertile acid soils where grassland was scarce. Heather species are evergreen and provide a useful source of forage all year round. Grazing encourages rapid vegetative regeneration, maintaining the canopy in the vigorous building phase. The livestock were often removed from the heath to adjacent arable land at night.

Cutting
In the past, older, woody heather was cut to for a variety of uses including animal feed and bedding, thatching material and for the foundation of roads. This practice also served to rejuvenate the heathland, improving the quality of forage for grazing animals.

Burning
The periodic, controlled burning of the heathland canopy in February and March can be used to rejuvenate age stands of heather to produce a flush of more palatable shoots. Frequent rotational burning at this time of year ensured that the fires removed only the woody stems and left the litter and moss layer intact to protect the stem bases of the heather and permitting vegetative regeneration. It is likely that this was a traditional management practice in some areas of lowland Britain, although it is likely that the warm, dry climate would have made the occurrence of accidental summer fires more common. Such fires can be more catastrophic: burning off the litter layer and killing the stem bases of the heather, making regeneration much slower.

Occasional cropping
In some lowland regions, such as Breckland and Dorset, small strips of heathland close to farms were cultivated and suitable crops were grown. After two to four harvests the impoverished soils became exhausted and the sites were allowed to revert to heathland.

Fuel-gathering
Heathlands have traditionally provided sources of fuel. Trees and scrub species, such as Gorse, would have been frequently cut from the heath. In addition, the shallow surface litter and organic layer of the soil was stripped off and dried for domestic fuel. Evidence suggests this practice of turf cutting or 'turbary' was carried out over very long periods on many of the southern lowland heaths. Typically for every spade-sized turf removed, two were left.

Table 6.1 Traditional management of heathland and acid grassland communities defined by the NVC (Rodwell 1991)

NVC community	Livestock grazing	Periodic burning (accidental or controlled)	Occasional cultivation	Fuel gathering
Dry heathland				
H1	✓	✓	(✓)	✓
H2	✓	✓	(✓)	✓
H3	✓	✓	(✓)	✓
H4	✓	✓	(✓)	✓
Wet heathland				
M16	✓	✓		✓
Acid grasslland				
U1	✓		✓	
U2	✓			

6.7 Nature conservation value of lowland heath

Like calcareous grassland, lowland heaths have long been valued as a resource of great ecological interest and value for nature conservation. Heathland habitats are characterised by their extreme acidity, and oligotrophic (nutrient poor) nature, together with a great diversity of habitats with gradients from wet to dry and cool to hot. Management plays a vital role in the creation and maintainence of these habitat types. A very distinctive, specialised flora and fauna have evolved to exploit these habitats. Some plant species require a degree of disturbance in order to perisit. These include the nationally rare Heath Lobelia (*Lobelia urens*), and the nationally scarce Marsh Gentian (*Gentiana pneumonanthe*) and Yellow Centaury (*Cicendia filiformis*). Other species have become very specialised, evolving specific adaptations to the heathland environment. For example, insectivorous plants like the Round-leaved Sundew *(Drosera rotundifolia*) overcome the lack of nitrogen in heathland soil by trapping the abundant insect life. Other species, such as Dodder (*Cuscuta epithymum*) parasitise heather, whilst the Yellow Barsia (*Parentucellia viscosa*) is a hemi-parasite of grasses. Table 6.2 lists the vascular plants and ferns of lowland heaths and acid grasslands which are classified as either nationally rare or nationally scarce.

Table 6.2 Nationally scarce (NS) and nationally rare (NR) vascular plants of lowland heath and acidic grasslands. Red Data species are further classified as endangered (e), vulnerable (v) or rare (r).

Scientific Name	English Name	Status
Carex montana	Soft-leaved Sedge	NS
Cicendia filiformis	Yellow Centaury	NS
Crassula tillaea	Mossy stonecrop	NS
Dianthus deltoides	Maiden Pink	NS
Erica ciliaris	Dorset Heath	NRr
Erica vagans	Cornish Heath	NRr
Gentiana pneumonanthe	Marsh Gentian	NS
Lobelia urens	Heath Lobelia	NRv
Parentucellia viscosa	Yellow Bartisa	NS
Scleranthus perennis	Perennial Knawel	NRe
Silene conica	Sand Catchfly	NR
Silene otites	Spannish Catchfly	NRr
Thymus serpyllum	Breckland Thyme	NRr
Veronica spicata spp. spicata	Spiked Speedwell	NS
Viola lactea	Pale Dog-violet	NS

Lowland heaths are considered to have a rich invertebrate fauna despite the comparatively low diversity of vascular plants. Heathland invertebrates can be classified as those feeding on heather and the other members of the plant community. The former group of phytophagous invertebrates comprise only a relatively few species, including the Heather Beetle (*Lochmaea suturalis*) which have become specifically adapted to tolerate the natural toxins present in heather. A further group of invertebrates depend upon the particular physical conditions which are only available on heathland. This latter group of invertebrates are much more diverse, containing many rare species. These are the most vulnerable to change in management of the heath. Some, such as the very rare Lady-bird Spider (*Eresus niger*) depend upon the sandy soil for burrowing and the hot, dry conditions at the soil surface. Others, including the Silver-studded Blue Butterfly (*Plebejus argus*) and the Green Tiger Beetle (*Cicendela campestris*) utilise the hot open spaces of pioneer dry and humid heath. Finally, the structural diversity of the much-branched heathland canopy is important for many groups of invertebrates, including the mite *Tetranychus lintearicus*. There is a well defined succession of invertebrate communities which correspond to the different growth stages of heather. This is especially true for ants (Elmes 1971) and spiders (Merrett 1976).

Of the heathland vertebrates, the reptiles are probably of the greatest interest to conservation. All six species of native British reptiles can be found on lowland heaths. Of these, the Sand Lizard (*Lacerta agilis*) and Smooth Snake (*Coronella austriaca*) are confined to them. Both species are at the northern limits of their geographic range in Britain. These species are thermophilous, relying on the favourable vegetation structure of heathland in order to thermoregulate properly. In addition, these species are reliant on the soft, sandy soils for egg laying and have

exacting temperature requirements for egg incubation.

In common with calcareous grasslands, relatively few species of bird are dependant on open heathland habitat for breeding. However, they are important habitats for several specialist and uncommon species including the Hobby (*Falco subbuteo*) and Stonechat (*Saxicola torquata*) . The nationally rare Stone Curlew (*Burhinus oedicnemus*) also occurs on the dry, open ground of the Breck heaths and acid grasslands in East Anglia. Several rare species have adapted to utilise the heathland edge or where scrub or young conifers occur within the heath. These include rarities such as the Nightjar (*Caprimulgus europaeus*), Dartford Warbler (*Sylvia undata*) and Woodlark (*Lullula arborea*).

Box 6.5 Summary of the threats to lowland heath

The lowland heath ecosystem contains an extremely specialised assemblage of plant and animal species which are adapted to the acidity and lack of nutrients. Floristic diversity is not as high as that of calcareous grassland but micro-habitats with gradients ranging from cool to hot, and wet to dry, ensure that invertebrate diversity is extremely high. In addition, heathland provides vital habitat for all six native reptile species and several rare birds. Losses to agriculture, forestry and urban development have traditionally constituted the main threats to lowland heath. Recently these losses have lessened in importance as heathland has been protected under the Wildlife and Countryside Act. The major threat to heathland today is the cessation of traditional forms of management which prevented the succession to woodland and scrub. Once this has occurred, more drastic types of management are required to restore the heathland vegetation (restoration management). The main effects of the lack of grazing, burning and other management on lowland heaths are as follows:

- invasion and dominance of grass and scrub species;
- accumulation of nutrients in the system;
- heather becoming degenerate;
- increased fuel loading causing catastrophic summer fires where the topsoil is burn off;
- loss of micro - habitat variability, especially warm, dry habitats required for thermophilous fauna.

7.0 LOWLAND HEATH STUDY SITES

7.1 Site selection and recording

Seven areas of lowland heathland were studied, encompassing a wide geographical distribution across southern England. These areas are: Aylesbeare Nature Reserve in Devon, Arne Nature Reserve in Dorset, the New Forest in Hampshire, Thursley Common Nature Reserve in Surrey, Ashdown Forest in West Sussex, the Norfolk Brecklands and the Suffolk Sandlings. These provided a broad representative sample of heathland management techniques and effects over the whole range of lowland heath in southern England and involved some of the most important heathland areas in the country. Within each area, a number of sites were surveyed to assess the effects of different management techniques. The management techniques investigated represented the range of those used in the area, and they are summarised in Table 7.1.

Table 7.1 The heathland management techniques studied.

Management	Heath types managed in this way	Study areas managed in this way
Burning	Dry heath Humid heath	Aylesbeare, Devon Arne, Dorset
Mowing	Dry heath Humid heath Acid grassland	Arne, Dorset Ashdown Forest, Sussex Brecklands, Norfolk Sandlings, Suffolk
Burning & mowing	Dry heath Humid heath	Thursley, Surrey Ashdown Forest, Sussex
Scraping	Dry heath	Aylesbeare, Devon
Rotovation	Dry heath	Brecklands, Norfolk
Grazing (with a variety of stocking rates and livestock)	Dry heath Humid heath Wet heath Mire Acid grassland Grass lichen heath	Aylesbeare, Devon New Forest, Hampshire Ashdown Forest, Sussex Brecklands, Norfolk Sandlings, Suffolk
Burning & grazing	Dry heath Humid heath Wet heath Mire	Aylesbeare, Devon New Forest, Hampshire
Mowing & grazing	Dry heath Humid heath Mire	Aylesbeare, Devon New Forest, Hampshire

Table 7.1 cont.

Pine clearance	Dry heath Wet heath	Arne, Dorset Thursley, Surrey
Bracken control	Dry heath Humid heath Acid grassland	Aylesbeare, Devon New Forest, Hampshire Thursley, Surrey Ashdown Forest, Sussex Brecklands, Norfolk Sandlings, Suffolk

7.1.1 The five western heathlands

A common methodology was used at the five most westerly sites: Aylesbeare, Arne, New Forest, Thursley and Ashdown Forest. This involved the comparison of two or more adjacent sites which had different management histories. We were careful to ascertain that the adjacent sites were of similar vegetation types (e.g. dry heath) and had similar topographies and soil types. To the best of the manager's knowledge in all five heathland areas, there had been no management of any of the sites for the last twenty years and probably since the 1940s other than the recent, recorded management. The one exception is the New Forest where there has been grazing by free-ranging ponies and cattle for centuries. Thus any differences in the plant species composition and vegetation structure between the adjacent sites could be attributed, with reasonable confidence, to the differences in recorded management. The sites were delimited by the visible edges of management impacts (e.g. the edge of a burn), by anthropogenic structures (e.g. sheep fencing) or by maps of management created by the manager or warden. In many cases there were only two adjacent and abutting sites: one which had been managed recently and the other which had had no management for a number of decades. However, we also carried out direct comparisons of different management techniques where possible. Each group of two or more adjacent sites was designated by a different letter, e.g. A, B, etc, and each individual site within the group was given a number, e.g. A_1, A_2, etc.

For each site, the detailed management history was elucidated from the warden or manager of the heathland, who usually had carried out the recent management themselves. Five quadrats of 2m × 2m were placed at random within the site and we recorded:

1. The percentage cover by vegetation in each layer. There were a maximum of three layers. The bryophyte layer included mosses and lichens growing on the soil or litter surface. The dwarf shrub/herb layer was often the only extra layer in the vegetation. However, in some cases there was an separate well-defined tall shrub layer including young trees (e.g. *Pinus sylvestris* or *Betula pubescens*), tall shrubs (e.g. mature *Ulex europaeus*) or tall bracken (*Pteridium aquilinum*). We also estimated the percentage of bare ground. Bare ground was classified as soil or litter both not covered by bryophytes and not in contact with vegetation in the dwarf shrub/herb or shrub layers. Thus the percentage cover by vegetation in all layers

and by bare ground often summed to more than 100%.

2. The percentage cover by each plant species in each of the layers.
3. The average height of each layer.
4. The average depth of litter or peat.

7.1.2 The Suffolk Sandlings and Norfolk Brecklands

A slightly different methodology and approach were followed in the two eastern areas surveyed, and hence a different method of designation has been used. The reasons for this are twofold. Heathlands in this region were small compared to the western areas and for this reason were commonly managed as a single unit (particularly for grazing), though at some of the heathlands sub-compartments had extra management superimposed.

Four of the Suffolk Sandlings heaths (the Sutton and Hollesley heaths) had previous survey data available, so the temporal effects of management could be identified, and hence the format of the tables are different to allow comparison between the two years of sampling. Unfortunately the data from the first survey have a number of problems; they were recorded using a Braun Blanquet scale and so have been converted to the cover value of the midpoint of each cover category, and a number of categories were lumped - lichens and mosses were often recorded as one category and the cover of fine grasses (mostly *Agrostis capillaris* and *Festuca ovina*, with some *Aira praecox*) was also recorded as one category. A large number of compartments on these eastern heaths were surveyed, and so a representative sample of data from the compartments are shown.

Methodological differences included - use of 1m x 1m quadrat rather that 2m x 2 m, vegetation height and litter depth were not recorded, and generally 5 to 15 quadrats were recorded in each compartment.

7.2 Site details and management

7.2.1 Aylesbeare Common Nature Reserve, Devon

This RSPB reserve is 12km east of Exeter, Devon (SY059903) and is an important part of the 1112ha East Devon Pebble Bed heathlands. It is an Area of Outstanding Natural Beauty and is of national importance for the Dartford Warbler (*Sylvia undata*), the Nightjar (*Caprimulgus europaeus*) and the Southern Damselfly (*Ceriagrion mecuriale*) (Kerry & Evans 1989). The reserve comprises 184ha of mixed dry and wet heath and mire communities which form a mosaic because of the complex topography of the area. The main management objective involves grazing by cattle

of the dry and wet heath and mire areas to promote plant species diversity and to control *Molinia caerulea* in the wetter areas. Burning and mowing are also used to achieve these ends. Bracken is a major problem in parts of the reserve and control techniques involve cutting, soil scraping and herbicide. Surveys were carried out on 6th - 8th September 1994. The NVC classifications derive from a survey of the whole of Aylesbeare by the RSPB in 1989, before any management began.

Site group A. Burning and grazing of mire.

All were large areas (A_1 = 1.6 ha, A_2 = 1.25 ha, A_3 = 0.25 ha, A_4 = 0.5ha) of mire dominated by *Molinia caerulea* (NVC type M24c - *Molinia caerulea-Cirsium dissectum* fen meadow, *Juncus acutiflorus-Erica tetralix* sub-community). Grazing and burning managements were carried out to reduce the dominance and cover of *Molinia caerulea* and to increase plant species diversity; the different sites represented differences in precise management (Plates 20 & 21). All sites were grazed at a fairly high stocking rate by Limousin X stores which ranged freely over the whole of the sites. A_1, A_2 and A_4 had the same grazing periods and stocking rates: November 1989 - January 1990 @ 32 $LU.ha^{-1}.y^{-1}$, May 1992 - October 1992 @ 25 $LU.ha^{-1}.y^{-1}$, April 1993 - September 1993 @ 30 $LU.ha^{-1}.y^{-1}$ and May 1994 - October 1994 @ 69 $LU.ha^{-1}.y^{-1}$. A_3 had the same grazing management in 1992 - 1994 but a heavier stocking rate was applied initially: November 1989 - January 1990 @ 150 $LU.ha^{-1}.y^{-1}$. A managed burn was carried out in February/March 1992. A_1 and A_2 were also subjected to controlled burns, A_1 in February/March 1992 and A_2 one year later in February/March 1993.

Site group B. Burning and grazing of wet heath.

These were areas of wet heath (NVC type M16a - *Erica tetralix-Sphagnum compactum* wet heath, typical sub-community) dominated by *Molinia caerulea*. As for the sites in A, grazing and burning were carried out to reduce *Molinia* cover to allow other species to establish. Grazing of the whole area by Limousin X stores started in 1994 (May 1994 - October 1994 @ 69 $LU.ha^{-1}.y^{-1}$) and site B_1 (1ha) was subjected to a controlled burn in March 1994 while B_2 (5ha) was not burnt.

Site group C. Mowing and grazing of humid heath.

The whole of this area of heath, dominated by *Calluna vulgaris*, *Erica tetralix*, *Molinia caerulea* and *Ulex gallii* (NVC type H4c - *Ulex gallii-Agrostis curtisii* heath, *Erica tetralix* sub-community) was subject to the same grazing regime as for sites A_1, A_2 and A_4. This grazing was applied to open up the tall and dense dwarf shrub and *Molinia* cover. This was the only management of site C_2 (0.8ha), but site C_1 (0.2ha) was also mown with a brushcutter in February 1989 to create a firebreak. The mowings were removed.

Site group D. Mowing and grazing of mire.

This was another area of M24c mire dominated by *Molinia caerulea*. Both D_1 (1ha) and D_2 (0.3ha) had the same

grazing management as site group B and for the same reason, to reduce *Molinia*. As an additional management to decrease *Molinia*, site D_1 was mown with a brushcutter and the mowings baled and removed in March 1994.

Site group E. Bracken control on dry heath.

This whole area was classified as NVC community W25 - *Pteridium aquilinum-Rubus fruticosus* underscrub in the 1989 survey due to the dominance of bracken. However, this was once a dry heath community and several bracken control measures were carried out to restore a heath community. E_4 (0.3ha) was a area of uncontrolled bracken. On site E_1 (0.75ha) the bracken was cut in October 1989 and the remaining vegetation was mown and the mowings raked in November 1989. The litter was bulldozed away with a tractor frontloader to expose the mineral soil in March 1990. Bracken regrowth in the regenerating vegetation was sprayed with Asulam in July 1991 and July 1993. On site E_2 (0.2ha) the bracken and litter were bulldozed with a tractor frontloader to expose the mineral soil in February 1991 and the bracken regrowth was sprayed with Asulam in July 1991 and July 1993. On E_3 (0.4ha) the bracken and litter were bulldozed with a JCB excavator in March 1992 and the bracken regrowth was sprayed in July 1993.

Site group F. Burning and scraping of dry heath.

This was a large area of dry heath dominated by *Calluna vulgaris*, *Erica tetralix* and *Ulex gallii* (NVC type H4a - *Ulex gallii-Agrostis curtisii* heath, *Erica cinerea* sub-community), most of which was unmanaged (F_3 - 13ha). There were two managed sites which were created as firebreaks. F_1 (0.8ha) was burnt between October 1988 and February 1989 and F_2 (0.3ha) was mown and then the mowings and litter scraped away using a tractor frontloader in March 1991.

7.2.2 Arne Nature Reserve, Dorset.

This is a RSPB reserve near Wareham, Dorset (SY973882) which overlooks Poole Harbour. It is a Grade I Site of Special Scientific Interest and supports all six British reptile species, breeding populations of the rare Dartford Warbler (*Sylvia undata*) and Nightjar (*Caprimulgus europaeus*), and a number of rare and scarce invertebrates (Pickess et al 1992). The reserve covers 498ha and contains a large area of dry heath (240ha) with some humid heath (40.5ha) and a small amount of wet heath. The major managements are burning or mowing of heathland to promote regeneration of degenerate dwarf shrubs and to open up the vegetation to promote a diversity of plant and animal species. Tree and scrub removal, ranging from cutting individual trees in open heathland to clearing plantations and woods of *Pinus sylvestris*, are carried out to maintain or restore heathland. Other management includes burning or coppicing of *Ulex europaeus* to provide habitat for Dartford warblers, and control of invasive bracken. Surveys were carried out on 22nd-24th July 1994.

Site group A. Pine clearance.

A large area (*c* 10ha) of *Pinus sylvestris* wood grew up over 30 years ago on an area of dry heath. The trees were cut down in 1991 and, in the 2ha area surveyed (A_1), the litter was vacuumed up in 1991. South of the pinewood was a large area of dry heath dominated by *Calluna vulgaris* and *Erica cinerea* (NVC type H2a - *Calluna vulgaris-Ulex minor* heath, typical sub-community). An unmanaged 5ha strip of this dry heath lying along the border of the cleared pinewood (A_2) was surveyed to provide a representation of the preferred target for heathland regeneration following the pine clearance.

Site group B. Mowing of dry heath.

Several mowing treatments were carried out within this large area of dry heath dominated by *Calluna vulgaris* and *Erica cinerea* (NVC type H2a). Site B_1 (0.1ha) was mown with a forage harvester and the mowings removed in 1976 and it was mown again in 1991. Site B_2 (0.1ha) was mown only in 1991 and B_3 (0.2ha) was mown only in 1976. A large area of many hectares of heathland surrounding these sites was unmanaged for over 40 years and a strip of this heathland within 15m from the managed sites was surveyed (B_4).

Site group C. Mowing of dry/humid heath.

A 0.6ha area within several hectares of mixed dry and humid heath dominated by *Calluna vulgaris*, *Erica tetralix* and *Erica cinerea* (NVC types H2a and H3 - *Ulex minor-Agrostis curtisii* heath) was forage harvested in November 1989 and the mowings removed (site C_1). The unmanaged heathland within 15m of this site constituted site C_2.

Site group D. Burning of dry heath.

A small site (D_1 = 0.25ha) within a large area of dry heath dominated by *Calluna vulgaris* and *Erica cinerea* (NVC type H2a) was subjected to a controlled burn in March 1989. The unmanaged heath within 15m of the burnt area was surveyed to provide site D_2.

Site group E. Burning of humid heath.

Site E_1 was subjected to a controlled burn in March 1990. This was a small site (0.3ha) within several hectares of unmanaged humid heath dominated by *Calluna vulgaris* and *Erica tetralix* (NVC type H3). Site E_2 comprised the area of the unmanaged humid heath within 15m of the burnt site.

7.2.3 The New Forest, Hampshire

The New Forest covers about 37,907ha in south-west Hampshire. 15,213ha of this forms the largest area of lowland heath in Britain and for this reason, along with the fact that it contains many nationally scarce and rare plant and animal species, it is of international conservation importance and has been recognised by the Government as

equivalent in status to a National Park (Westerhoff 1992). The heathland consists of large expanses of dry, humid and wet heath, scrub areas dominated by tall *Ulex europaeus*, grass heaths, acid grasslands, valley mires and fens. The management of the New Forest is unusual in that the ancient practise of grazing heathland, which probably dates back to prehistoric times, continues little-changed to the present day over the Forest. Grazing has ceased on most other lowland heaths. In the New Forest the Commoners continue to exercise their rights to graze cattle and ponies freely over the heaths and this is still the major form of management (Tubbs 1986). The grazing animals show large-scale patterns in their grazing behaviour. Some heath areas have been grazed intensively for many years, others are scarcely grazed at all, and others show more intermediate grazing intensities (Tubbs 1986). This pattern is maintained as the heavily grazed areas produce the nutritious new growth preferred by the animals. Therefore, all the sites described below (surveyed 29th June - 1st July 1994) were exposed to grazing animals, but the intensity of grazing varied. Other management carried out by Forest Enterprise includes burning and mowing of heathland to maintain an open, short dwarf shrub vegetation which promotes a diversity of species and to produce nutritious new growth plants to attract grazers. Scrub (especially *Pinus sylvestris* and *Betula* spp) and bracken invasion of heath are also a problem and management is carried out to control these.

Site group A. Cutting and grazing of dry/humid heath

On this area of mixed dry/humid heath and acid grassland dominated by *Calluna vulgaris* site A_1 (5ha) was forage harvested in the winter of 1990-1991 to open up the vegetation to grazing animals. Site A_2 (3.3ha) had been heavily grazed and a short vegetation maintained for many years and probably decades (Plate 17). Site A_3 (4.5ha) was an adjacent stand of much taller vegetation and showed evidence of only light grazing (Plate 18).

Site group B. Burning and grazing of dry/humid heath

In this area of mixed dry and humid heath dominated by *Calluna vulgaris* and *Molinia caerulea* site B_1 (10ha) was subjected to a controlled burn in the winter of 1989-1991 to open up the vegetation. Site B_2 (9ha) was not burnt.

Site group C. Burning and grazing of wet heath

A controlled burn was carried out at site C_1 (3.6ha) in the winter of 1992-1993. The remainder of this large area of wet heath dominated by *Calluna vulgaris*, *Erica tetralix* and *Molinia caerulea* had not been burnt recently and the heath within 15m of site C_1 was surveyed as site C_2.

Site group D. Bracken control on dry heath.

This area was dominated by tall *Pteridium aquilinum* with remnants of dry heath vegetation in the understorey. 2.5ha (site D_1) of the bracken was forage harvested in July 1992 and again in July 1993 but an adjacent 2ha (site D_2) was not managed.

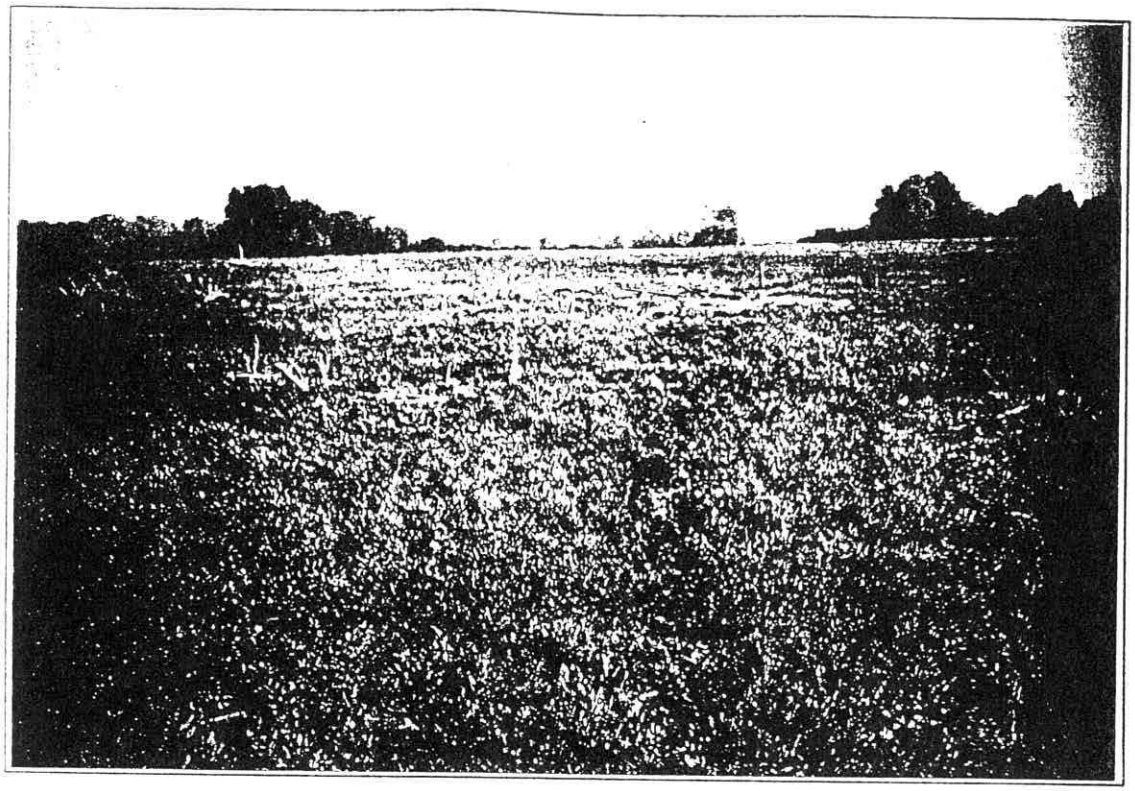


Plate 17. The effects of intensive pony grazing on dry heathland in the New Forest, Hants (Site F).

Plate 18. Degenerate heather resulting from too little grazing (New Forest, Site E).

Site group E. Bracken control on dry/humid heath.

3.6ha of this *Pteridium aquilinum* dominated dry/humid heath (some *Calluna vulgaris* and *Molinia caerulea* understorey) was forage harvested in July 1992 and July 1993 (site E_1). The adjacent site E_2 (2ha) was not managed.

7.2.4 Thursley NNR, Surrey

This is a National Nature Reserve south of Goldalming in Surrey (SU906405) managed by English Nature. It covers 325ha with about 200ha of heathland. The majority of it is dry heath (150ha) but there are also wet heaths and valley mires. This is one of the most important areas of heathland on Lower Greensand in southern England and contains many scarce or rare plant and animal species including the Dartford Warbler (*Sylvia undata*), the Nightjar (*Caprimulgus europaeus*) and the sand lizard (*Lacerta agilis*) (Gibbons 1994). There is a variety of management at Thursley which includes mowing of heathland to maintain the dwarf shrubs and herbs and to control invasion by *Betula pubescens*, control of birch by herbicide and cutting, bracken control by a number of methods and restoration of heathland from pine plantations. Surveys were carried out from 13th - 15th September 1994.

Site group A. Burning and cutting of dry heath.

Burning is not a standard management tool at Thursley, but recent accidental fires can be used to give some indication of the effects of burning. The whole area of dry heath (dominated by *Calluna vulgaris*: NVC type H2 - *Calluna vulgaris-Ulex minor* heath) in site group A was burnt in an accidental fire in the summer of 1976. Site A_1 (10ha) burnt again in an accidental fire in March 1993 (Plates 22). Since 1988 site A_2 (6ha) had been given a yearly mow between July and September with a swipe-cutter and the mowings removed. Not the whole site was mown, but a series of 2 m-wide swathes were mown, accounting for about 10% of the area. The swathes were randomly positioned each year. Site A_3 (6ha) had no management or fires since the fire in 1976 (Plate 23).

Site group B. Pine clearance

A *Pinus sylvestris* plantation had been on site B_1 (5ha) for 40 - 50 years before it was cleared in the winter of 1990 - 1991 to allow the original *Calluna vulgaris*-dominated, H2, dry heathland to regenerate (Plates 18 & 19). The pine litter was scraped away and removed during the winter of 1991 - 1992. Some of this plantation had not been cleared (site B_3, 2ha) and part of the unmanaged dry heath within 15m of B_1 was surveyed (B_2) to provide a representation of the target community for heathland regeneration.

Site group C. Pine clearance

The same pine plantation described for site group B extended onto an area of wet heath. Sites C_1 (0.5ha) and C_2 (0.5ha) were cleared of trees in the winter of 1992 - 1993 to allow restoration of heathland. In C_1 the pine litter was scraped up and removed directly after pine clearance but in C_2 the litter remained. Some pine plantation remained

and the ground flora under this was surveyed in an area 15m from sites C_1 and C_2 (C_3).

Site group D. Bracken control on dry heath

Two methods of controlling the dominant *Pteridium aquilinum* were tested on these dry heath sites. In D_1 (1ha) the bracken litter was burnt off in the winter of 1991 -1992, the growing bracken was swipe-cut and raked off in the early summer of 1992 and then the site was chisel ploughed in July 1992 in order to break up the bracken rhizomes and to expose them to desiccation. Bracken regrowth was swipe-cut in the summer of 1993. In D_2 (1ha) exactly the same management was carried out except that instead of chisel ploughing the site was rotovated to expose the bracken rhizomes. There was a large area of uncontrolled bracken and the area within 15m of the controlled sites was surveyed (D_3).

7.2.5 Ashdown Forest, Sussex

The Ashdown Forest, situated near East Grinstead (TQ432234), is the largest area of lowland heath in south-eastern England, covering about 2,590ha. The conservation of this large area is important for the maintenance of viable populations of the plant and animal species associated with heathland in the south east. It lies on fairly wet soils derived from the Hastings Beds and is higher than the surrounding Sussex countryside, forming a system of valleys draining the dryer, high areas. There is much wet heathland and valley mire along with dry heathland. The area was once extensively grazed under Commoners rights but this practise has died out and the Forest is now managed by a board of Conservators whose duty is to preserve the Forest's unique character. This is being pursued by sheep grazing and heathland mowing to maintain the dwarf shrubs and to allow a diversity of species to grow in the heathland. Invasion by bracken and birch are a problem and much of the management activity is to control these plants. The surveys were carried out on 20th - 22nd September 1994.

Site group A. Grazing of wet heath

This area of wet heath was dominated by *Calluna vulgaris, Erica tetralix* and *Molinia caerulea.* As part of a plan to re-introduce grazing to the Forest, sheep and Welsh Black cattle had been grazed on site A_1 (40ha) by a Commoner since 1989 at roughly the rate of 2.5 $LU.ha^{-1}$ (although the rate is very variable). The site was grazed from June 1989 through the 1989 - 1990 winter and since then it had been grazed between May - October every year. A_1 was surrounded by a large area of unmanaged heathland and the ungrazed heath within 20m of A_1 was surveyed (A_2).

Site group B. Burning and mowing of humid heath

This was an area of humid heath dominated by *Calluna vulgaris* and *Molinia caerulea.* Sites B_1 (0.5ha) and B_3

(0.5ha) were both forage-harvested in the summer of 1992 in order to open up the vegetation and to encourage growth of the dwarf shrubs. Sites B_2 (25ha) and B_4 (consisting of a 15m wide strip of the unmanaged heath adjacent to B_3) were not mown. An accidental spring fire in 1994 burnt a large area of the heath consisting of sites B_1 and B_2, allowing us to survey the effects of burning plus mowing (site B_1) and of burning alone (B_2).

Site group C. Mowing of humid heath

3.5ha of this humid heath area (dominated by *Calluna vulgaris* and *Erica tetralix*) was forage harvested in the summer of 1982 (site C_1). The unmanaged vegetation within a 15m strip adjacent to C_1 was surveyed as site C_2.

Site group D. Mowing of dry heath

Site D_1 was a 2ha area within this *Calluna vulgaris*-dominated dry heath which was forage harvested in the summer of 1992. The contrasting site D_2 was an area of the unmanaged heathland within 15m of the mown site.

Site group E. Bracken control on dry heath

Bracken control within this dry heath dominated by *Pteridium aquilinium* was carried out in a 1ha site E_1 in November 1993. The bracken was forage-harvested, then the litter was scraped up and removed with a JCB and disc ploughing was used to expose the bracken rhizomes. Mowings from a nearby heathland site were then scattered over the soil to provide propagules for the regeneration of the heathland vegetation. Any bracken regrowth was cut in the early summer of every subsequent year (Plate 24). The adjacent uncontrolled bracken within a distance of 15m from the controlled site was also surveyed (site E_2).

Site groups F & G. Bracken control on dry heath

Site groups F and G were *Pteridium aquilinum* dominated dry heaths similar to site group E, but in different locations. Sites F_1 and G_1 were both 1ha sites subjected to the same cutting, scraping, ploughing, seeding and yearly cutting management as site E_1, with F_1 being managed in November 1991 and G_1 being managed in November 1992. Sites F_2 and G_2 were the uncontrolled sites (Plate 25).

Site group H. Bracken control on dry heath

This was a *Pteridium aquilinum* dominated dry heath area which was subjected to two bracken control treatments. Site H_1 (1ha) was managed in November 1990 using the same cutting, scraping, ploughing, seeding and yearly cutting management as site E_1. Site H_2 (1ha) was forage-harvested in June 1991 and then the litter was scraped up and removed using a JCB. The bracken regrowth was forage-harvested six weeks after the first cut. This site was then forage-harvested in June and again six weeks later every subsequent year. Site H_3 was the adjacent uncontrolled bracken within a distance of 15m from the two managed sites.

Site group I. Bracken control on dry heath

Site I_1, a 1ha area within this *Pteridium aquilinum* dominated dry heath, had been cut and scraped and given a 2-yearly cut since 1988 in the same way as site H_1. I_2 was the unmanaged site.

7.2.6 Breckland, Norfolk

This area of Norfolk and Suffolk is characterised by the lowest rainfall in Britain and relatively high sunshine levels, leading to high soil moisture deficits in the summer. It is also prone to frost. The soils are an intricate mix of those derived from the underlying chalk and those from blown sand, and it on these sands that a heathland and acidic grasslands are found. Their development is intricately bound up with rabbit warrening and with the shifting agriculture practised before the nineteenth century which maintained low nutrient levels, and their subsequent grazing by sheep and rabbits. However, much has been lost to agricultural improvement during this century. The area was designated as an Environmentally Sensitive Area in 1987.

7.2.6.1 Cavenham-Tuddenham Heath National Nature Reserve

This English Nature reserve is c. 15 km south-west of Thetford, Norfolk (TL758728) and was designated as it contained some of the best examples of the highly acidic Breckland heath (Ratcliffe 1977). The total area of the two heaths is 175 ha. The surveyed sites were restricted to the Cavenham Heath part of the reserve.

No stock grazing had taken place on the reserve since 1952 until 1977 when the northern part was fenced and grazed with sheep and cattle at varying numbers. Between 1985 and 1989 there was large increase in rabbit numbers, and livestock levels had to be reduced to prevent overgrazing. The last figures available are that 20 cattle grazed this part of the reserve during the winter of 1993-4. No stock grazing has been carried out on the southern half of the reserve, though a number of other management activities have been carried out, including the removal of birch seedlings from this part of the reserve. The areas surveyed are listed below along with their management history.

South Cavenham

Area HW - Mature heather in good condition. This stand was in the best condition of any area on this heath (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area HE - Mature to degenerate heather suffering invasion by *Festuca ovina* and *Rumex acetosella* as the canopy opens out (NVC H1c - *Calluna vulgaris* - *Festuca ovina* heath, *Teucrium scorodonia* sub-community).

Area C92 - Part of area HE which was cut in 1992 in an attempt to rejuvenate the heather (NVC H1c - *Calluna vulgaris* - *Festuca ovina* heath, *Teucrium scorodina* sub-community).

Area R77 - Mature heather in good condition. This area was rotovated in 1977 to encourage heather regeneration.

It was indistinguishable from area HW except for its very even height (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area R89 - This area had been invaded by *Deschampsia flexuosa*, and in an attempt to encourage heather regeneration was rotovated in 1989 (NVC U1b - *Festuca ovina* - *Agrostis capillaris* - *Rumex acetosella* grassland, typical sub-community).

Area R92 - This was part of the area rotovated in 1989. However, heather regeneration was poor so this part of the area was rotovated a second time in 1992 to break up the developing sward of Festuca ovina (NVC U1 - *Festuca ovina* - *Agrostis capillaris* - *Rumex acetosella* grassland).

Area DF - This part of the heath had been invaded by *Deschampsia flexuosa* which has suppressed the heather (NVC U2 *Deschampsia flexuosa* grassland).

North Cavenham

Area NED - Heavily grazed, in part by livestock but particularly by rabbits. There were large areas of bare ground and invasion by *Festuca ovina* has occurred (NVC H1c - *Calluna vulgaris* - *Festuca ovina* heath, *Teucrium scorodina* sub-community).

Area NWD - Heavily grazed, in part by livestock but particularly by rabbits. Heather had survived better on this part of the heath, with *Rumex acetosella* the main invader (NVC H1b - *Calluna vulgaris* - *Festuca ovina* heath, *Hypogymnia physodes* - *Cladonia impexa* sub-community).

Area NDF - Heavily grazed. Heather had been replaced by *Deschampsia flexuosa* and *Festuca ovina* (NVC U2 *Deschampsia flexuosa* grassland).

Roper's Heath

This site was heath until 1954 when it was ploughed. It was in arable cultivation until 1978 when a decision was made to return the site to heathland. It was cropped with barley in 1979 and rye in 1980 and 1981 in an attempt to remove nutrients and had been grazed since 1982, with occasional topping to control ragwort and nettles (NVC U1c - *Festuca ovina* - *Agrostis capillaris* - *Rumex acetosella* grassland, *Erodium cicutarium* - *Teesdalia nudicaulis* sub-community).

7.2.6.2 Brettenham Heath National Nature Reserve, Breckland

This English Nature reserve is 6 km north west of Thetford, Norfolk (TL928867), and comprises mainly acidic grassland, though with some heather and birch woodland. It was neglected until 1983 when the Nature Conservancy Council leased the site and instituted a program of bracken and scrub control, as well as regulating the grazing of site by sheep.

Area A (Corresponding to EN compartments 1 & 7) - These two areas at the edge of the reserve retained much of their original bracken cover, though some acidic grassland was present (NVC mix of U1 - *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland and U20 - *Pteridium aquilinum - Galium saxatile* community). Heather had regenerated along the course of a gas pipeline.

Area B (Corresponding to EN compartments 3, 4, 6, 8, 15 & 16) - Over much of the reserve, bracken had been controlled successfully, and it was dominated by an acidic grassland vegetation (NVC U1 - *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland).

Area C (Corresponding to EN compartments 17 & 18) - These areas had also been subject to bracken control, but there had been substantial invasion by heather (NVC U1 - *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland).

7.2.6.3 Icklingham Plains, Breckland

This heathland area is owned by the Elveden Estate. It is an extension of Cavenham to the north of the river Lark and showed considerable areas of sand dunes and *Carex arenaria* dominated grassland. Much of the area is acidic grassland, and it was these areas that were surveyed (52 ha). It is currently grazed by sheep.

Area A - Damper grassland with *Anthoxanthum odoratum* and *Holcus lanatus*, no management except grazing (NVC U1d - *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland, *Anthoxanthum odoratum - Lotus corniculatus* sub-community).

Area B - Grass lichen heath, no management except grazing (NVC U1a - *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland, *Cornicularia aculeata - Cladonia arbuscula* sub-community).

Area C - Heather/grass lichen heath, no management except grazing (NVC H1b - *Calluna vulgaris - Festuca ovina* heath, *Hypogymnia physodes - Cladonia impexa* sub-community).

7.2.7 Suffolk Sandlings

These heathlands lie on a narrow belt of glacial sands and gravel which run long the Suffolk Coast between Lowestoft and Ipswich. The area is designated as an Area of Outstanding Natural Beauty and as part of the Suffolk Heritage Coast. Much of the land is common land, and have largely been maintained by grazing and the exercise of rights such as heather and gorse cutting as well as turf stripping. Many of these heathlands are currently and

managed by the Suffolk Wildlife Trust, including those sampled in this survey. The Hollesley and Sutton areas form a large complex of heathland, grassland and woodland habitats which have been designated as an SSSI. Details of the area of each habitat in these four heaths are shown in Table 7.2. Purdis Heath is another site in the Sandlings area which has not been managed. As these sites are large and comparatively uniform, only a representative number of the areas surveyed are presented.

Table 7.2 Area of vegetation types on Sutton and Hollesley Heaths, Suffolk.

Site	Vegetation type	Area 1985 (ha)	Area 1993 (ha)
Lower Hollesley Common	Heathland	32.77	45.40
	Acid grass	4.08	3.60
	Woodland	28.81	33.40
	Bracken	51.69	31.20
	Other	6.43	1.70
	Total	123.66	115.30
Upper Hollesley Common	Heathland	17.22	31.30
	Acid grass	1.87	0.40
	Woodland	49.13	47.00
	Bracken	19.67	11.20
	Other	1.51	0.00
	Total	89.00	89.90
Sutton Heath	Heathland	8.61	7.10
	Acid grass	2.60	2.45
	Woodland	36.15	49.50
	Bracken	15.95	3.55
	Other	0.00	0.00
	Total	63.31	62.60
Sutton Common	Heathland	25.20	39.75
	Acid grass	15.73	18.70
	Woodland	33.13	13.30
	Bracken	45.39	45.45
	Other	19.77	0.00
	Total	139.22	117.20

7.2.7.1 Lower Hollesley Common, Suffolk

This area is c. 19 km east of Ipswich, Suffolk (TM352458) and covers c. 115 ha of which 45 ha is heathland. The

site was ungrazed until 1994 - stocking rates are unavailable.

Area A (Corresponding to SWT compartment 2c) - No management (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area B (Corresponding to SWT compartment 2g) - No management (closest fit NVC H10 - *Calluna vulgaris* - *Erica cinerea* heath).

Area C (Corresponding to SWT compartment 6c) - Burnt in 1976, no management since (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area D (Corresponding to SWT compartment 9b) - Bracken sprayed in 1987 and 1989. No management (closest fit NVC H10 - *Calluna vulgaris* - *Erica cinerea* heath).

7.2.7.2 Upper Hollesley Common, Suffolk

This is c. 17 km east of Ipswich, Suffolk (TM335475) and covers c. 89 ha, of which 31 ha is heathland. This has been grazed since 1991. In 1993 sheep were put on in June, to give 112 grazing days ha^{-1}.

Area A (Corresponding to SWT compartment 1c) - Scrub clearance had been carried out over much of the site (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area B (Corresponding to SWT compartment 2b) - Burnt in 1976, compartment cut in 1988 and some in 1992 (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area C (Corresponding to SWT compartment 3b) - No management apart from grazing (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

7.2.7.3 Sutton Heath, Suffolk

This heath is c. 15 km east of Ipswich, Suffolk (TM312482) and covers c. 63 ha, of which 7 ha is heath. The site has been grazed by since 1990, and was grazed in the summer of 1993 at 131 grazing days ha^{-1}.

Area A (Corresponding to SWT compartment 1b) - No management apart from grazing (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area B (Corresponding to SWT compartment 4c) - No management apart from grazing (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area C (Corresponding to SWT compartment 6b) - No management apart from grazing (NVC U20 - *Pteridium aquilinum* - *Galium saxatile* community).

7.2.7.4 Sutton Common, Suffolk

This area is c. 16 km east of Ipswich, Suffolk (TM325475) and covers 117 ha, of which 40 ha is heathland. The site has been grazed since 1990, and was grazed in the summer of 1993 at 326 sheep grazing days ha^{-1}.

Area A (Corresponding to SWT compartment 4b) - Cut in 1989 (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area B (Corresponding to SWT compartment 7b) - No management apart from grazing (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

Area C (Corresponding to SWT compartment 16a) - No management apart from grazing and some bracken control (NVC H1c - *Calluna vulgaris* - *Festuca ovina* heath, *Teucrium scorodina* sub-community).

7.2.7.5 Purdis Heath, Suffolk

This small heath is 5 km east of Ipswich, Suffolk (TM213426) and the surveyed areas correspond to SWT compartments 2d, 4a and 4c-e. There has been no management except scrub control (NVC H1e - *Calluna vulgaris* - *Festuca ovina* heath, species poor sub-community).

8.0 EFFECTS OF MANAGEMENT ON THE STRUCTURE AND FLORISTIC COMPOSITION OF LOWLAND HEATHS

The survey data are given in Appendix 1 and we summarise the results in this section. Figs. 8.1-8.7 illustrate some of the management effects.

8.1 Grazing

The effects of the different forms of grazing management were analysed separately. For the larger western sites, the effects of different grazing regimes on adjacent stands were analysed, both for sites with long established grazing management (New Forest) and for sites where grazing management has been recently re-introduced or modified (Ashdown Forest, Aylesbeare, New Forest). In the latter, we are examining the early stages of vegetation response to grazing management.

The eastern sites are smaller, and are usually managed as one unit for grazing purposes. Hence a different approach was used so that the effects of different grazing intensities were compared between the different sites. The historical data for the four Suffolk heaths were used to assess the trajectory of vegetation change between the surveys.

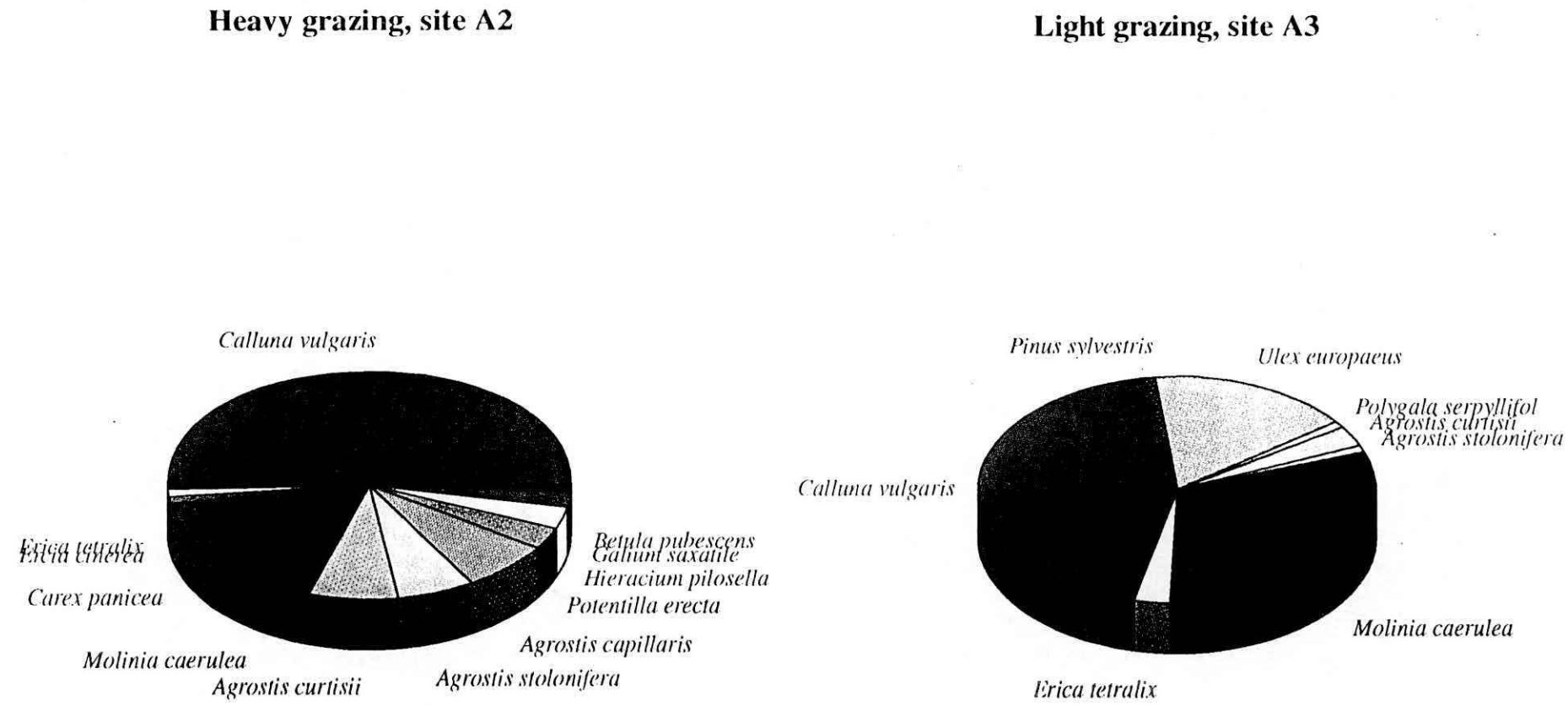
As grazing was often implemented in conjunction with other management techniques, the effects of combining mowing or burning with grazing were analysed separately.

8.1.1 Within site comparison - Long-term grazing

New Forest, sites A_2 and A_3

Here we compared a lightly grazed dry/humid heath site (A_3) with a site grazed heavily by ponies and cattle for many years (A_2) (Fig. 8.1). The lightly-grazed site had a tall vegetation (dwarf shrub layer = 54cm), including many tall bushes of *Ulex europaeus* (125cm), and, although there was little bare ground (4%), the dwarf shrubs were becoming degenerate and *Betula pubescens* was beginning to invade. Under heavy grazing the vegetation was very short (11cm) but was also closed (94% cover) and consisted of a small-scale mosaic of heath and acid grassland vegetation. This mixture of heath species (e.g. *Calluna vulgaris* and *Erica cinerea*) and grassland species (e.g. *Agrostis capillaris* and *Hieracium pilosella*) had resulted in a higher number of vascular plant species (12 in A_2 *vs* 8 in A_3). The more heavily grazed plant community was also more equitable (and therefore more diverse); in A_3 the two commonest species accounted for 77% of the dwarf shrub/herb cover, but in A_2 the five commonest species

Fig 8.1 The effect of long-term grazing by cattle and ponies on plant species composition of dry/humid heath in the New Forest



accounted for 78% of the cover. The heavier grazing had also reduced the cover of *Molinia caerulea* and there were fewer seedlings of scrub species.

8.1.2 Within site comparison - Recently-introduced grazing

In these other sites grazing had been introduced recently and often in tandem with a second form of management designed to reduce the amount of woody material and to increase the amount of fresh growth to feed the grazing animals.

Ashdown Forest

In Ashdown A_1 fairly light sheep grazing was introduced in 1989 with no extra treatment. In comparison with the ungrazed site A_2, grazing of this humid heath reduced the height of the dwarf shrub vegetation to some degree (62cm in A_2 *vs* 32cm in A_1) and decreased the litter depth (0.5cm in A_2 *vs* 4cm in A_1), but otherwise had little effect. Both sites had closed vegetation (97% dwarf shrub cover in both) and similar, low numbers of vascular plant species (5 and 6 in A_1 and A_2 respectively). *Molinia caerulea* actually had an increased cover in the grazed site and although Bog Asphodel (*Narthecium ossifragum*) was found, this was in the ungrazed site.

Aylesbeare

Aylesbeare A_4 and A_3 were both mires grazed by cattle for 4 years at fairly high stocking rates, but in the first year of grazing A_3 had a stocking rate five times that of A_4. The vegetation in A_4 seemed little affected by this management. Grazing here was only light (the cattle were not restricted and could feed on the other A sites) and the vegetation was very tall (56cm) and closed (94% cover) with a large cover of rank *Molinia*. Only seven vascular plant species were detected. The initial heavier grazing (A_3) had caused a shorter (40cm) and more open (82% cover) vegetation with more herb species (12 species) such as *Mentha sylvatica* and *Viola pumila* and had allowed some *Sphagnum* to establish.

8.1.3 Between site comparison - Suffolk Sandlings and Breckland

Ungrazed sites

Three sites were effectively ungrazed - the southern half of Cavenham Heath and Purdis Heath grazed by low numbers of rabbits and deer, and Lower Hollesley Heath again grazed by natural grazers and by sheep for the first time in 1994.

All three sites had a good heather cover in good condition. In the nine years between surveys *Calluna vulgaris* and *Erica cinerea* both showed considerable increases in cover at Lower Hollesley, and the overall area of heathland

vegetation increased though this was partly due to effective bracken control. In parallel at this site the cover and area of fine grasses (*Agrostis capillaris* and *Festuca ovina*) had declined, as well as the cover of bracken and litter as a result of the bracken control.

However, this part of Cavenham had been subject to considerable invasion by birch, bracken and *Deschampsia flexuosa*, and similarly there had been considerable invasion by trees at Lower Hollesley (Sibbett 1994).

Low grazing intensity

Two sites were grazed by livestock at low intensity; Sutton Heath and Upper Hollesley Common. On both sites the general trend between 1985 and 1994 was an increase in the cover of *Calluna vulgaris*, accompanied by an increase in moss cover, but for no expansion in heathland vegetation. Some compartments showed significant increases and decreases in the cover of fine grasses (mainly *Agrostis capillaris* and *Festuca ovina*) and some showed a large decrease in the cover of *Rumex acetosella*. There had been considerable tree invasion at Sutton Heath, though it had largely occurred in bracken dominated areas.

Moderate grazing intensity

Three sites had much higher grazing intensities than the two above; Sutton Common, Icklingham Plains and Brettenham Heath. The response of the vegetation on Sutton Common between 1985 and 1994 was variable. Most compartments showed an increase in heather cover (Fig. 8.2), though some showed a decrease. Apparently independent of this, some compartments showed increases and decreases in the cover of *Agrostis capillaris* and *Festuca ovina*. The areas of acidic grassland and heathland had both increased largely as a result of tree clearance.

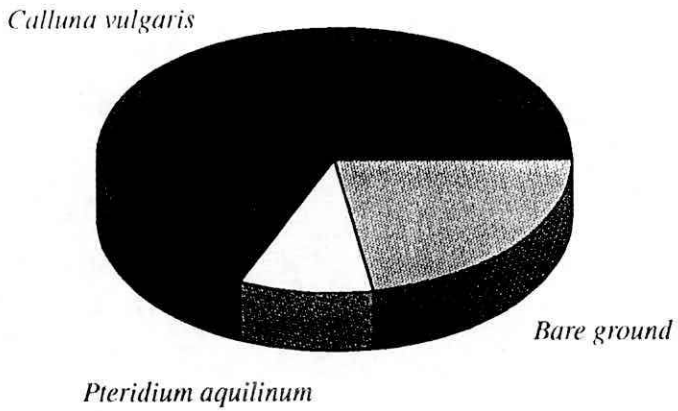
Icklingham Plains had a considerably higher grazing intensity than Sutton Common, though as some of the damper parts of the site were grassland dominated by *Holcus lanatus* and *Anthoxanthum odoratum*, more sheep could be supported. Most of the rest of the site had a high cover of lichens (*Cladonia* spp.), either co-dominant with *Festuca ovina* or *Calluna vulgaris*, though *C. vulgaris* was mainly restricted to one part of the site. No grazing figures are available for Brettenham, though sheep numbers were high enough to keep a short sward. Most of this site was dominated by acidic grassland, comprising mainly *Festuca ovina* with some *Agrostis capillaris*. Heather was restricted to a small part of the reserve where there had been disturbance (pipeline laying and motorcycle scrambling) or beneath birch. At both Icklingham and Brettenham, the dense sward and substantial grazing appeared to be preventing the germination and establishment of heather, though seeds were present in considerable numbers in the seedbank (Pakeman & Marshall, unpublished data).

High grazing intensity

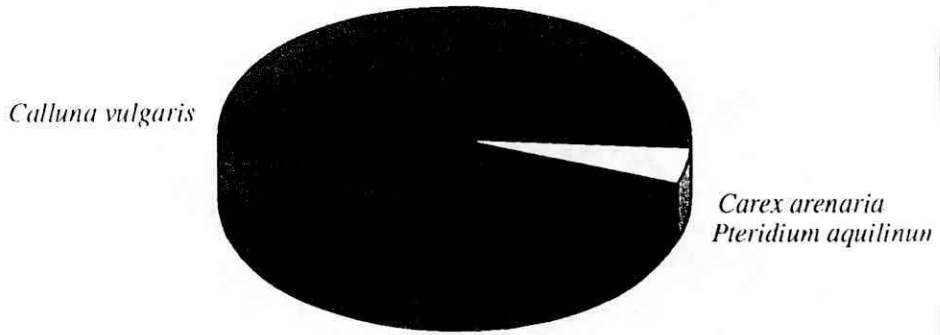
Part of Cavenham Heath was subjected to a very high grazing pressure. Sheep and cows grazed the site, but much

Fig 8.2 The effect of introducing sheep grazing in 1990 on the vegetation of Sutton Common, Suffolk Sandlings, site 7b

Before grazing, 1985



With grazing, 1994



of the offtake was performed by the very high rabbit population. Much of the heather had died, leaving large areas of bare ground, and a considerable degree of invasion by *Festuca ovina*. In one part there had been a considerable amount of heather regeneration, but the high grazing pressure had resulted in the heather being suppressed in the pioneer and early building phases. On the areas where the soil was higher in pH, there had also been good growth of lichens (*Cladonia* spp.).

Adjacent to this area, and accessible by both livestock and rabbits was Roper's Heath, an ex-arable site which had returned to acid grassland dominated by *Festuca ovina* and *Agrostis capillaris*, with numerous low growing herbs present. There had been minimal invasion *Calluna vulgaris* during the years since its abandonment, and what had established in the dense sward was suppressed by the high grazing.

8.1.4 Burning with grazing

Aylesbeare

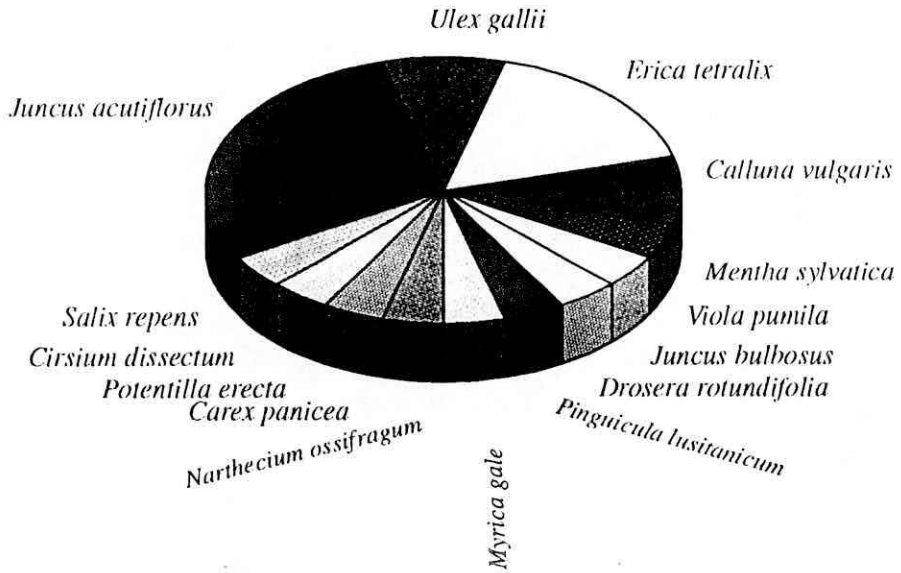
Sites A_1 and A_2 in an area of mire at Aylesbeare were subject to the same grazing management as A_4 (see above). A_1 was burnt in 1992 and this had a drastic effect on the grazing behaviour of the cattle in comparison to their grazing of A_4. Grazing was very heavy and had created a short vegetation (20cm) which was very open (80% cover) compared to the tall, closed vegetation in A_4 (see above; Plates 21 & 22). Although *Molinia* was still extremely dominant, this heavier grazing had allowed many more herb species to establish (16 species) both in the open areas between *Molinia* tussocks and actually amongst the short grass of the *Molinia* tussocks. These included desirable and rare mire species not present in A_4, such as *Narthecium ossifragum*, *Myrica gale*, *Pinguicula lusitanica* and *Drosera rotundifolia*. *Sphagnum auriculatum* had also established in the burnt site (Fig 8.3).

Site A_2 was also burnt, but more recently in 1993. Again this burning caused an increased grazing intensity and the vegetation was short (25cm) and this had allowed some more herb species (10 species), such as *Pinguicula lusitanica*, and *Sphagnum auriculatum* to establish. However, the vegetation was probably still recovering from the burn - there was a large percentage of bare ground (36%) - and it seems likely that more species would establish in the future, as had occurred in site A_1.

Site B_2 had been grazed by cattle for only one season and the wet heath vegetation seemed hardly affected by grazing. The vegetation was hardly grazed and was tall (43cm) and closed (99% cover) and there were very few vascular plant species (5 species; Plate 22). Site B_1 was burnt in addition to the grazing and this had created a very open vegetation (73% cover) which was being heavily grazed by the cattle (height = 8cm). Because this management had only begun recently there were not many more vascular plant species on the burnt site (7 species),

Fig 8.3 The effect cattle grazing on mire vegetation at Aylesbeare, Devon, with and without a controlled burn in 1992 (Note that the cover of *Molinia caerulea* (64% in A1 and 73% in A4) is not included in the figures)

With a management burn, site A1



Without a management burn, site A4

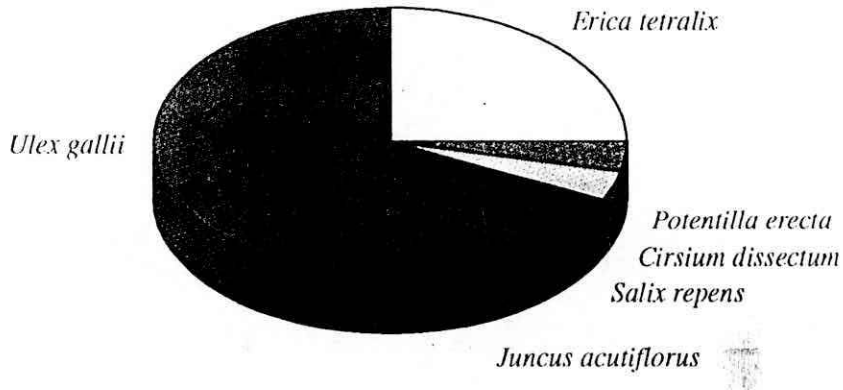


Plate 21. The open and diverse structure of wet heath following burning and grazing at Aylesbeare Common, Devon (Site C).

Plate 22. Grass-dominated wet heath at Aylesbeare (Site E). The site has been grazed but not burnt.

but *Juncus* species (these were noticeably avoided by the grazing animals) had established, and the thinner litter layer (2cm in B_1 vs 7cm in B_2) and decreased cover of *Molinia* suggested that more species may establish in the future.

New Forest

Site B_2, an area of dry/humid heath, was hardly grazed at all by the New Forest ponies and cattle and the vegetation was tall (35cm), becoming degenerate (70% cover, 40% bryophyte cover) and was being invaded by a number of shrub and tree species: *Ulex europaeus*, *Quercus robur* and *Pinus sylvestris* (Plate 17). Other than these invading species there were only four vascular plant species recorded. Site B_1 was also lightly grazed until it was burnt in 1990. When surveyed this site consisted of very short (8cm) and closed (9% bare ground) vegetation which was heavily grazed and formed a small-scale mosaic of heath and grassland (Plate 16). As well as the heath species (e.g. *Calluna vulgaris, Erica tetralix*), several grassland species were present (e.g. *Potentilla erecta, Festuca rubra*) and there were many more vascular plant species (10 species) than in B_2.

In the same way, C_1 and C_2 formed a pair of sites in a wet heath area, the latter being subject to only light grazing and the former having been burnt in 1993. Again, the vegetation in C_2 was tall (35cm), closed (90% cover) with relatively few vascular plant species (5 species). The burning of C_1 encouraged much heavier grazing, creating very short (7cm) and more open (61% cover) grassy vegetation with a large cover of *Sphagnum*. This had a spectacular effect on the plant community, with an increased number of vascular plant species (9 species) which included several desirable wet heath species not present in C_2: *Drosera intermedia*, *Polygala serpyllifolia*, *Eriophorum angustifolium*, and an high density of *Narthecium ossifragum*.

8.1.5 Cutting with grazing

Aylesbeare

Despite the introduction of grazing into C_2 in 1990 this humid heath site was only lightly grazed and the vegetation was tall (44cm) and closed (95% cover) with some of the dominant *Calluna vulgaris* becoming degenerate. C_1 was mown before grazing began in 1990 and this had encouraged heavy grazing (height = 23cm) which had opened up the vegetation somewhat (86% cover). No more vascular plant species were present in C_1 (5 and 7 in C_1 and C_2 respectively), but the mowing and increased grazing had removed the degenerate growth of *Calluna vulgaris* and had increased the cover of grasses in the heath.

Both D sites had been grazed since 1990, but D_1 was mown in 1994. The tall (51cm) and closed (100% cover) vegetation seen in D_2 had, in D_1, become much more open (61% cover) and shorter (9cm) and the depth of litter

had been reduced (1cm and 6cm in D_1 and D_2 respectively) and the cover of dwarf shrubs, *Calluna vulgaris, Erica tetralix* and *Ulex gallii*, had decreased drastically, although *Molinia* was unaffected. The cattle were now grazing the mown site heavily and, although there had been no effect on the number of vascular plant species (7 and 6 in D_1 and D_2 respectively) in the few months since mowing, one might expect that more herb species would eventually establish in the more open conditions of D_1.

New Forest

Site A_1 was adjacent to the lightly grazed site A_3 and presumably had a tall, closed vegetation with encroaching scrub species similar to A_3 (see description of A_3 above) before it was mown in 1991. The vegetation was now heavily grazed and was short (8cm) and closed (6% bare ground) and there was no scrub. However, there were very few vascular plant species (5 in A_1 *vs* 8 in A_3) and the plant community did not resemble at all the long-term heavily grazed site, A_1 (see above).

Suffolk Sandlings

Area B on Upper Hollesley Common was cut in 1988, and like most compartments on this has shown an increase in heather cover under the low grazing intensity regime imposed. Area A on Sutton Common was cut in 1989 and part again in 1992. Heather cover is increasing in this compartment even under the imposed moderate grazing regime.

8.1.6 Summary

The long-term grazing of dry or humid heathland by cattle, sheep or ponies had very strong effects on the vegetation (Fig 8.1). Compared with sites where grazing was very light or did not occur, the grazed vegetation had a more diverse structure, especially when it had formed a mosaic either of tall and short dwarf shrub vegetation or of heath and acid grassland vegetation. Grazing also tended to increase species numbers; in the more heavily grazed areas allowing species more characteristic of acid grassland to establish. Grazing also prevented the dwarf shrubs becoming degenerate and slowed or prevented scrub and bracken invasion and tended to decrease the cover of *Molinia caerulea* and *Deschampsia flexuosa*. Very high grazing pressure tended to kill the dwarf shrub heath species and moved the vegetation more towards an acid grassland and could even create bare patches in the vegetation.

If grazing was introduced onto recently unmanaged heathland or mire with no extra management it tended to have little effect, at least within the first few years accounted for in this survey (Fig 8.3). Even under high stocking rates grazing was light, the animals presumably being deterred by the large amount of woody (dwarf shrubs) or standing

dead (*Molinia*) material. Therefore this grazing reduced the vegetation height, but the dwarf shrub- or *Molinia*-dominated vegetation remained closed and it did not promote the regeneration of dwarf shrubs or allow the establishment of scarcer heath species into the vegetation. If a very high stocking rate was applied, e.g. in Aylesbeare A_3, this opened up the vegetation to some extent and allowed in more heath species, although grazing was still light and the effect may have been due more to trampling.

This survey clearly showed that an additional management to open up the vegetation to the grazing animals had dramatic effects (Fig 8.3). This additional management was either burning or mowing and in all cases grazing intensity was increased on these sites compared to sites with no additional management. As a result the vegetation was shorter and more open and in a majority of cases this increased grazing increased species richness by allowing other heath species to establish. The most dramatic consequences of this were seen in the wetter sites. For example: the mire in Aylesbeare A_1 where a number of new species were seen, including Bog Asphodel (*Narthecium ossifragum*), Butterwort (*Pinguicula lusitanica*) and Bog Myrtle (*Myrica gale*); and the wet heath in New Forest C_1 where the new species included Bog Asphodel, Heath Milkwort (*Polygala serpyllifolia*) and Oblong-leaved Sundew (*Drosera intermedia*).

8.2 Cutting

Aylesbeare

The dry heath in site F_2 was not only mown in 1991, but the litter was scraped away as well. The unmanaged site, F_3, had a tall (60cm), closed (96% cover) vegetation dominated by mature and degenerate dwarf shrubs, *Calluna vulgaris*, *Erica cinerea* and *Ulex gallii*. In contrast, site F_2 had a shorter (30cm), more open (83% cover) vegetation dominated by the colonising grass *Agrostis curtisii*, but the vigorously growing plants of the three dwarf shrub species indicated that these would rapidly return to dominance. The was little effect of the mowing on the number of vascular plant species (5 in F_2 *vs* 4 in F_3).

Arne

The unmanaged dry heath site B_4 had a tall (34cm), closed (93% cover) vegetation dominated by mature and degenerate bushes of *Calluna vulgaris* and *Erica cinerea* and with some *Pinus sylvestris* scrub. In B_3 the vegetation was also tall and the dwarf shrubs were mature or degenerate, but there were remaining effects of the single mow 18 years previously. There was a more open vegetation (77% cover), in this case consisting almost exclusively of *Calluna vulgaris*, an extensive cover of bryophytes (87% vs 18% in B_4), and little encroachment of scrub. B_2, which had been mown once, but more recently in 1991, had a more open, patchy (55% cover) and shorter (18cm) vegetation, but again the only vascular plants were *Calluna vulgaris* and *Erica cinerea*, although these dwarf shrubs

were small (18cm height) and growing vigorously. Interestingly, the bryophyte cover of 14% was not greater than in the unmanaged site. Finally, B_1 was mown both in 1976 and in 1991. As in the other mown sites, the dwarf shrub vegetation consisted solely of *Calluna vulgaris* and *Erica cinerea* and these bushes were short (18cm) and growing vigorously. The vegetation was open (68%) with an extensive bryophyte cover (66%). All the mowing treatments had only two vascular plant species, compared with four (excluding the invading pine) in the unmown site.

Both C sites were dry/humid heath dominated by *Calluna vulgaris*, *Erica cinerea* and *E. tetralix*, and the mowing of C_1 in 1989 had reduced the dwarf shrub cover (75% in C_1 vs 98% in C_2) and increased the bryophyte cover (51% in C_1 vs 21% in C_2). Whereas the dwarf shrubs were small (26cm height) and growing well in C_1, in the unmanaged site they were tall (40cm) and becoming degenerate and *Pinus sylvestris* was beginning to invade.

Thursley

Although it was burnt in 1976, the unmown dry heath site, A_3, was becoming degenerate. It had a very tall (73cm) dwarf shrub vegetation of almost exclusively *Calluna vulgaris* which was closed in the dwarf shrub layer, but which was becoming very open under this canopy (22% bare ground and 67% bryophytes). We also observed the beginnings of encroachment by scrub and bracken. A_2 had been mown in swathes since 1988. The *Calluna vulgaris* in the both the recently mown swathes (height = 19cm) and the remaining swathes (height = 48cm) was regenerating well, forming vigorous bushes and a closing canopy (77% in the short swathes, 89% in the taller areas), though in the taller areas there was some bare ground (17% *vs* 2% in the short areas) and scrub seedlings were detected. Mowing did not affect the small number of non-scrub vascular plant species in the heath (2 each in A_2 and A_3).

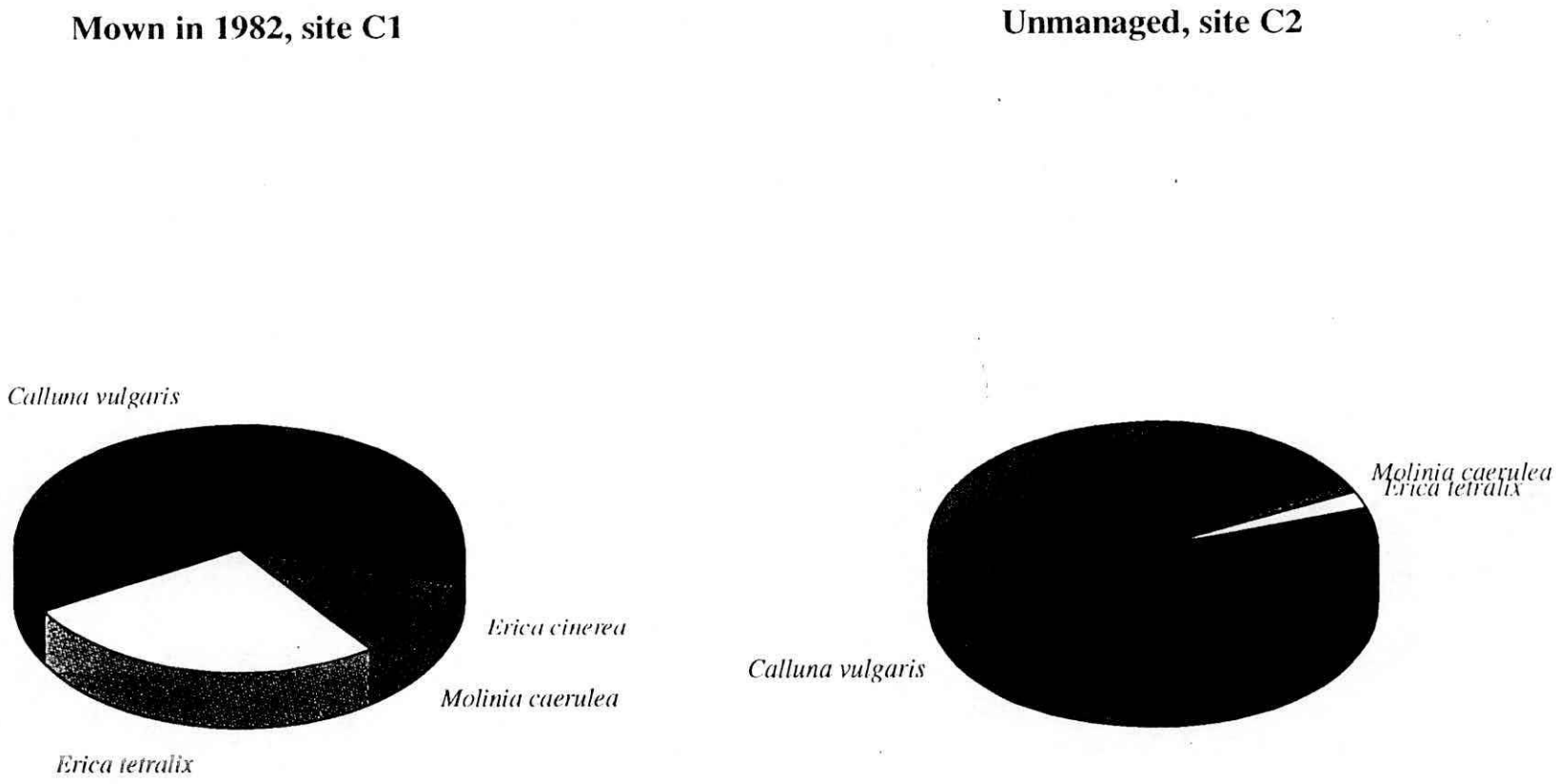
Ashdown Forest

The unmanaged humid heath in site B_4 was very tall (72cm) and closed (97% cover) and, although *Erica tetralix* and *Molinia caerulea* were present, *Calluna vulgaris* was extremely dominant (88% cover). The mowing of site B_3 in 1992 reduced the cover (62%) and height (18cm) of the dwarf shrubs. *C. vulgaris*, *E. tetralix* and *M. caerulea* were now co-dominant and some plants of *Ulex minor* had established.

Site C_2 was also unmanaged humid heath and was similar to B_4, having a tall (74cm), closed (91% cover) vegetation comprised of the same three dwarf shrub species, with *C. vulgaris* dominant. C_1 had been mown 12 years earlier in 1982 and the vegetation was more open (86% cover) and shorter (32cm). As in B_4, *E. tetralix* and *M. caerulea* had increased cover and another dwarf shrub, *Erica cinerea*, had established, although *C. vulgaris* was still dominant (Fig. 8.4).

The mowing of the dry heath site D_1 in 1992 had reduced vegetation height (23cm cover in D_2 *vs* 74cm cover in D_1) and cover (78% cover in D_2 *vs* 92% cover in D_1), but the number of vascular plant species was higher in the

Fig 8.4 The effect of mowing in 1982 on the vegetation of a dry heath in Ashdown Forest



unmown site (4 in D_2 *vs* 2 in D_1).

Breckland

At Cavenham one small area was mown in 1992 and by 1993 the vegetation was regenerating well (14% cover of pioneer heather and 26% of building phase heather). With the dry climate of eastern England, heather stand rejuvenation by cutting is perhaps less risky than forcing regeneration to go through the vulnerable seedling stage (either by burning or after stand death).

Summary

All the mown sites were showing good regeneration of the same dwarf shrub species that were dominant in the unmanaged sites (Fig 8.4). Some were passing through intermediate stages where the colonising grasses *Agrostis curtisii* (e.g. Aylesbeare F_2) or *Molinia caerulea* (e.g. Ashdown Forest B_3) were dominants and/or the *Erica* species were relatively more abundant than in the unmanaged sites (e.g. Ashdown Forest C_1), but it seemed likely that all would return to dominance by *Calluna vulgaris*. Mowing removed the degenerate growth of the dwarf shrubs and regeneration was generally through resprouts. Unlike grazing, mowing had little effect on species richness, aside from the removal of invading scrub. This was probably because mowing caused a single perturbation to the system from which the dwarf shrubs could recover and maintain their dominance, whereas grazing was more long-term and decreased the dwarf shrub/*Molinia* dominance.

8.3 Burning

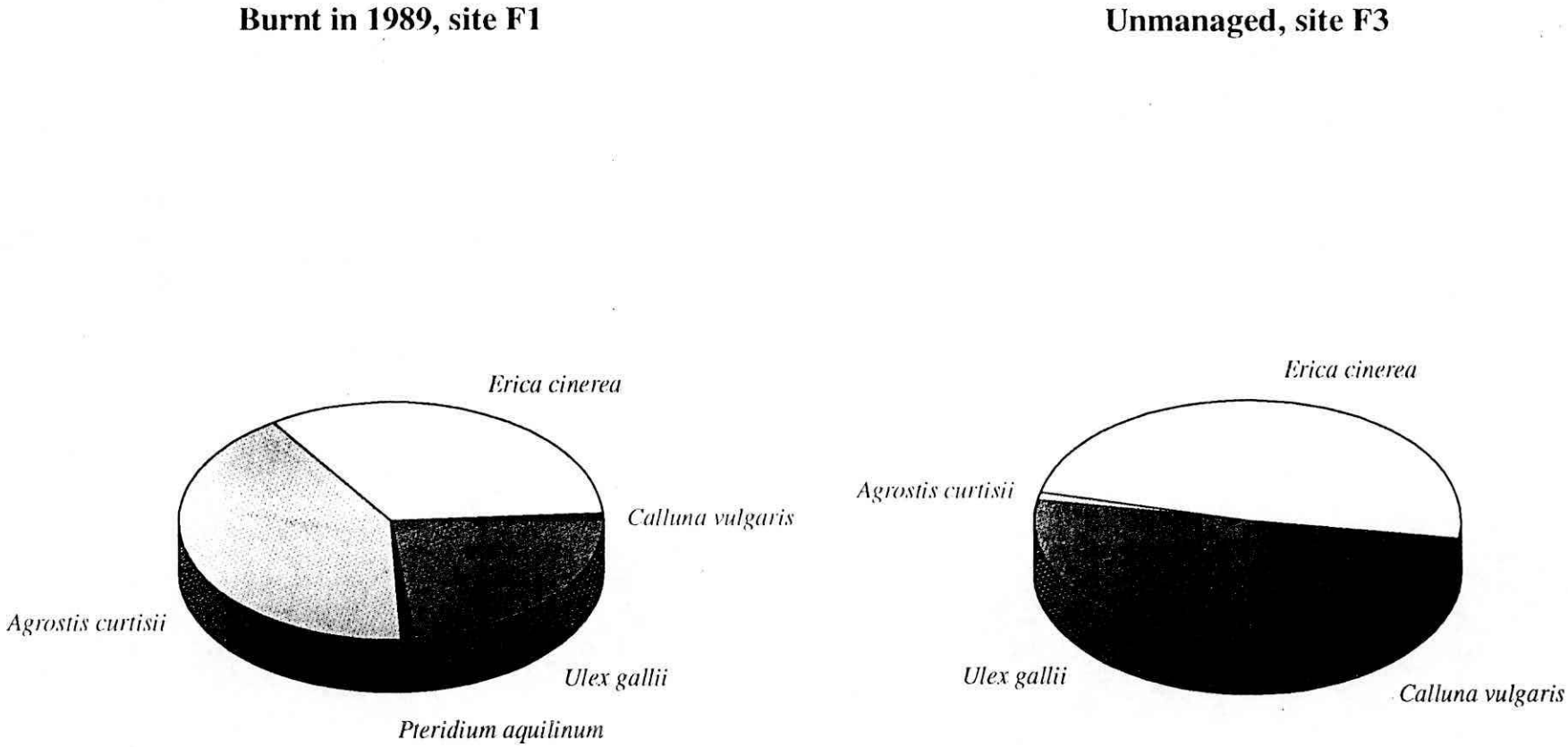
Aylesbeare

Site F_1 was burnt in 1989 and the dry heath had regenerated well (cover in F_1 = 97%, cover in unmanaged F_3 = 96%), although it was still short (30cm in F_1 *vs* 60cm in F_3) and, like the adjacent mown site F_2 (see above), it was dominated by *Agrostis curtisii* rather than by *Erica cinerea* and *Calluna vulgaris* (Fig 8.5).

Arne

In the unmanaged dry heath in D_2 the dominant dwarf shrubs, *Calluna vulgaris* and *Erica cinerea,* were becoming degenerate with a number already dead and this had opened up the canopy (86% cover) and reduced the canopy height (30cm). Pine, birch and bracken were beginning to encroach. D_1 was burnt in 1989 and the dwarf shrub/herb cover was still low (37%) and there were large open areas dominated by the moss *Campylopus introflexus* (53% cover), in contrast to the low bryophyte cover in D_2. Although *Agrostis curtisii* was present in the burnt site, *Calluna vulgaris*, *Erica cinerea* and *Ulex minor* had the most cover and there was a slight effect of burning on the number of vascular plant species if scrub and bracken were excluded from the total (5 in D_1 *vs* 3 in D_2).

Fig 8.5 The effect of burning in 1989 on the vegetation of a dry heath in Aylesbeare, Devon.



The burning of the humid heath site E_1 in 1990 had also left the site very open in 1994 (22% dwarf shrub/herb cover *vs* 90% cover in the unmanaged site E_2) and dominated by *Campylopus introflexus* (77% cover *vs* 55% cover in E_2). However *Erica tetralix* and *Calluna vulgaris* were the commonest vascular plant species in both sites and these plants in the burnt site were growing vigorously. The vegetation in the unburnt site was mature and healthy and no scrub was invading.

Thursley (Plates 23 & 24)

As described above, site A_3, which was burnt in 1976, was a dry heath site consisting of tall (73cm) dwarf shrubs which were becoming degenerate and the vegetation was being invaded by birch, pine and bracken. A_1 was burnt again in 1993 and there was good regeneration (58% cover) by small (19cm height), healthy bushes of *Calluna vulgaris* and *Ulex minor*. *Erica cinerea*, which was not seen in A_3, formed a large cover (15%). Burning also reduced the bryophyte cover (12% cover in A_1 vs 67% cover in A_3) and decreased the number of scrub seedlings and trees.

Ashdown Forest

Site B_4, an unmanaged humid heath, had a tall (72cm) and closed cover (97%) of healthy *Calluna vulgaris*, *Erica tetralix* and *Molinia caerulea*, and *C. vulgaris* was very dominant. Site B_2 was burnt only in 1994, but already exhibited good regeneration (56% cover) by these three species (the only species found), especially by *M. caerulea*. B_1 was mown in 1992 and burnt in 1994 by the same fire as B_2. Here the same three species were regenerating, but regeneration was much poorer (36% cover) with very little by *C. vulgaris* (<1% cover in B_1 *vs* 35% cover in B_2) and more by *M. caerulea* (34% cover in B_1 *vs* 19% cover in B_2).

Summary

Burning removed the degenerate growth of the dwarf shrubs and killed invading scrub. In most cases the heath vegetation was regenerating well through resprouts and seedling establishment and in some a transitory stage of dominance or increase relative abundance by *Agrostis curtisii* (e.g. Aylesbeare F_1), *Molinia caerulea* (e.g. Ashdown Forest B_2) or *Erica* species (e.g. Thursley A_1) was seen (Fig 8.5). As for the mown sites (and probably for the same reason) species richness was little affected by burning. These effects were similar for accidental summer fires and controlled spring burns, indicating that summer fires are not necessarily detrimental to heathland (Bullock & Webb 1995). In contrast to these general trends, the two Arne sites showed poor regeneration, with very low cover values for the dwarf shrub/herb vegetation 4 and 5 years after the burns (compare 37% cover in D_1 and 22% cover in E_1 with the 97% cover in the Aylesbeare site burnt at about the same time) and with large amounts of the invasive moss *Campylopus introflexus*. The reason for these differences from the other heathlands is not clear but the soils at Arne are extremely nutrient-poor (Chapman & Clarke 1980) and this may have retarded regeneration, especially from degenerate plants. Alternatively, the moss *Campylopus introflexus* may have inhibited seed germination of the dwarf

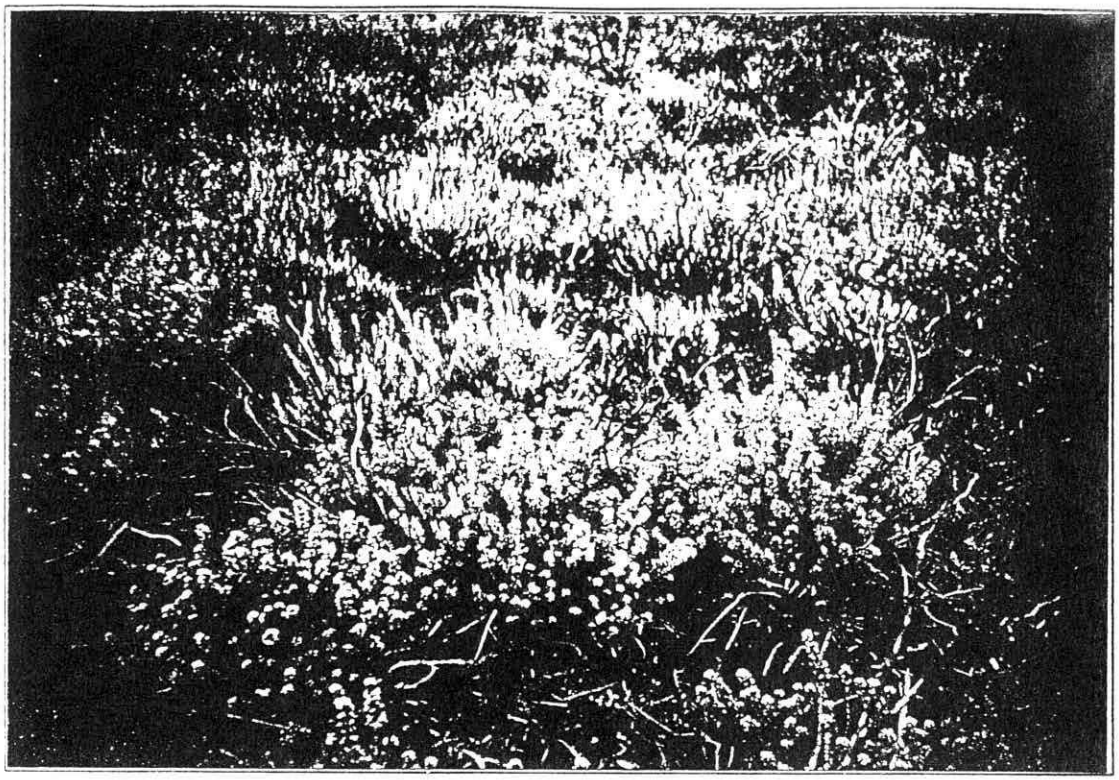


Plate 23. The regeneration of dry heathland following a burn at Thursley Common, Surrey.

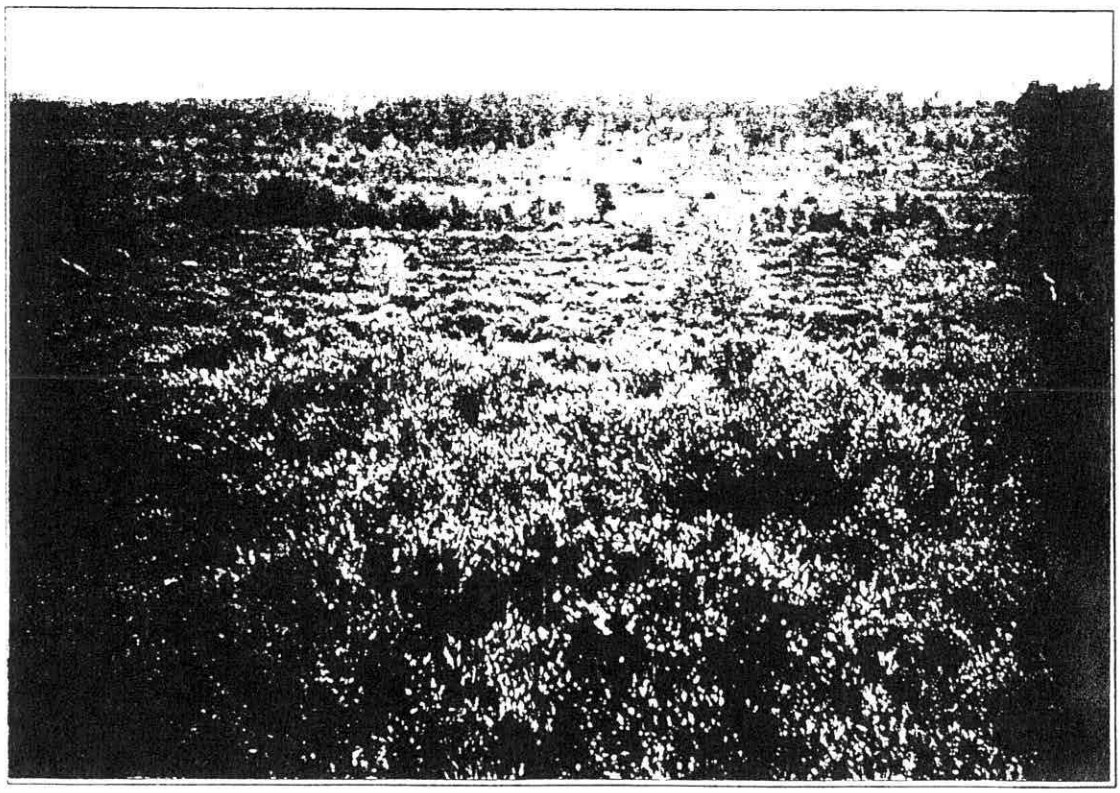


Plate 24. Unmanaged dry heath at Thursely. Note the invasion of pine and scrub.

shrub species (e.g. Equihua & Usher 1993) and thus have slowed regeneration.

8.4 Other management practices

8.4.1 Bracken control

Aylesbeare

The uncontrolled site E_4 was almost a monoculture of bracken (*Pteridium aquilinum*), which formed a tall canopy (110cm) with 100% cover. There was a very sparse understorey (5% cover) and a deep litter (5cm). Sites E_1, E_2 and E_3 were subjected to similar control measures, but in different years, and they can be viewed as showing different stages of vegetation development following cutting of the bracken and scraping away of the litter and vegetation followed by occasional spraying of Asulam. All regeneration in these plots was by seed. E_3 was treated in 1992 and had a very sparse (40% cover) and short (8cm) vegetation, but eight heath species were establishing - *Agrostis curtisii* and *Erica cinerea* were dominant - and bracken was rare (<1% cover). E_2 was treated one year earlier in 1991 and had a denser (77% cover) and taller (23cm) dwarf shrub/herb vegetation consisting of six heath species and very little bracken (<1% cover), with *Agrostis curtisii* and *Molinia caerulea* dominant. Unlike E_3 there was little bare ground (1% *vs* 56% in E_3) and an extensive covering of moss (22% *vs* 3% in E_3). E_1 was treated in 1989 and a dense (99% cover), tall (45cm) vegetation had developed with no bryophytes and little bare ground (1% cover). Bracken had not re-established (<1% cover) and there were 5 heath species (excluding scrub species), although *Agrostis curtisii* and *Molinia caerulea* were still dominant.

New Forest

The two sites of uncontrolled bracken, D_2 and E_2, each had a dense (95% cover in both), tall (90cm-100cm) cover of bracken with a sparse understorey (26%-28% cover) which consisted of a low cover of heathland species, such as *Calluna vulgaris* and *Molinia caerulea*, and several species more characteristic of the understorey of scrub and woodland, such as *Lonicera periclymenum* and *Rubus fruticosus*. D_1 and E_1 were cut in 1992 and 1993 and this had resulted in a moderate reduction in bracken cover (66% and 50% for D_1 and E_1 respectively) and in the height of the bracken (90cm and 54cm D_1 and E_1). In both controlled sites the understorey was much more dense than in the uncontrolled sites (69% in D_1 and 90% in E_1) and it was also much more species-rich (12 in D_1 *vs* 5 in D_2 and 21 in E_1 *vs* 7 in E_2). However, these were not all heath species and some of these understorey species were more characteristic of a woodland understorey. There were five heath species in D_1, with a total cover of 9% and eight in E_1, having a combined cover of 53%.

Thursley

The uncontrolled bracken in site D_3 was not as dense as in the sites described above, it had a cover of 79% and the understorey was fairly dense (71% cover) although this was composed almost exclusively of *Agrostis curtisii*.

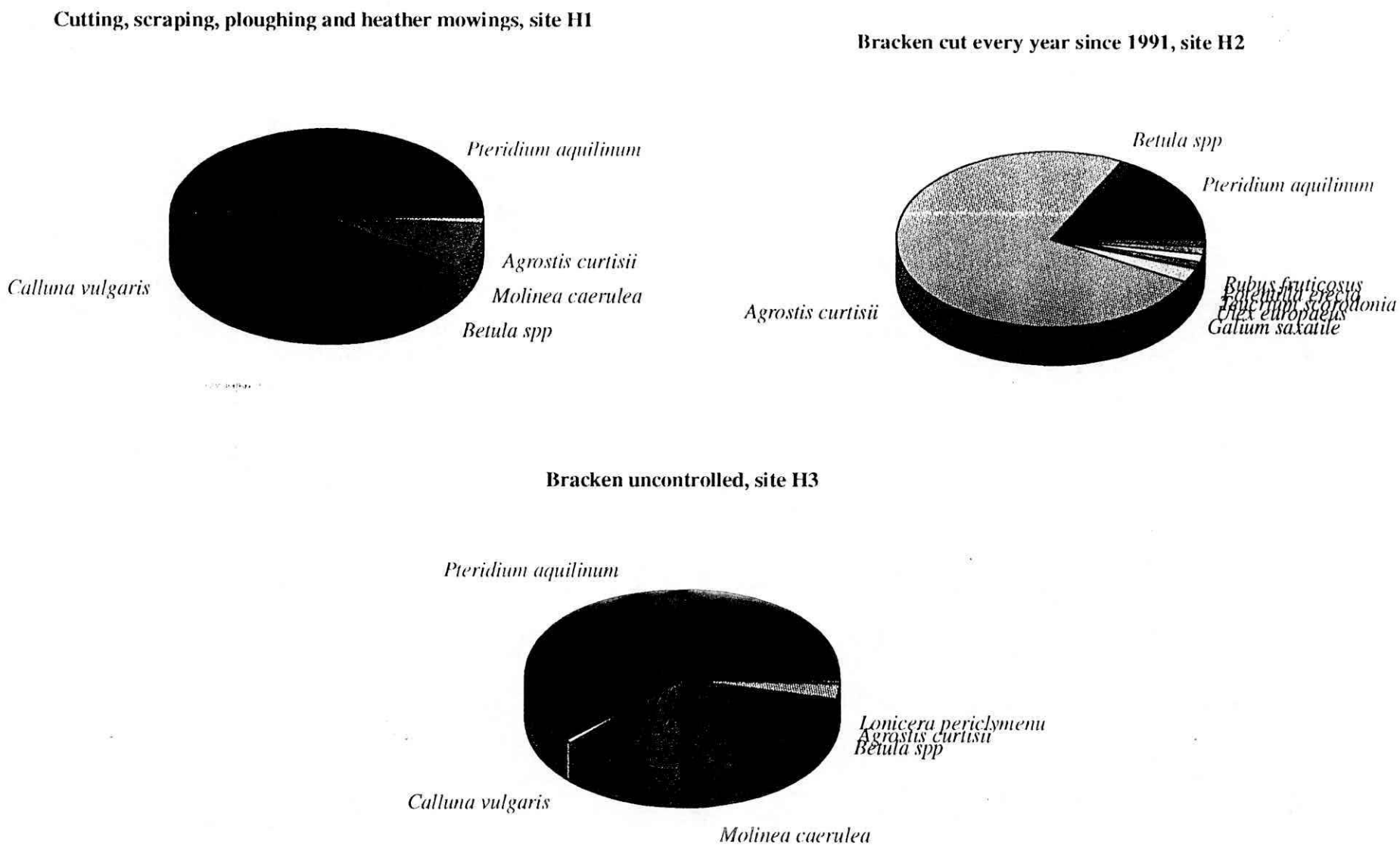
Bracken was controlled in D_1 by cutting and chisel ploughing in 1992 and in D_2 by cutting and rotovating in 1992. Both bracken control measures had similar effects on the vegetation. The cover (20% in D_1 and 13% in D_2) and height (63cm in D_1 and 56cm in D_2 *vs* 82cm in D_3) of bracken were reduced. However, the understorey was little different to the uncontrolled site, with similar cover values for *Agrostis curtisii* (70% in D_1 and 63% in D_2). D_2 had a higher understorey cover than the other sites (87% in D_2 *vs* 74% in D_1 and 71% in D_3), due to an extensive cover of seedlings of the ruderal *Rumex acetosella* caused, presumably, by the high soil disturbance.

Ashdown Forest (Plates 25 & 26)

E_2, F_2 and G_2 were all sites of uncontrolled bracken. The bracken was tall (E_2 = 102cm, F_2 = 120cm, G_2 = 80cm) had an almost total cover (E_2 = 94%, F_2 = 100%, G_2 = 90%), and there was a deep litter (E_2 = 9cm, F_2 = 6cm, G_2 = 10cm). The understorey was sparse in E_2 and F_2 (37% and 6% cover respectively), but it was more dense in G_2 (70% cover), although in all sites it was composed of few species (E_2 = 5, F_2 = 2, G_2 = 3) and was dominated by *Molinia caerulea*. The same bracken control methods were used in E_1, F_1 and G_1 in 1993, 1991 and 1992 respectively. This involved cutting the bracken, scraping up the litter, ploughing, scattering heather mowings and cutting the regrowth every subsequent year. This method removed all the litter and reduced bracken cover on all sites, but its success varied among the sites. The best result was seen in F_1 where bracken was reduced to a very low cover (1%) and the plants were very short (19cm). The understorey was fairly closed (87% cover) and contained 11 species, eight of which were heath species. *Calluna vulgaris, Carex panicea* and *Agrostis curtisii* were among the dominants and *Erica cinerea* was also showing good establishment. E_1 showed the worst response. Bracken cover was somewhat reduced (28%) and the plants were of medium height (32cm), but the understorey cover was actually lower than in the uncontrolled site E_2 (21% in E_1 *vs* 37% in E_2). However, a number of heath species had established which were not present in E_2 - *Calluna vulgaris, Carex panicea, Agrostis curtisii, Galium saxatile* and *Potentilla erecta* - although these all had very low cover values and *Molinia caerulea* was still dominant. The success of bracken control was intermediate at site G_1. Bracken cover was reduced to 13% and the plants were of medium height. The understorey cover was 70%, the same as in the uncontrolled site G_2. However, instead of the dominance by one species, *Molinia caerulea*, three species had high cover values in G_1 - *M. caerulea, Calluna vulgaris* and *Carex panicea*. These latter two species were not seen in G_2. The difference in success of the control measures among the sites may have been related to the date of control; the best result was seen in the oldest control site, and the worst result was seen in the youngest site. The more years for which the bracken had been cut, the less dominant it became and a greater period of time since the initial control allowed a more characteristic heathland vegetation to develop.

The uncontrolled bracken in site H_3 was tall (100cm) and dense (92% cover) and the understorey was fairly sparse, and was again dominated by *Molinia caerulea*. Two control measures were compared: site H_1 was treated in 1990 the same way as were E_1, F_1 and G_1, and H_2 had been simply cut yearly since 1991. The bracken still had a fair cover

Fig 8.6 The effectiveness of bracken control methods to regenerate dry heath at Ashdown Forest



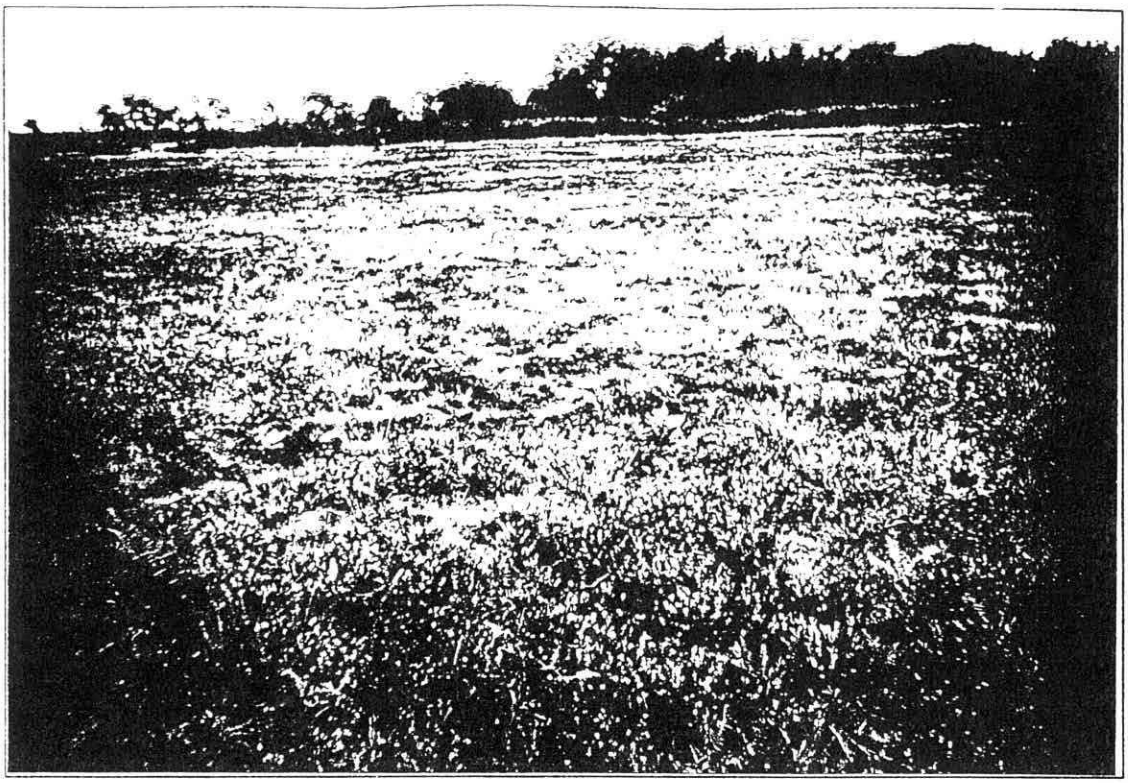


Plate 25. Successful bracken 'scraping' at Site E, Ashdown Forest.

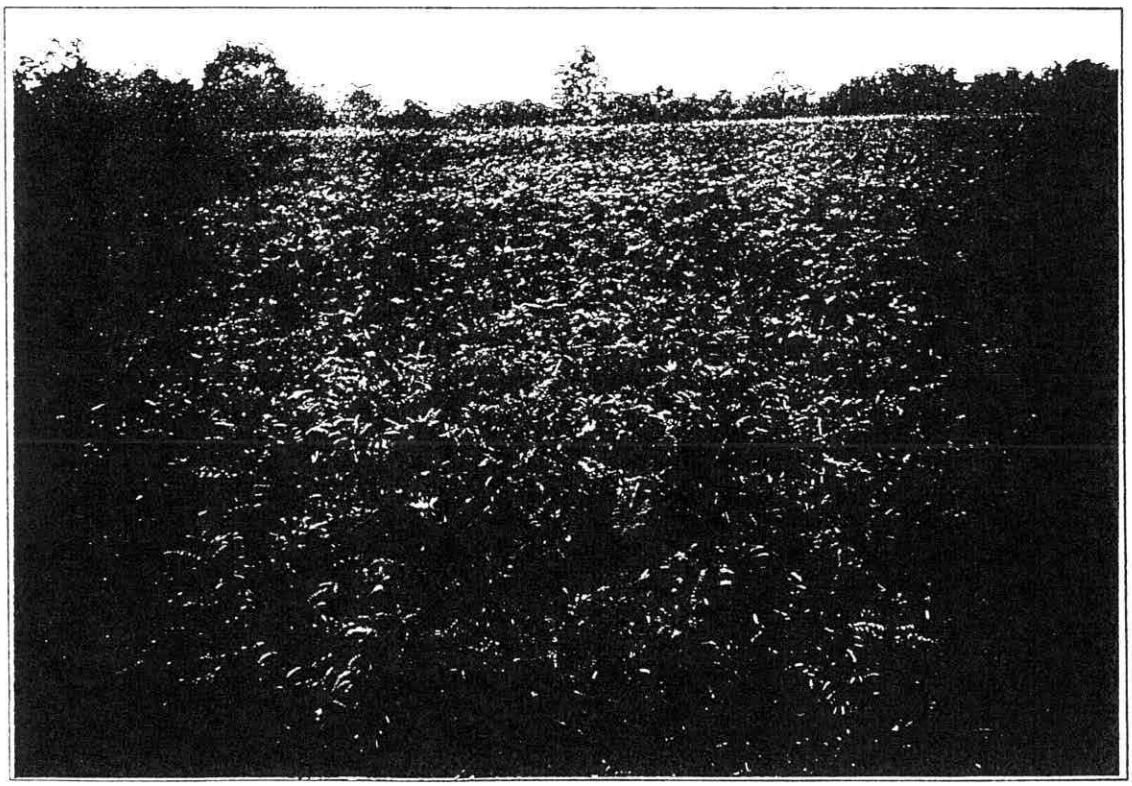


Plate 26. Unsuccessful bracken 'scraping' at Site F, Ashdown Forest.

in H_1 (19%), but there was a dense understorey (76% cover) which was dominated by *Calluna vulgaris* (64% cover) and had none of the wood and scrub understorey species seen in the more recent bracken control sites. This supports the hypothesis given above; the greater length of time since the initial control had allowed the development of a more advanced stage of heathland vegetation. The simple cutting of H_2 was less successful. Although the bracken cover was reduced to a similar degree (12%), the understorey was less dense (58% cover) and it was dominated by the early-successional grass *Agrostis curtisii*. There was no *Calluna vulgaris* or other dwarf shrub species, and a number of wood and scrub understorey species (e.g. *Lonicera periclymenum* and *Teucrium scorodonia*) were still present (Fig 8.6).

Site I_1 had been cut since 1988. Although the bracken cover was reduced (14% in I_1 *vs* 78% in the uncontrolled site, I_2), there was little change in the cover (89% in I_1 *vs* 92% in I_2) or the species composition of the controlled site. *Molinia caerulea* and *Agrostis curtisii* were the dominant species in both sites and, although *Galium saxatile* had a greater cover in I_1 (12% *vs* <1% in I_2), no new heathland species had established as a consequence of the cutting.

Suffolk Sandlings and Breckland

Bracken control in these areas has largely been carried out by cutting or asulam application. However, no sites where bracken control was carried out were sampled explicitly, though it appeared to have been successful in re-instating heathland at Brettenham Heath (Wright 1993) and at various sites in the Suffolk Sandlings (Sibbett 1994).

Summary

Two main strategies for bracken control have been used on the heathlands in this review; conventional methods including cutting and herbicide application, or some method of producing a severe disturbance followed by more conventional means to maintain control.

Yearly cutting alone (New Forest, Ashdown Forest H_2, I_1) had little effect (Fig 8.6). The cover of bracken was reduced but there has been little spread of heathland vegetation. A combination of frequent cutting and application of asulam, followed by grazing has substantially reduced the bracken cover on Brettenham Heath (Wright 1993). However, these conventional methods need continual treatment over a number of years to suppress bracken and allow regeneration of a heathland community, unless carried out in combination with other methods of accelerating species invasion (Pakeman & Marrs 1994).

The implementation of a severe initial disturbance, such as scraping (Aylesbeare) or scraping and ploughing (Ashdown Forest E_1, F_1, G_1, H_1), has two beneficial effects: the bracken rhizomes are damaged and exposed to frost and desiccation, and the bracken litter is removed, allowing seedlings of heath species to establish. Subsequent continual yearly spraying (Aylesbeare) or cutting (Ashdown Forest E_1, F_1, G_1, H_1) of the regrowth controlled the

bracken to a greater or lesser extent and allowed the continued development of a characteristic heathland vegetation (Fig 8.6). The Thursley sites, which were ploughed or rotovated and then cut yearly, showed poor regeneration of a heathland vegetation, despite a fairly good decrease in the bracken cover, probably because the control had only been initiated two years previously. These methods do allow vegetation to be established quickly with little competition from bracken, however, they can only be implemented on land accessible by tractor and on soils that are not too stony.

8.4.2 Rotovation

Breckland

This technique was used at Cavenham Heath for two purposes: 1. to rejuvenate heather stands and 2. to return areas dominated by *Deschampsia flexuosa* to heather.

Rejuvenation of heather.

One area of Cavenham Heath was rotovated in 1977 to improve heather regeneration. When surveyed this had a good cover of heather, 82%, compared to the neighbouring area of good heather (80%) - the best on the reserve. It was distinguishable from this neighbouring area only by the more even canopy and age structure.

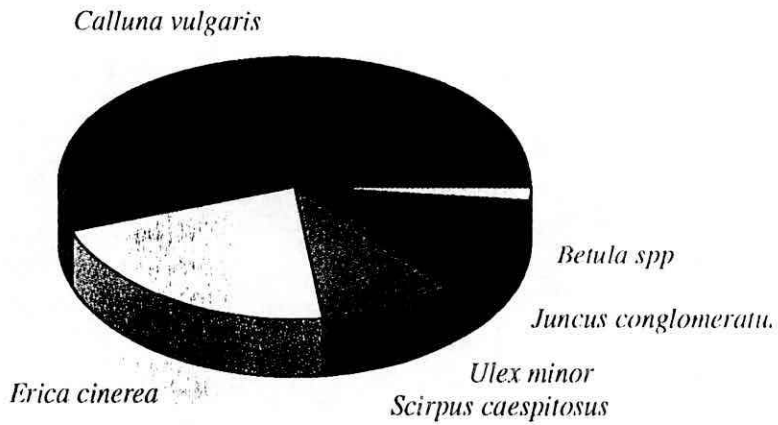
Management of *D. flexuosa* to increase heather cover.

Cavenham had experienced considerable invasion of *D. flexuosa* and management was aimed at reducing the cover of this species. One area of grass dominated heath was rotovated in 1989, and because of the poor regeneration of heather and an increase in cover of *Festuca ovina* part of this area was rotovated again in 1992. Neither the area rotovated once in 1989 or that rotovated twice in 1989 and 1992 showed much heather growth (0.9% and 2% cover respectively), but they showed considerable growth of *F.ovina* (40% and 27%) and areas of bare ground. The poor success of *Calluna vulgaris* was possibly a result of drought, a common problem in an area with such a low rainfall.

Because of the poor chances of establishing heather after rotovation due to the effects of drought, this management technique carries a certain amount of risks. Repeated rotovation had depleted the seedbank by 60% compared to nearby areas still dominated by *D. flexuosa* and 85% compared to adjacent mature heather (Pakeman & Marshall, unpublished), thus a few failed attempts at producing good heather regeneration would effectively result in a grass dominated area with any increase in heather cover needing to come from outside seed.

Fig 8.7 Regeneration of wet heath at Thursley, Surrey following pine clearance in 1993, with or without litter removal

With litter removal, site C1



Without litter removal, site C2

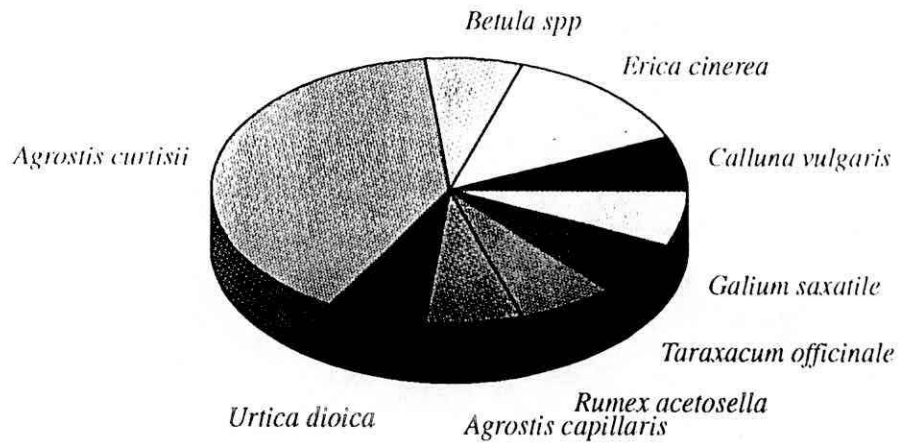


Plate 19. *Calluna* & *Erica* regeneration following pine clearance at Thursely Common, Surrey

Plate 20. Heathland regeneration one year after pine clearance at Arne, Dorset. Note the dominance of mosses.

8.4.3 Pine clearance

Arne

Although the pine clearance and litter removal in site A_1 had taken place only 3 years previously and the dwarf shrub vegetation was still fairly open compared to the adjacent dry heath site A_2 (54% cover in A_1 vs 97% cover in A_2), there was good regeneration of a dry heath vegetation (Plate 20). The same two species, *Calluna vulgaris* and *Erica cinerea*, were dominant in both sites and other heath species were establishing (e.g. *Carex panicea*), although some present in A_2 were still absent in A_1 (e.g. *Ulex minor*). *Pteridium aquilinum* was also establishing in A_1 and might be a problem in the future.

Thursley

The understorey in the pine plantation site B_3 was very sparse (5% cover) with a few remnant plants of heathland species *Calluna vulgaris, Erica cinerea* and *Agrostis curtisii.* The heath plants were excluded by a dense pine canopy (95% cover) and a deep, 8cm, litter, which caused a predomination of the moss *Hypnum cupressiforme* (54% cover). The pine clearance and litter scrape in 1991 on site B_1 had allowed the three heath species to increase their cover and *Molinia caerulea* and *Ulex minor* had also established, giving a similar species composition to the adjacent mature dry heath site B_2. The regeneration of heathland plants on site B_1 had resulted in a more extensive, although still open, vegetation (37% cover) and these heath plants were young and vigourous, suggesting that a closed heathland vegetation similar to B_2 (90% cover) would be achieved within a few years (Plate 19).

The pine plantation on the former wet heath site C_3 had an even more drastic effect on the understorey vegetation than in B_3 (Fig 8.7). There were no vascular plants in the understorey, but there was an extensive cover of mosses (42% cover) on the thick litter (8cm). In C_2 the pines had been cleared but the litter was intact (7cm) and only a very sparse vegetation had developed (13% cover). This consisted of nine vascular plant species, of which *Agrostis curtisii* was the commonest, and although *Calluna vulgaris* and *Erica cinere*a were also present, many of the other species were not characteristic of heathland. (e.g. *Urtica dioica, Taraxacum officinale*). The litter had been scraped away (depth = 0cm) following pine clearance in site C_1 and this had allowed a much denser vegetation than in C_2 to develop (64% cover) and it was much more characteristic of heathland. *Calluna vulgaris* was dominant and *Erica cinerea* was common, and all the six vascular plant species present were heath species.

Summary

At both Arne and Thursley there was the potential for the fairly rapid development of a good heathland vegetation after clearance of the pine trees (Fig 8.7). This was despite the fact that the woods were over 40 years old, and it indicates that the heathland species had maintained viable seedbanks over this time and/or there was a good seed rain from adjacent heath sites. However, the evidence from Thursley C_2 showed that it is essential to remove the pine litter as well as the trees, as this inhibited the establishment of heath plants and allowed non-heath plants to establish (Fig 8.7).

9.0 RECOMMENDATIONS FOR THE MANAGEMENT OF LOWLAND HEATH

9.1 Summary of the survey results

Management to maintain heath vegetation

- Heathland which has been unmanaged for a number of years undergoes succession as the dwarf shrubs become degenerate and coarse grasses, trees, scrub, bracken and other invasive species become established.
- Grazing by cattle, sheep and/or ponies can be used to maintain heathland or mire in an early successional stage or as a mosaic of patches in different successional stages.
- Early successional stages on dry, humid and wet heath, grass heath and mire are characteristically more open and have a higher plant species diversity (with more low-growing herbs and grasses) than more mature stages.
- Different grazing intensities bring about different vegetation states; all of which can be desirable forms of heathland vegetation.
- If grazing is introduced or reinstated on a mature heath or mire, an initial burning or mowing removes standing woody or dead biomass and thus encourages grazing and accelerates the development of a early successional stage.
- The intensity of grazing is important: overgrazing will cause the suppression of heath vegetation and cause a change to acid grassland or the loss of all vegetation; undergrazing will have little effect in halting succession.
- Dry, humid and wet heath are also managed by burning or mowing.
- Burning or mowing of mature heath temporarily returns the vegetation to an early successional stage, but, unlike continued grazing, they will not maintain the vegetation in the pioneer state.
- Therefore burning or mowing must be repeated occasionally to maintain the heathland or mire vegetation.
- Because burning or mowing are only a temporary perturbation to the heath vegetation they have little effect on species richness, unlike grazing.
- Rotovation or scraping of dry heath allows regeneration from degenerate or mature heather stands.

Management to restore heath vegetation on degenerate sites

- Bracken, if uncontrolled, can become dominant on dryer heaths and cause a loss of heathland species.
- Cutting of bracken does little to control it, even if cutting is carried out yearly.
- Rapid and stable heathland regeneration can be achieved if an initial severe disturbance of the bracken is

carried out and followed by control of any bracken regrowth.

- The initial severe control can be achieved by cutting of the bracken followed by scraping away of the litter or ploughing - this removes the bracken litter, exposes the bracken rhizomes to damage and allows regeneration of heath plants from the seedbank.
- Control of bracken regrowth can be by cutting or spraying of Asulam, but each should be continued over a number of years.
- Rotovation of degenerate dry heath, e.g. dominated by *Deschampsia flexuosa*, has been carried out to encourage regeneration of heath vegetation, but this has showed limited success.
- Rapid regeneration of heathland can occur following clearance of pine plantations (where the plantation was on heathland), even for plantations >40 years old.
- However, it is essential to remove the pine litter to allow establishment from seedbanks of heath species.

9.2 Existing ESA and Countryside Stewardship guidelines

ESA guidelines

The only current ESA that contains lowland heathland is the Breckland. The guidelines for the grass heath in this area include prohibitions against: re-seeding and mechanical operations (e.g. ploughing) which will destroy the heath, irrigation, fertilisation, liming or other techniques to reduce soil acidity, use of fungicides and insecticides, use of herbicides except against named weeds (including bracken or scrub stumps), and widespread supplementary feeding of stock.

Actual management techniques for the grass heath vegetation are addressed only briefly.

- Hard graze the sward.

  Preferably with sheep - never with pigs or poultry.

  Avoid overgrazing and damage to heather by careful stock management.

  Avoid undergrazing which will allow spread of coarse grasses, scrub and bracken.
- Rotovation of small areas (0.3ha) on heaths of low conservation value will provide bare patches which are of benefit to plants and animals.
- Bracken and scrub control should be by mechanical means, although chemicals may be necessary.

Several criticisms can be made of these guidelines:

1. Hard grazing of the sward will push the heaths towards grass-dominated grass heath. While this may be desirable in certain heaths, lighter grazing can produce a different form of heathland vegetation which may contain habitat for different plant and animal species. In the interests of diversifying the landscape, it will be more desirable to have a range of grazing intensities over Breckland heaths rather than to hard graze

all heaths. By a similar argument, cattle grazing could be encouraged on some heaths.

2. If a heath has been ungrazed and consists of tall mature or degenerate dwarf shrub vegetation it may not be sufficient to introduce grazing alone. An initial perturbation, such as burning or mowing, may be necessary to open up the vegetation to grazers. While these are not traditional practises in the Breckland, the abandonment of many heaths in modern times may necessitate unusual practises to return these heaths to their traditional state.

3. Rotational mowing or burning are not mentioned in the guidelines, but these may comprise useful forms of management in the absence of grazing.

4. There is no clear benefit in rotovation of small patches in heathlands of low conservation value. While it is not clear what 'of low conservation value' means, it would be more beneficial to manage the whole heath to increase its conservation value.

5. Where there is extensive invasion by coarse grasses or bracken more dramatic control measures than those stated may be of greater benefit. Thus, rotovation, cutting, ploughing or scraping, with continued control of regrowth, may allow a rapid regeneration of heathland vegetation.

Countryside Stewardship guidelines

These target (among others of no relevance to this review) existing heaths that need a reintroduction of management and managed heaths which require measures to improve the conservation value. Management in either type to prevent a decline in the heath would normally include a combination of the following.

- Light summer grazing by suitable livestock.
- Rotational burning where traditional and beneficial on the heath.
- Cutting to control scrub or as a substitute for grazing.
- Bracken control, by herbicide or, preferably, by cutting
- Scrub management by cutting, and stump treatment or removal of regrowth.

As might be expected, these guidelines are broader than those for the Breckland ESAs. They cover the three main types of management: grazing, burning and cutting. However, they are vague in not assigning priority to certain management types and there is little consideration of problems in managing degenerate heathlands and those dominated by invasive species.

9.3 Recommendations

The management of a heath should be planned with clear objectives in mind. There are two levels to the planning procedure: objectives for the particular heath, and objectives for the whole heathland system or landscape. The heathland system must be considered because the biodiversity of heathlands was traditionally maintained by the variety of management practices carried out in a region. This created a mosaic of different vegetation types at different successional stages and provided habitat for a wide diversity of plant and animal species (Bullock & Webb 1995). Modern management practices would be best targeted to create a mosaic of heathland vegetation types on a (rough) scale of several hectares.

Within this wider set of objectives, the following should be considered in deciding the management practises for a heath.

Assessment

- The heath should be assessed -
  - What is the vegetation type (perhaps using NVC categories)?
  - Is the vegetation degenerate or in a satisfactory state?
- The objectives should be set -
  - Should the vegetation be maintained in its current state or be changed by management?
  - Should the vegetation change be drastic (e.g. regeneration of bracken-dominated heath) or more subtle (e.g. returning a mature heath to an early-successional stage)?

Long-term management

- Past management should be used to decide long-term management -
  - What management is used now and is it sufficient?
  - What was the traditional management of the heath, i.e. that used earlier this century, and can this be used to achieve the objectives?
- New long-term management practices should be decided -
  - What management practices are relevant to the heath type (e.g. healthy wet heath or mire should not be burnt)?
  - What management will best achieve the objectives?
- Grazing should be the generally preferred management of lowland heath -
  - Grazing was the traditional management of much lowland heath.
  - Burning and cutting were traditionally used to open up heath to grazing animals, not as sole management practises.

Burning and cutting without grazing do not substitute fully for grazing, especially in terms of diversity of plant species and vegetation structure.

- The species and breed of grazing animals should be decided based on the tradition for the area, the management objectives and the tolerances of the animals -

  Sheep, cattle, ponies and, sometimes, goats are species usually used.

  Cattle and ponies (and, possibly goats) will be able to open up rough vegetation.

  Sheep can close graze to produce a very short sward.

  The breed must be of a type able to tolerate the heath vegetation: e.g. Friesian cattle should not be used, but Highland cattle, Shorthorns, Limousin X, etc are more hardy.

- The stocking rate and grazing season should be based on the tradition for the area, the management objectives and the welfare of the animals -

  Different stocking rates will result in different vegetation.

  Summer grazing is usually used.

- Burning or mowing, if used alone, should be applied rotationally -

  The frequency of the rotation should be decided based on tradition and management objectives

  Burns should be carried out in the winter, following the MAFF code.

  It may be desirable to burn or mow only parts of the heath each year, to establish a mosaic of vegetation types.

- Other management should be considered, e.g rotovation or turf-stripping (see Gimingham 1992, Traynor 1995)

Initial management

- Degenerate or mature heathland may require an initial one-off perturbation to remove invasive species or excessive biomass before the long-term management can be initiated -

  If tall and mature heath is to be grazed the standing woody and dead biomass should be removed by burning or cutting to provide fresh growth for grazers (in such cases it is acceptable to burn wet heaths and mires).

  Degenerate heaths may require initial control of invasive species such as bracken, *Molinia caerulescens, Deschampsia flexuosa*, and scrub (e.g. *Betula* spp, *Rhododendron ponticum, Pinus sylvestris*).

- It may be possible to regenerate even extremely altered heath -

  Regeneration from the heathland seedbank on pine plantations can be achieved by cutting trees and litter removal.

  Dominant bracken or coarse grasses can be removed by severe disturbance (which also exposes the heath seedbank) and continued control of regrowth.

- The long-term management can be put in place after this initial management.

10.0 CONCLUSIONS

The results from this study provide a greater understanding of the ecological implications of a wide variety of management regimes on both calcareous grassland and heathland. This, together with the careful consideration of practical and agronomic factors, offers a clearer definition of practical management prescriptions needed for the conservation of both habitats.

1. Both calcareous grassland and lowland heath are products of many centuries of human use and management, that has typically included such activities as grazing, cutting, burning and turf cutting. They are both dynamic systems and the cessation of these practices, or changes in the type, intensity and frequency of management will affect the composition and structure of the vegetation. Typically, there is a progression to woodland and scrub, and loss of biodiversity.

2. In the context of this review, the current ESA and Countryside Stewardship guidelines for the management of calcareous grassland and heathland were found to be too general to achieve the aim of these policies, namely to maintain and enhance the biodiversity of these habitats. Such habitats may act as sources for the colonisation of newly restored sites established elsewhere within the ESA (BD0315, BD0306).

3. In order to achieve these policy aims, it is important to consider the ecological, practical and agronomic issues concerning the management a given site or region. This should take the form of a simple model or check list for management decision making (sections 5, 9 & Fig. 10.1).

4. Site evaluation is important to determine the assemblages of plants and animals which need managing, together with their conservation status (rare, threatened etc). This should be underpinned by detailed knowledge of the ecological requirements of these species. This will enable the clear definition of ecological management objectives. These must be balanced with what is realistically achievable with the resources available (e.g. livestock and machinery) and the local constraints (e.g. topography and soils). This should produce a suite of viable and practical management options which will achieve the conservation objectives of management.

5. It is recommended that site specific and flexible management plans are formulated. These should be frequently reviewed and up-dated on the basis of monitoring. This can take the form of simple sward-based measurements. These should be underpinned by guidanceon stocking rates in more appropriate units (e.g. Utilized Metabolisable Energy Output);

6. Such integrated land management could be underpinned by a computer based decision support system. This would provide advisors with the relevant information in order to make informed decisions regarding the management of a given site.

10.1 FUTURE RESEARCH REQUIREMENTS

1. Reviews of this nature help to identify gaps in practical and scientific knowledge. In particular, it has highlighted the need for more information on the management requirements of individual species and habitats. Using this information, future research should investigate the potential use of traditional management procedures (grazing and cutting) as tools to promote and accelerate the dispersal of species into grasslands that are otherwise floristically impoverished.

2. Specifically designed, large-scale, replicated experiments proved the most valuable in determining the effects of different management practices on the structure and function of the ecosystem. More of these experiments are required to determine the ecological effects of type, frequency and intensity of management on a variety of different heathland and grassland types. Inference of the effects of management from sites of known management history proved less satisfactory. This was because of the often large variation in management practices between years and the many 'unknown factors' which confounded the effects of management.

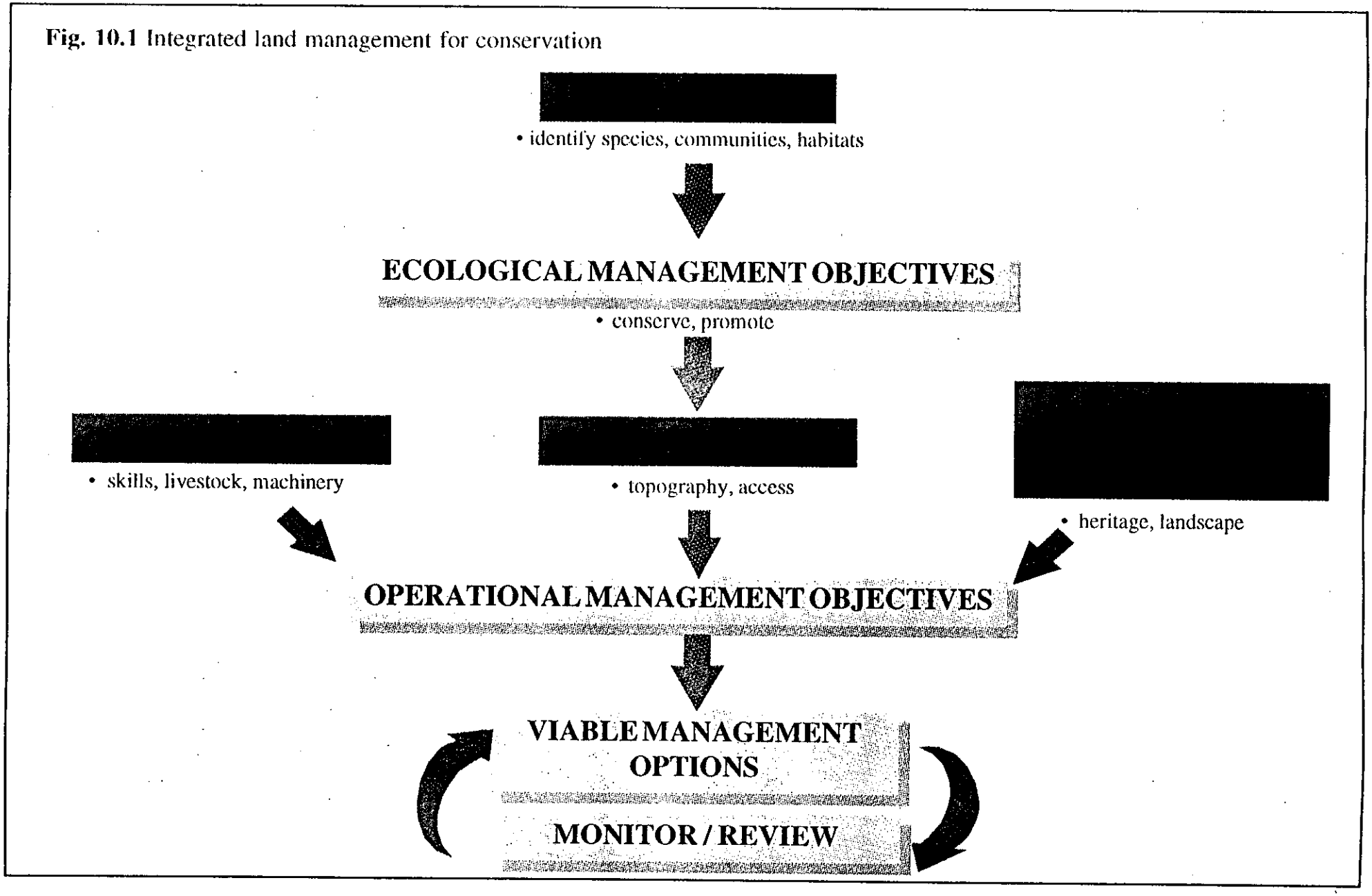
3. Some of the ecological effects of management take many years to become apparent. This was especially true of sward composition and the associated invertebrates communities. The provision for long-term monitoring of future management experiments is essential.

4. The ecological effects of management should be studied at a variety of spatial scales. This will help determine the optimum patch size and rotation frequency for different management types. This is especially important for some invertebrate groups (sections 2 & 6). Biodiversity will often be greatest on sites where there is a mosaic of different vegetation structures and types created at a range of spatial and temporal scales.

5. There is currently little understanding of the techniques for lowland heathland management (e.g. Stocking rates, best breeds, grazing season, or the spatial and temporal frequency of burning or mowing) required to achieve specified objectives. This urgently requires investigation.

6. The ability to manage semi-natural habitats, such as calcareous grassland and heathland, has been constrained by a general lack of both scientific and practical knowledge. If existing information were more widely available,

Fig. 10.1 Integrated land management for conservation



it would enable a more flexible and integrated approach to land management (Fig. 10.1) which should have a greater certainty of achieving the policy objectives. Such a system would also make easier the application of current and future guidelines for environmental land management schemes. In order to achieve this, it would be very beneficial to develop a computerised decision support system for habitat management with the following objectives:

(i) Provide decision-makers and those involved with land management an inter-active, computerised database system to help define appropriate, site-specific ecological objectives for management;
(ii) Identify the key species of plants of a given habitat and supply details of their ecological characteristics, habitat requirements and biogeographic distribution;
(iii) Provide a range of viable management presciptions to achieve these objectives.
(iv) Make predictions as to the rate and direction of vegetation development under different management scenarios.

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13.0 APPENDIX II

The detailed survey data for the heathland management sites. Each table shows the percentage cover of each species in each layer of the vegetation, calculated as the mean of five 2m × 2m quadrats (the five westerly heathlands) or of 10 - 20 1m × 1m quadrats (the Suffolk sandlings and the Brecklands). If cover was <1% this is indicated by a +. Also shown are the mean cover values and the average height for each layer, the amount of bare ground and the depth of litter or peat, if they were measured. For the five westerly heathland areas adjacent sites for comparisons of managements are grouped. For the Sutton and Hollesley heaths in the Suffolk Sandlings data for two survey dates are shown.

Aylesbeare Nature Reserve, Devon

Site: Aylesbeare A_1 (Mire). Management: Burnt 1992 + Grazed since 1990
Comments: Heavily grazed. Very churned up. Bare muddy areas with standing water between tussocks of *Molinia* and *Juncus*. *Molinia* grazed and herbs growing on the grazed tussocks and in the gaps.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+	*Sphagnum auriculatum*	+		
Erica tetralix	4%				
Molinia caerulea	64%				
Ulex gallii	2%				
Juncus acutiflorus	6%				
Juncus bulbosus	1%				
Cirsium dissectum	1%				
Potentilla erecta	+				
Carex panicea	+				
Narthecium ossifragum	+				
Myrica gale	+				
Pinguicula lusitanica	+				
Drosera rotundifolia	+				
Salix repens	+				
Viola pumila	+				
Mentha sylvatica	+				
Total	80%	Total	+	Bare ground	20%
Height	20cm	Height	2cm	Peat depth	8cm

Site: Aylesbeare A_2 (Mire). Management: Burnt 1993 + Grazed since 1990
Comments: Heavily grazed. Churned up. Bare muddy areas with standing water between tussocks of *Molinia* and *Juncus*. *Molinia* grazed and herbs growing on the grazed tussocks and in the gaps.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+	*Sphagnum auriculatum*	+		
Erica tetralix	2%				
Molinia caerulea	58%				
Ulex gallii	1%				
Juncus acutiflorus	+				
Juncus bulbosus	+				
Potentilla erecta	+				
Carex panicea	+				
Pinguicula lusitanica	+				
Potomageton spp	+				
Total	63%	Total	+	Bare ground	36%
Height	25cm	Height	2cm	Peat depth	8cm

Site: Aylesbeare A_3 (Mire). Management: Initial heavy grazing + grazed since 1990
Comments: Only lightly grazed and little disturbance. Tussocks of *Molinia* and *Juncus* tall with standing dead material.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+	*Sphagnum auriculatum*	+		
Erica tetralix	1%				
Molinia caerulea	75%				
Ulex gallii	2%				
Juncus acutiflorus	4%				
Juncus bulbosus	+				
Cirsium dissectum	+				
Potentilla erecta	+				
Viola pumila	+				
Mentha sylvatica	+				
Equisetum palustre	+				
Rubus fruticosus	+				
Total	82%	Total	+	Bare ground	16%
Height	40cm	Height	2cm	Peat depth	9cm

Site: Aylesbeare A_4 (Mire). Management: Grazed since 1990
Comments: Only lightly grazed and little disturbance. Closed vegetation. Tussocks of *Molinia* and *Juncus* tall with standing dead material. Tall dwarf shrubs

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Erica tetralix	7%				
Molinia caerulea	73%				
Ulex gallii	14%				
Juncus acutiflorus	4%				
Cirsium dissectum	+				
Potentilla erecta	+				
Salix repens	+				
Total	94%	Total	0%	Bare ground	2%
Height	56cm	Height	--	Peat depth	8cm

****

Site: Aylesbeare B_1 (Wet heath). Management: Burnt 1994 + Grazed since 1994
Comments: Heavily grazed with tussocks of *Molinia* broken up. Much dead *Sphagnum* spp.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Erica tetralix	3%				
Molinia caerulea	67%				
Ulex gallii	2%				
Juncus acutiflorus	+				
Juncus bulbosus	+				
Potentilla erecta	+				
Agrostis curtisii	+				
Total	73%	Total	0%	Bare ground	43%
Height	8cm	Height	--	Litter depth	2cm

Site: Aylesbeare B_2 (Wet heath). Management: Grazed since 1994
Comments: Lightly grazed. Closed vegetation with tall tussocks of *Molinia* mixed with mature/degenerate dwarf shrubs.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	20%	*Hypnum cupressiforme*	1%		
Erica tetralix	27%				
Molinia caerulea	46%				
Ulex gallii	6%				
Erica cinerea	+				
Total	99%	Total	1%	Bare ground	2%
Height	43cm	Height	0.5cm	Litter depth	7cm

****

Site: Aylesbeare C_1 (Humid heath). Management: Mown 1990 + grazed since 1990
Comments: Heavily grazed. Young and vigorous grass and shrubs. Small dwarf shrubs (20cm diameter)

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	20%	*Hypnum cupressiforme*	5%		
Erica tetralix	18%	*Cladonia impexa*	1%		
Molinia caerulea	19%				
Ulex gallii	13%				
Agrostis curtisii	16%				
Total	86%	Total	6%	Bare ground	12%
Height	23cm	Height	1cm	Litter depth	0cm

Site: Aylesbeare C_2 (Humid heath). Management: Grazed since 1990
Comments: Very lightly grazed. Closed vegetation with tall tussocks of *Molinia* and tall mature/degenerate dwarf shrubs.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	61%	*Hypnum cupressiforme*	+		
Erica tetralix	2%				
Molinia caerulea	13%				
Ulex gallii	18%				
Erica cinerea	1%				
Agrostis curtisii	+				
Quercus robur	+				
Total	95%	Total	+	Bare ground	1%
Height	44cm	Height	1cm	Litter depth	2cm

****

Site: Aylesbeare D_1 (Mire). Management: Mown 1994 + grazed since 1990
Comments: Heavily grazed with bare areas. Tussocks of *Molinia* grazed and small (25cm diameter).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+	*Hypnum cupressiforme*	+		
Erica tetralix	+				
Molinia caerulea	56%				
Ulex gallii	5%				
Potentilla erecta	+				
Salix repens	+				
Betula pubescens	+				
Total	61%	Total	+	Bare ground	39%
Height	9cm	Height	0.5cm	Litter depth	1cm

Site: Aylesbeare D_2 (Mire). Management: Grazed since 1990
Comments: Lightly grazed. Tall, mature dwarf shrubs and tall *Molinia* tussocks (35cm diameter).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	13%				
Erica tetralix	13%				
Molinia caerulea	55%				
Ulex gallii	18%				
Cirsium dissectum	1%				
Juncus acutiflorus	+				
Total	100%	Total	0%	Bare ground	0%
Height	51cm	Height	--	Litter depth	6cm

****

Site: Aylesbeare E_1 (Dry heath). Management: Bracken control - scraped 1989 + sprayed 1991, 1993
Comments: Closed and tall vegetation. Large *Molinia* and *Agrostis* tussocks. Small bushes of dwarf shrubs. Small amount of short bracken.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	3%				
Erica cinerea	4%				
Molinia caerulea	60%				
Ulex gallii	4%				
Agrostis curtisii	25%				
Pteridium aquilinum	+				
Rubus fruticosus	+				
Betula pubescens	+				
Total	99%	Total	0%	Bare ground	1%
Height	45cm	Height	--	Litter depth	0.5cm

Site: Aylesbeare E_2 (Dry heath). Management: Bracken control scraped 1991 + sprayed 1991, 1993
Comments: Fairly open and short vegetation. Small plants and grass tussocks. Fairly mossy. Some short bracken.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	2%	*Hypnum cupressiforme*	22%		
Erica cinerea	11%				
Molinia caerulea	34%				
Ulex gallii	3%				
Agrostis curtisii	25%				
Pteridium aquilinum	+				
Carex panicea	1%				
Total	77%	Total	22%	Bare ground	1%
Height	23cm	Height	0.5cm	Litter depth	0cm

Site: Aylesbeare E_3 (Dry heath). Management: Bracken control scraped 1992 + sprayed 1993
Comments: Very bare. Small *Agrostis* tussocks and small dwarf shrubs. Many seedlings.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+	*Dicranum scoparium*	3%		
Erica cinerea	18%				
Erica tetralix	3%				
Molinia caerulea	1%				
Ulex gallii	1%				
Agrostis curtisii	17%				
Pteridium aquilinum	+				
Carex panicea	+				
Potentilla erecta	+				
Total	40%	Total	3%	Bare ground	56%
Height	8cm	Height	0.5cm	Litter depth	0cm

Site: Aylesbeare E_4 (Dry heath). Management: Uncontrolled bracken
Comments: Tall bracken with deep litter. Little other vegetation

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	100%	*Molinia caerulea*	5%				
		Agrostis curtisii	+				
Total	100%	Total	5%	Total	0%	Bare ground	95%
Height	110cm	Height	30cm	Height	--	Litter depth	5cm

****

Site: Aylesbeare F_1 (Dry heath). Management: Burnt 1989
Comments: Closed but short vegetation. Dwarf shrubs medium sized (30cm - 40cm diameter) and *Agrostis* tussocks large (40cm - 50cm diameter).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+				
Erica cinerea	33%				
Agrostis curtisii	41%				
Ulex gallii	23%				
Pteridium aquilinum	+				
Total	97%	Total	0%	Bare ground	4%
Height	30cm	Height	--	Litter depth	0.5cm

Site: Aylesbeare F_2 (Dry heath). Management: Scraped 1991
Comments: Short, fairly closed vegetation. Seedling dwarf shrubs and small *Agrostis* tussocks large (10cm - 20cm diameter).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+				
Erica cinerea	20%				
Agrostis curtisii	59%				
Ulex gallii	4%				
Carex panicea	+				
Total	83%	Total	0%	Bare ground	20%
Height	30cm	Height	--	Litter depth	0cm

Site: Aylesbeare F_3 (Dry heath). Management: Unmanaged
Comments: Tall, closed vegetation. Dwarf shrubs large and mature/degenerate. Large bushes (50cm - 60cm diameter).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	22%	*Hypnum cupressiforme*	+		
Erica cinerea	47%				
Agrostis curtisii	+				
Ulex gallii	27%				
Total	96%	Total	+	Bare ground	4%
Height	60cm	Height	2cm	Litter depth	0.5cm

Arne Nature Reserve, Dorset

Site: Arne A_1 (Dry heath). Management: Pine clearance + litter scrape 1991
Comments: Much bare ground. Patchy cover by small, young dwarf shrubs. Dwarf shrubs small (10cm - 40cm diameter). Much grass and bryophytes. Occasional bracken.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	3%	*Calluna vulgaris*	28%	*Polytrichum juniperinum*	36%		
		Erica cinerea	21%	*Hypnum cupressiforme*	+		
		Agrostis capillaris	3%				
		Rumex acetosella	2%				
		Carex panicea	+				
		Betula pubescens	+				
Total	3%	Total	54%	Total	36%	Bare ground	21%
Height	30cm	Height	6cm	Height	1cm	Litter depth	0.6cm

Site: Arne A_2 (Dry heath). Management: Unmanaged old heath
Comments: Closed dwarf shrub cover. Scattered *Pinus* seedlings, saplings and trees.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	80%	*Cladonia impexa*	+		
Erica cinerea	16%	*Hypnum cupressiforme*	79%		
Erica tetralix	+				
Ulex minor	+				
Pinus sylvestris	+				
Quercus robur	+				
Total	97%	Total	79%	Bare ground	0%
Height	45cm	Height	3cm	Litter depth	5cm

****

Site: Arne B_1 (Dry heath). Management: Mown 1976 & 1991
Comments: Fairly open. Dwarf shrubs large (0.5m - 1m diameter) and growing vigorously.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	60%	*Cladonia impexa*	57%		
Erica cinerea	8%	*Hypnum cupressiforme*	9%		
		Dicranum scoparium	+		
Total	68%	Total	66%	Bare ground	6%
Height	18cm	Height	2cm	Litter depth	3cm

Site: Arne B_2 (Dry heath). Management: Mown 1991
Comments: Much bare ground. Patchy cover by dwarf shrubs. Dwarf shrubs large (40cm - 60cm diameter) and growing vigorously.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	28%	*Cladonia impexa*	8%		
Erica cinerea	27%	*Hypnum cupressiforme*	5%		
		Campylopus introflexus	1%		
		Dicranum scoparium	+		
Total	55%	Total	14%	Bare ground	37%
Height	18cm	Height	1cm	Litter depth	2cm

Site: Arne B_3 (Dry heath). Management: Mown 1976
Comments: Closed dwarf shrubs. Dwarf shrubs mature/degenerate. Scattered *Pinus* (2 ha^{-1})

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	76%	*Cladonia impexa*	79%		
Erica cinerea	1%	*Hypnum cupressiforme*	5%		
		Dicranum scoparium	3%		
Total	77%	Total	87%	Bare ground	+
Height	35cm	Height	6cm	Litter depth	4cm

Site: Arne B_4 (Dry heath). Management: Unmown.
Comments: Closed dwarf shrub vegetation. Tall mature bushes with some degenerate or dead. Scattered *Pinus* (0.01 ha^{-1}).

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pinus sylvestris	+	*Calluna vulgaris*	55%	*Cladonia impexa*	1%		
		Erica cinerea	34%	*Hypnum cupressiforme*	17%		
		Erica tetralix	+	*Dicranum scoparium*	+		
		Ulex minor	+	*Hypnogymnia physodes*	+		
Total	+	Total	93%	Total	18%	Bare ground	2%
Height	100cm	Height	34cm	Height	2cm	Litter depth	3cm

****

Site: Arne C_1 (Dry/Humid heath). Management: Mown 1989
Comments: Fairly open and mossy. Dwarf shrubs large (40cm - 60cm diameter) and growing vigorously.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	21%	*Cladonia impexa*	31%		
Erica cinerea	18%	*Hypnum cupressiforme*	20%		
Erica tetralix	34%				
Ulex minor	1%				
Agrostis curtisii	+				
Total	75%	Total	51%	Bare ground	5%
Height	26cm	Height	2cm	Litter depth	2cm

Site: Arne C_2 (Dry/Humid heath). Management: Unmanaged
Comments: Closed dwarf shrubs. Dwarf shrubs mature/degenerate, some dead. Scattered *Pinus* (2 ha^{-1}) and occasional *Ulex europaeus*.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	52%	*Cladonia impexa*	20%		
Erica cinerea	24%	*Hypnum cupressiforme*	1%		
Erica tetralix	21%				
Ulex minor	1%				
Pinus sylvestris	+				
Total	98%	Total	21%	Bare ground	1%
Height	40cm	Height	3cm	Litter depth	6cm

****

Site: Arne D_1 (Dry heath). Management: Burnt 1989
Comments: Vigorous growth of young dwarf shrubs (25cm diameter) and *Agrostis curtisii* and seedlings. Open, mossy areas.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	9%	*Cladonia impexa*	+		
Erica cinerea	13%	*Campylopus introflexus*	53%		
Ulex minor	12%				
Agrostis curtisii	2%				
Holcus lanatus	+				
Pteridium aquilinum	+				
Total	37%	Total	53%	Bare ground	10%
Height	11cm	Height	0.1cm	Litter depth	4cm

Site: Arne D_2 (Dry heath). Management: Unmanaged
Comments: Closed dwarf shrubs, mature/degenerate with some dead bushes. Occasional *Pinus* (2 ha^{-1}) and very occasional bracken.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	47%	*Cladonia impexa*	1%		
Erica cinerea	37%	*Hypnum cupressiforme*	2%		
Ulex minor	2%	*Dicranum scoparium*	+		
Betula pubescens	+	*Campylopus introflexus*	+		
Total	86%	Total	4%	Bare ground	13%
Height	30cm	Height	3cm	Litter depth	3cm

****

Site: Arne E_1 (Humid heath). Management: Burnt 1990
Comments: Very bare and mossy. Small vigorous dwarf shrubs (25cm diameter) and seedlings.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	10%	*Campylopus introflexus*	77%		
Erica cinerea	+				
Erica tetralix	10%				
Ulex minor	2%				
Agrostis curtisii	+				
Holcus lanatus	+				
Total	22%	Total	77%	Bare ground	0%
Height	12cm	Height	0.6cm	Litter depth	4cm

Site: Arne E_2 (Humid heath). Management: Unmanaged
Comments: Closed dwarf shrubs growing vigorously. Scattered *Molinia caerulea*.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	20%	*Campylopus introflexus*	5%		
Erica tetralix	61%	*Cladonia impexa*	27%		
Molinia caerulea	9%				
Total	90%	Total	32%	Bare ground	1%
Height	29cm	Height	3cm	Litter depth	5cm

New Forest, Hampshire
All open to grazing by free-ranging ponies and cattle

Site: New Forest A_1 (Dry/Humid heath). Management: Mown 1991+ grazing
Comments: Heavy grazing. Short, closed vegetation. Vigorous growth.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	45%	*Hypnum cupressiforme*	15%		
Erica tetralix	13%	*Leucobryum glaucum*	12%		
Molinia caerulea	16%	*Polytrichum juniperinum*	2%		
Carex panicea	+	*Cladonia impexa*	+		
Pinus sylvestris	+	*Cladonia spp*	+		
Total	79%	Total	29%	Bare ground	6%
Height	15cm	Height	2cm	Litter depth	3cm

Site: New Forest A_2 (Dry/Humid heath). Management: Heavy grazing
Comments: Very heavy grazing. Very short, closed, vigorous vegetation. Mosaic of acid grassland and heath.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	49%	*Hypnum cupressiforme*	18%		
Erica tetralix	+	*Rhytidiadelphus squarrosus*	3%		
Erica cinerea	+	*Dicranum scoparium*	3%		
Carex panicea	8%				
Molinia caerulea	9%				
Agrostis curtisii	7%				
Agrostis capillaris	7%				
Agrostis stolonifera	6%				
Potentilla erecta	3%				
Hieracium pilosella	3%				
Galium saxatile	2%				
Betula pubescens	+				
Total	94%	Total	24%	Bare ground	2%
Height	11cm	Height	0.1cm	Litter depth	1cm

Site: New Forest A_3 (Dry/Humid heath). Management: Light grazing
Comments: Very lightly grazed. Tall dwarf shrubs interspersed with more heavily grazed patches. Dwarf shrubs mature/degenerate. A few birch saplings.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Ulex europaeus	14%	*Calluna vulgaris*	45%	*Hypnum cupressiforme*	26%		
		Erica tetralix	3%	*Rhytidiadelphus squarrosus*	+		
		Agrostis curtisii	3%	*Leucobryum glaucum*	+		
		Molinia caerulea	32%				
		Ulex europaeus	3%				
		Agrostis stolonifera	+				
		Polygala serpyllifolia	+				
		Pinus sylvestris	+				
Total	14%	Total	90%	Total	26%	Bare ground	4%
Height	125cm	Height	54cm	Height	0.5cm	Litter depth	3cm

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Site: New Forest B_1 (Dry/Humid heath). Management: Burnt 1990 + grazing
Comments: Heavily grazed. Fairly open, very short vegetation in a small grain mosaic of heath and grassland.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	48%	*Campylopus introflexus*	25%		
Erica tetralix	1%	*Hypnum cupressiforme*	4%		
Erica cinerea	+	*Dicranum scoparium*	+		
Molinia caerulea	23%	*Leucobryum glaucum*	+		
Carex panicea	+				
Poa annua	+				
Polygala serpyllifolia	+				
Rumex acetosella	+				
Potentilla erecta	+				
Festuca rubra	+				
Total	76%	Total	30%	Bare ground	9%
Height	8cm	Height	0.6cm	Litter depth	1cm

Site: New Forest B_2 (Dry/Humid heath). Management: Grazing
Comments: Lightly grazed. Tall, mature, vigorous dwarf shrubs with patches of *Ulex europaeus*. Scattered *Pinus* and *Rhododendron*.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	59%	*Cladonia impexa*	3%		
Erica tetralix	12%	*Hypnum cupressiforme*	33%		
Erica cinerea	+	*Dicranum scoparium*	1%		
Molinia caerulea	13%	*Leucobryum glaucum*	2%		
Ulex europaeus	+	*Cladonia spp*	+		
Pinus sylvestris	+				
Quercus robur	+				
Total	70%	Total	40%	Bare ground	8%
Height	35cm	Height	2cm	Litter depth	2cm

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Site: New Forest C_1 (Wet heath). Management: Burnt 1993 + grazing
Comments: Heavily grazed, short vegetation. Open and very grassy.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	2%	*Sphagnum compactum*	55%		
Erica tetralix	33%				
Molinia caerulea	24%				
Narthecium ossifragum	1%				
Carex panicea	+				
Scirpus caespitosus	+				
Drosera intermedia	+				
Polygala serpyllifolia	+				
Eriophorum angustifolium	+				
Total	61%	Total	55%	Bare ground	14%
Height	7cm	Height	2cm	Litter depth	2cm

Site: New Forest C_2 (Wet heath). Management: Grazing
Comments: Lightly grazed, closed vegetation. Large, mature dwarf shrubs

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	36%	*Cladonia impexa*	+		
Erica tetralix	21%	*Hypnum cupressiforme*	2%		
Molinia caerulea	33%	*Sphagnum cuspidatum*	+		
Scirpus caespitosus	+	*Leucobryum glaucum*	8%		
Ulex europaeus	+				
Total	90%	Total	12%	Bare ground	6%
Height	35cm	Height	2cm	Litter depth	2cm

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Site: New Forest D_1 (Dry heath). Management: Bracken control - cut 1992
Comments: Fairly dense and tall bracken. Understorey of grasses and a few dwarf shrubs. Thick litter.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	66%	*Calluna vulgaris*	5%	*Dicranum scoparium*	+		
		Erica cinerea	2%	*Polytrichum juniperinum*	+		
		Rubus fruticosus	6%				
		Rumex acetosella	14%				
		Agrostis capillaris	33%				
		Carex panicea	1%				
		Holcus lanatus	3%				
		Galium saxatile	1%				
		Lonicera periclymenum	1%				
		Ulex europaeus	+				
		Teucrium scorodonia	+				
		Frangula alnus	+				
Total	66%	Total	69%	Total	+	Bare ground	32%
Height	90cm	Height	8cm	Height	0.5cm	Litter depth	3cm

Site: New Forest D_2 (Dry heath). Management: Uncontrolled bracken
Comments: Dense and tall bracken. Very sparse understorey. Thick litter

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	95%	*Calluna vulgaris*	+	*Polytrichum juniperinum*	+		
		Lonicera periclymenum	2%				
		Rubus fruticosus	4%				
		Rumex acetosella	2%				
		Agrostis capillaris	20%				
Total	95%	Total	28%	Total	+	Bare ground	62%
Height	100cm	Height	10cm	Height	0.5cm	Litter depth	3cm

Site: New Forest E_1 (Dry/Humid heath). Management: Bracken control 1992 + 1993 - cut
Comments: Patchy bracken with understorey of grasses and dwarf shrubs. No litter.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	50%	*Calluna vulgaris*	13%	*Campylopus introflexus*	+		
		Erica tetralix	+				
		Potentilla erecta	20%				
		Hieracium pilosella	5%				
		Agrostis capillaris	24%				
		Carex panicea	5%				
		Molinia caerulea	15%				
		Galium saxatile	+				
		Leontodon taraxacoides	+				
		Ulex europaeus	+				
		Teucrium scorodonia	+				
		Polygala serpyllifolia	+				
		Rubus fruticosus	+				
		Prunella vulgaris	+				
		Euphrasia nemorosa	+				
		Medicago lupulina	+				
		Lotus corniculatus	+				
		Bellis perennis	+				
		Hypericum pulchrum	+				
		Taraxacum officinale	+				
		Rosa spp	+				
Total	50%	Total	90%	Total	+	Bare ground	12%
Height	54cm	Height	6cm	Height	1cm	Litter depth	0cm

Site: New Forest E_2 (Dry/Humid heath). Management: Uncontrolled bracken
Comments: Dense and tall bracken. Sparse understorey. Thick litter

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	95%	*Calluna vulgaris*	+				
		Lonicera periclymenum	2%				
		Rubus fruticosus	5%				
		Molinia caerulea	9%				
		Agrostis capillaris	10%				
		Polygala serpyllifolia	+				
		Teucrium scorodonia	+				
Total	95%	Total	26%	Total	0%	Bare ground	67%
Height	90cm	Height	11cm	Height	--	Litter depth	3cm

Thursley Common Nature Reserve, Surrey

Site: Thursley A_1 (Dry heath). Management: Burnt 1976 + 1993
Comments: Vigorous growth of young and small (10cm - 20cm diameter) dwarf shrubs including seedlings. Bare, mossy patches. Scattered *Pinus* and *Betula* (5 ha^{-1}).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	42%	*Campylopus introflexus*	2%		
Erica cinerea	15%	*Hypnogymnia physodes*	10%		
Ulex minor	1%				
Rumex acetosella	+				
Total	58%	Total	12%	Bare ground	32%
Height	19cm	Height	0.1cm	Litter depth	1cm

Site: Thursley A_2 (Dry heath). Management: Burnt 1976 + Mown (swathes) since 1988
Recently mown (short) swathes
Comments: Short, vigorous dwarf shrubs. Fairly closed canopy.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	77%	*Campylopus introflexus*	2%		
		Hypnogymnia physodes	1%		
		Cladonia impexa	40%		
		Cladonia spp	21%		
Total	77%	Total	64%	Bare ground	2%
Height	19cm	Height	0.3cm	Litter depth	0.1cm

Site: Thursley A_2 (Dry heath). Management: Burnt 1976 + Mown (swathes) since 1988
Recently unmown (tall) swathes
Comments: Tall, mature dwarf shrubs growing vigorously. Fairly closed canopy.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	89%	*Campylopus introflexus*	2%		
Erica cinerea	+	*Hypnogymnia physodes*	1%		
Pinus sylvestris	+	*Cladonia impexa*	18%		
Betula pubescens	+	*Cladonia spp*	15%		
		Hypnum cupressiforme	+		
Total	89%	Total	36%	Bare ground	17%
Height	48cm	Height	0.3cm	Litter depth	1cm

Site: Thursley A_3 (Dry heath). Management: Burnt 1976
Comments: Tall, mature dwarf shrubs, some degenerate or dead. Open patches. Scattered bracken and some *Betula* (20 ha^{-1}) and *Pinus* (5 ha^{-1}).

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Betula pubescens	+	*Calluna vulgaris*	84%	*Campylopus introflexus*	3%		
		Ulex minor	6%	*Polytrichum juniperinum*	20%		
		Pteridium aquilinum	+	*Cladonia impexa*	26%		
		Betula pubescens	+	*Cladonia spp*	1%		
				Hypnum cupressiforme	17%		
Total	+	Total	90%	Total	67%	Bare ground	22%
Height	140cm	Height	73cm	Height	0.7cm	Litter depth	2cm

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Site: Thursley B_1 (Dry heath). Management: Pine clearance 1991 + litter scrape 1992
Comments: Bare with some moss cover and few young, small dwarf shrubs (10cm - 20cm diameter).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	18%	*Campylopus introflexus*	30%		
Erica cinerea	11%	*Polytrichum juniperinum*	6%		
Agrostis curtisii	9%	*Hypnum cupressiforme*	1%		
Molinia caerulea	1%				
Ulex minor	+				
Total	39%	Total	37%	Bare ground	33%
Height	18cm	Height	0.5cm	Litter depth	0cm

Site: Thursley B_2 (Dry heath). Management: Unmanaged heath
Comments: Tall, mature/degenerate dwarf shrubs, some dead. Scattered *Pinus* and *Betula* (3 ha^{-1})

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	88%	*Campylopus introflexus*	3%		
Erica cinerea	1%	*Cladonia impexa*	14%		
Agrostis curtisii	9%	*Hypnum cupressiforme*	50%		
Ulex minor	1%	*Hypnogymnia physodes*	6%		
Pinus sylvestris	+				
Quercus robur	+				
Total	90%	Total	73%	Bare ground	7%
Height	68cm	Height	1cm	Litter depth	1cm

Site: Thursley B_3 (Dry heath). Management: Pine plantation
Comments: Dense *Pinus* and some *Betula* trees. Understorey very bare with deep litter. Few, small patches of dwarf shrubs and moss.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pinus sylvestris	95%	*Calluna vulgaris*	+	*Hypnum cupressiforme*	54%		
Betula pubescens	+	*Erica cinerea*	4%				
		Agrostis curtisii	1%				
Total	95%	Total	5%	Total	54%	Bare ground	35%
Height	>5m	Height	10cm	Height	3cm	Litter depth	8cm

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Site: Thursley C_1 (Wet heath). Management: Pine clearance + litter scrape 1993
Comments: Dense, short vegetation. small dwarf shrubs (1cm diameter). Little litter.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	36%	*Polytrichum juniperinum*	21%		
Erica cinerea	14%				
Scirpus caespitosus	6%				
Ulex minor	1%				
Juncus conglomeratus	7%				
Betula pubescens	+				
Total	64%	Total	21%	Bare ground	17%
Height	16cm	Height	1cm	Litter depth	0cm

Site: Thursley C_2 (Wet heath). Management: Pine clearance 1993
Comments: Very open with deep litter. Small *Agrostis* tussocks (10cm diameter) and dwarf shrubs (5cm - 10cm diameter).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+	*Hypnum cupressiforme*	3%		
Erica cinerea	2%				
Agrostis curtisii	6%				
Betula pubescens	1%				
Urtica dioica	+				
Agrostis capillaris	+				
Rumex acetosella	+				
Taraxacum officinale	+				
Galium saxatile	+				
Total	11%	Total	3%	Bare ground	86%
Height	13cm	Height	1cm	Litter depth	7cm

Site: Thursley C_3 (Wet heath). Management: Pine plantation
Comments: Dense Pine. Understorey very bare with deep litter. No dwarf shrubs.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pinus sylvestris	98%			*Hypnum cupressiforme*	29%		
				Polytrichum cupressiforme	13%		
Total	98%	Total	0%	Total	42%	Bare ground	57%
Height	>5m	Height	--	Height	1cm	Litter depth	8cm

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Site: Thursley D_1 (Dry heath). Management: Bracken control - cut + chisel plough 1992
Comments: Fairly closed, short vegetation. Patches of bracken and small *Agrostis* tussocks (10cm - 20cm diameter).

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	20%	*Calluna vulgaris*	4%	*Polytrichum juniperinum*	3%		
		Agrostis curtisii	70%				
		Rumex acetosella	+				
		Erica cinerea	+				
		Molinia caerulea	+				
Total	20%	Total	74%	Total	3%	Bare ground	24%
Height	63cm	Height	9cm	Height	1cm	Litter depth	0cm

Site: Thursley D_2 (Dry heath). Management: Bracken control - cut + rotovate 1992
Comments: Similar to D_1 but soil more disturbed.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	13%	*Calluna vulgaris*	+	*Polytrichum juniperinum*	3%		
		Agrostis curtisii	63%				
		Rumex acetosella	24%				
		Rubus fruticosus	+				
		Molinia caerulea	+				
Total	13%	Total	87%	Total	3%	Bare ground	10%
Height	56cm	Height	8cm	Height	1cm	Litter depth	0cm

Site: Thursley D_3 (Dry heath). Management: Uncontrolled bracken
Comments: Tall, dense bracken with *Agrostis* understorey

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	79%	*Calluna vulgaris*	+				
		Agrostis curtisii	71%				
		Rumex acetosella	+				
		Rubus fruticosus	+	.			
Total	79%	Total	71%	Total	0%	Bare ground	18%
Height	82cm	Height	9cm	Height	--	Litter depth	3cm

Ashdown Forest, East Sussex

Site: Ashdown A_1 (Humid heath). Management: Grazing since 1989
Comments: Medium height, closed vegetation with intermixed *Molinia* and dwarf shrubs. Large bracken patches.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	33%	*Campylopus introflexus*	3%		
Erica tetralix	18%	*Hypnogymnia physodes*	+		
Ulex minor	8%	*Sphagnum auriculatum*	+		
Molinia caerulea	38%				
Pinus sylvestris	+				
Total	97%	Total	3%	Bare ground	2%
Height	32cm	Height	0.5cm	Litter depth	0.5cm

Site: Ashdown A_2 (Humid heath). Management: Unmanaged
Comments: Tall, mature/degenerate dwarf shrubs (60cm - 70cm diameter). Closed vegetation. Large bracken patches.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	48%	*Sphagnum auriculatum*	1%		
Erica tetralix	17%				
Ulex minor	2%				
Molinia caerulea	30%				
Narthecium ossifragum	+				
Ulex europaeus	+				
Total	97%	Total	1%	Bare ground	3%
Height	62cm	Height	1cm	Litter depth	4cm

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Site: Ashdown B_1 (Humid heath). Management: Mown 1992 + burnt 1994
Comments: Very bare with mostly small *Molinia* plants established from seed.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+				
Erica tetralix	2%				
Molinia caerulea	34%				
Total	36%	Total	0%	Bare ground	64%
Height	12cm	Height	--	Litter depth	2cm

Site: Ashdown B_2 (Humid heath). Management: Burnt 1994
Comments: Bare with regenerating dwarf shrubs (10cm - 20cm diameter). Small *Molinia* plants.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	35%				
Erica tetralix	2%				
Molinia caerulea	19%				
Total	56%	Total	0%	Bare ground	44%
Height	16cm	Height	--	Litter depth	2cm

Site: Ashdown B_3 (Humid heath). Management: Mown 1992
Comments: Fairly bare with small dwarf shrubs (20cm - 30cm diameter). Small *Molinia* plants (5cm - 10cm).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	16%				
Erica tetralix	17%				
Molinia caerulea	29%				
Ulex minor	+				
Total	62%	Total	0%	Bare ground	38%
Height	18cm	Height	--	Litter depth	3cm

Site: Ashdown B_4 (Humid heath). Management: Unmanaged
Comments: Tall, closed mature dwarf shrubs.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	88%				
Erica tetralix	7%				
Molinia caerulea	2%				
Total	97%	Total	0%	Bare ground	29%
Height	72cm	Height	--	Litter depth	3cm

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Site: Ashdown C_1 (Humid heath). Management: Mown 1982
Comments: Tall, closed mature dwarf shrubs (30cm - 50cm diameter). Vigorous growth.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	50%	*Cladonia impexa*	1%		
Erica cinerea	4%	*Cladonia spp*	2%		
Erica tetralix	23%				
Molinia caerulea	9%				
Total	86%	Total	3%	Bare ground	15%
Height	32cm	Height	1cm	Litter depth	2cm

Site: Ashdown C_2 (Humid heath). Management: Unmanaged
Comments: Tall, closed mature/degenerate dwarf shrubs (30cm - 50cm diameter).

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	89%	*Cladonia impexa*	+		
Erica tetralix	2%	*Hypnogymnia physodes*	+		
Molinia caerulea	+				
Total	91%	Total	+	Bare ground	41%
Height	74cm	Height	1cm	Litter depth	3cm

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Site: Ashdown D_1 (Dry heath). Management: Mown 1992
Comments: Short, vigorous dwarf shrubs. Some seedlings

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	77%	*Cladonia impexa*	+		
Erica tetralix	1%	*Cladonia spp*	+		
		Campylopus introflexus	+		
		Hypnum cupressiforme	+		
		Hypnogymnia physodes	+		
Total	78%	Total	+	Bare ground	21%
Height	23cm	Height	1cm	Litter depth	2cm

Site: Ashdown D_2 (Dry heath). Management: Unmanaged
Comments: Tall, closed mature dwarf shrubs. Vigorous growth.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	92%	*Cladonia spp*	+		
Erica tetralix	+	*Hypnum cupressiforme*	+		
Erica cinerea	+	*Hypnogymnia physodes*	+		
Molinia caerulea	+				
Total	92%	Total	+	Bare ground	28%
Height	74cm	Height	1cm	Litter depth	2cm

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Site: Ashdown E_1 (Dry heath). Management: Bracken control - cut, scrape, plough, heath mowings 1993 + cut every year subsequently
Comments: Bare but some bracken regeneration. Small plants and seedlings of various species

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	28%	*Calluna vulgaris*	1%				
		Carex panicea	1%				
		Molinia caerulea	17%				
		Ulex europaeus	1%				
		Agrostis curtisii	+				
		Galium saxatile	+				
		Potentilla erecta	+				
		Betula pubescens	+				
		Teucrium scorodonia	+				
		Rubus fruticosus	+				
Total	28%	Total	21%	Total	0%	Bare ground	73%
Height	32cm	Height	7cm	Height	--	Litter depth	0cm

Site: Ashdown E_2 (Dry heath). Management: Uncontrolled bracken
Comments: Tall, dense bracken with large *Molinia* tussocks.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	94%	*Molinia caerulea*	17%				
		Ulex europaeus	1%				
		Betula pubescens	+				
		Teucrium scorodonia	+				
		Alnus glutinosa	+				
Total	94%	Total	37%	Total	0%	Bare ground	57%
Height	102cm	Height	34cm	Height	--	Litter depth	9cm

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Site: Ashdown F_1 (Dry heath). Management: Bracken control - cut, scrape, plough, heath mowings 1991 + cut every year subsequently
Comments: Short, closed vegetation. Small dwarf shrubs (10cm - 20cm) and many seedlings.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	1%	*Calluna vulgaris*	24%	*Polytrichum juniperinum*	2%		
		Erica cinerea	4%				
		Agrostis curtisii	26%				
		Carex panicea	10%				
		Agrostis capillaris	23%				
		Galium saxatile	+				
		Potentilla erecta	+				
		Molinia caerulea	+				
		Ulex europaeus	+				
		Rubus fruticosus	+				
		Rumex acetosella	+				
Total	1%	Total	87%	Total	2%	Bare ground	10%
Height	19cm	Height	10cm	Height	0.5cm	Litter depth	0cm

Site: Ashdown F_2 (Dry heath). Management: Uncontrolled bracken
Comments: Tall, dense bracken with a sparse understorey.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	100%	*Agrostis curtisii*	1%				
		Molinia caerulea	5%				
Total	100%	Total	6%	Total	0%	Bare ground	90%
Height	120cm	Height	10cm	Height	--	Litter depth	6cm

****

Site: Ashdown G_1 (Dry heath). Management: Bracken control - cut, scrape, plough, heath mowings 1992 + cut every year subsequently
Comments: Short, closed vegetation. Some bracken cover. Small dwarf shrubs and many seedlings.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	13%	*Calluna vulgaris*	33%				
		Molinia caerulea	16%				
		Carex panicea	20%				
		Agrostis capillaris	1%				
		Juncus effusus	+				
		Agrostis curtisii	+				
		Rubus fruticosus	+				
		Ulex europaeus	+				
Total	13%	Total	70%	Total	0%	Bare ground	20%
Height	40cm	Height	16cm	Height	--	Litter depth	0cm

Site: Ashdown G_2 (Dry heath). Management: Uncontrolled bracken
Comments: Tall, dense bracken with a *Molinia* understorey.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	90%	*Molinia caerulea*	70%				
		Ulex europaeus	+				
		Rubus fruticosus	+				
Total	90%	Total	70%	Total	0%	Bare ground	30%
Height	80cm	Height	40cm	Height	--	Litter depth	10cm

****

Site: Ashdown H_1 (Dry heath). Management: Bracken control - cut, scrape, plough, heath mowings 1990 + cut every year subsequently
Comments: Short, fairly closed vegetation. Some bracken cover. Small dwarf shrubs (10cm - 20cm diameter) and many seedlings.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	19%	*Calluna vulgaris*	64%	*Campylopus introflexus*	2%		
		Molinia caerulea	8%	*Cladonia impexa*	+		
		Betula pubescens	2%	*Cladonia spp*	+		
		Agrostis curtisii	1%				
Total	19%	Total	76%	Total	2%	Bare ground	14%
Height	32cm	Height	10cm	Height	1cm	Litter depth	0.1cm

Site: Ashdown H_2 (Dry heath). Management: Bracken control - cut yearly since 1991
Comments: Closed vegetation. Some bracken and dense grass.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	12%	*Agrostis curtisii*	56%	*Campylopus introflexus*	+		
		Galium saxatile	2%				
		Betula pubescens	+				
		Ulex europaeus	+				
		Lonicera periclymenum	+				
		Teucrium scorodonia	+				
		Potentilla erecta	+				
		Rubus fruticosus	+				
Total	12%	Total	58%	Total	+	Bare ground	3%
Height	32cm	Height	19cm	Height	1cm	Litter depth	3cm

Site: Ashdown H_3 (Dry heath). Management: Uncontrolled bracken
Comments: Tall, dense bracken with a *Molinia* understorey.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	92%	*Calluna vulgaris*	+				
		Molinia caerulea	50%				
		Agrostis curtisii	4%				
		Betula pubescens	+				
		Lonicera periclymenum	+				
Total	92%	Total	54%	Total	0%	Bare ground	40%
Height	100cm	Height	24cm	Height	--	Litter depth	8cm

****

Site: Ashdown I_1 (Dry heath). Management: Bracken control - cut yearly since 1988
Comments: Closed vegetation. Bracken regeneration and much *Molinia*.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	14%	*Molinia caerulea*	51%				
		Agrostis curtisii	22%				
		Galium saxatile	12%				
		Agrostis capillaris	4%				
		Ulex europaeus	+				
		Epilobium hirsutum	+				
Total	14%	Total	89%	Total	0%	Bare ground	8%
Height	36cm	Height	23cm	Height	--	Litter depth	5cm

Site: Ashdown I_2 (Dry heath). Management: Uncontrolled bracken
Comments: Dense, tall bracken with grassy understorey.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	78%	*Molinia caerulea*	30%				
		Agrostis curtisii	60%				
		Rubus fruticosus	2%				
		Galium saxatile	+				
		Rumex acetosella	+				
		Ulex europaeus	+				
		Epilobium hirsutum	+				
Total	78%	Total	92%	Total	0%	Bare ground	0%
Height	90cm	Height	42cm	Height	--	Litter depth	8cm

Cavenham heath, Breckland

Site: Cavenham Heath HW Management: None
Comments: Mature heather in good condition, very light grazing by deer and rabbits.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Betula sp.	+	*Calluna vulgaris*	80%	*Cladonia sp.*	2%		
		Rumex acetosella	2%	*Polytrichum juniperinum*	2%		
Total	+	Total	82%	Total	4%	Bare ground	13%

Site: Cavenham Heath HE Management: None
Comments: Mature heather in good condition, very light grazing by deer and rabbits, some invasion by *Festuca ovina.*

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	45%	*Cladonia* sp.	9		
Festuca ovina	15%	*Dicranum scoparium*	2		
Galium saxatile	+	*Hypnum jutlandicum*	+		
Galium verum	+	*Polytrichum juniperinum*	+		
Rumex acetosella	10%				
Senecio sylvaticus	+				
Total	70%	Total	11%	Bare ground	7%

Site: Cavenham Heath C92 Management: Cut once in 1992
Comments: Light grazing by deer and rabbits, some invasion by *Festuca ovina.*

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Betula sp.	+	*Calluna vulgaris*	42%	*Cladonia sp.*	1%		
		Festuca ovina	17%	*Hypnum jutlandicum*	1%		
		Galium saxatile	+	*Pleurozium schreberi*	+		
		Rumex acetosella	9%	*Dicranum scoparium*	1%		
Total	+	Total	68%	Total	3%	Bare ground	11%

Site: Cavenham R77 Management: Rotovated once in 1977
Comments: Good cover of heather, very light grazing by deer and rabbits.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	82%	*Cladonia sp.*	+		
Rumex acetosella	7%	*Hypnum jutlandicum*	13%		
		Polytrichum juniperinum	8%		
Total	89%	Total	22%	Bare ground	3%

Site: Cavenham Heath R89 Management: Rotovated once in 1989
Comments: Very little heather regeneration, invasion by *Festuca ovina*. Treatment has controlled the previously dominant *Deschampsia flexuosa*.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Betula sp.	+	*Agrostis capillaris*	1%	*Cladonia sp.*	1%		
		Calluna vulgaris	1%	*Dicranum scoparium*	29%		
		Festuca ovina	40%	*Polytrichum juniperinum*	3%		
		Galium saxatile	1%				
		Holcus mollis	2%				
		Rumex acetosella	3%				
		Senecio sylvaticus	+				
Total	+	Total	48%	Total	33%	Bare ground	17%

Site: Cavenham Heath R92 Management: Rotovated twice, once in 1989 and once in 1992
Comments: Very little heather, invasion by *Festuca ovina*. Light grazing by deer and rabbits.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	2%	*Dicranum scoparium*	20%		
Festuca ovina	27%	*Hypnum jutlandicum*	+		
Galium saxatile	+	*Polytrichum juniperinum*	+		
Holcus mollis	10%				
Rumex acetosella	3%				
Senecio sylvaticus	+				
Total	42%	Total	20%	Bare ground	37%

Site: Cavenham Heath DF Management: None
Comments: Stand dominated by *Deschampsia flexuosa*, with little heather present. This stand has since been rotovated.Very little grazing.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	3%	*Cladonia sp.*	+		
Deschampsia flexuosa	80%	*Hypnum jutlandicum*	1%		
Festuca ovina	3%	*Pleurozium scheberi*	1%		
Galium saxatile	2%	*Polytrichum juniperinum*	2%		
Holcus mollis	1%				
Rumex acetosella	5%				
Total	94%	Total	4%	Bare ground	3%

Site: Cavenham Heath NED Management: Grazed by sheep and cattle.
Comments: Heavily grazed by livestock and particularly by rabbits. Heather in poor condition and invasion by *Festuca ovina*.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	3%	*Cladonia sp.*	1%		
Festuca ovina	23%	*Dicranum scoparium*	11%		
Rumex acetosella	1%	*Hypnum jutlandicum*	1%		
		Polytrichum juniperinum	1%		
Total	27%	Total	14%	Bare ground	42%

Site: Cavenham Heath NWD Management: Grazed by cattle and sheep.
Comments: Heavily grazed by livestock and rabbits. Heather is suppressed.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	42%	*Cladonia sp.*	+		
Festuca ovina	4%	*Dicranum scoparium*	5%		
Rumex acetosella	21%	*Hypnum jutlandicum*	+		
Total	67%	Total	5%	Bare ground	18%

Site: Cavenham Heath NDF Management: Grazed by sheep and cattle.
Comments: Heather has been replaced by *Deschampsia flexuosa* and *Festuca ovina*. Heavy grazing by livestock and rabbits.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Calluna vulgaris	+	*Cladonia sp.*	1%		
Deschampsia flexuosa	27%	*Dicranum scoparium*	12%		
Festuca ovina	28%	*Hypnum jutlandicum*	3%		
Poa pratensis	+	*Polytrichum juniperinum*	+		
Rumex acetosella	2%				
Total	57%	Total	16%	Bare ground	17%

Site: Cavenham Heath - Ropers Heath Management: Grazed by sheep and cattle.
Comments: Previously arable field. Acidic grassland developed with some invasion of heather from adjacent heath (NWD)

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Achillea millefolium	3%	*Ceratodon purpureus*	+		
Agrostis capillaris	12%	*Peltigera rufescens*	+		
Bellis perennis	+	*Polytrichum juniperinum*	+		
Calluna vulgaris	+	*Psuedoschleropodium purum*	+		
Capsella bursa-pastoris	+				
Cerastium fontanum	+				
Deschampsia flexuosa	+				
Erodium cicutarium	+				
Festuca ovina	56%				
Geranium molle	1%				
Gnaphalium uliginosum	+				
Hieracium pilosella	1%				
Leontodon autumnalis	+				
Linum catharticum	4%				
Medicago lupulina	5%				
Myosotis arvensis	2%				
Ornithopus purpusillus	1%				
Plantago lanceolata	4%				
Rumex acetosella	+				
Sedum sexangulare	+				
Senecio jacobeaea	1%				
Senecio sylvaticus	1%				
Senecio vulgaris	+				
Stellaria media	+				
Taraxacum officinale	1%				
Trifolium repens	2%				
Veronica arvensis	1%				
Vicia lathyriodes	+				
Total	97%	Total	+	Bare ground	3%

Brettenham Heath, Breckland

Site: Brettenham Area A Management: Sheep grazing
Comments: Acidic grassland and bracken.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	46%	*Agrostis capillaris*	11%	*Pseudoschleropodium purum*	6%		
		Calluna vulgaris	2%				
		Cerastium fontanum	+				
		Festuca ovina	29%				
		Festuca tenuifolia	+				
		Galium saxatile	4%				
		Glechoma hederacea	3%				
		Luzula campestris	+				
		Ornithopus perpusillus	1%				
		Potentilla erecta	+				
		Rumex acetosella	1%				
		Trifolium repens	+				
		Urtica dioica	+				
		Veronica officinalis	+				
Total	46%	Total	51%	Total	6%	Bare ground	1%

Site: Brettenham Area B Management: Sheep grazing
Comments: Acidic grassland. Heather present on path taken by pipeline.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	7%	*Achillea millefolium*	+	*Pseudoschleropodium purum*	7%		
		Agrostis capillaris	7%				
		Anthoxanthum odoratum	+				
		Calluna vulgaris	+				
		Cerastium fontanum	+				
		Cirsium sp.	+				
		Festuca ovina	68%				
		Festuca tenuifolia	+				
		Galium saxatile	4%				
		Glechoma hederacea	+				
		Luzula campestris	+				
		Potentilla erecta	+				
		Rumex acetosella	2%				
		Senecio sp.	+				
		Taraxacum officinale	+				
		Trifolium repens	+				
		Urtica dioica	+				
		Veronica arvensis	+				
		Veronica officinalis	+				
		Viola sp.	+				
Total	7%	Total	81%	Total	7%	Bare ground	5%

Site: Brettenham Area C Management: Sheep grazing.
Comments: Acidic grassland.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Pteridium aquilinum	+	*Agrostis capillaris*	5%	*Campylopus introflexus*	+		
		Calluna vulgaris	12%	*Campylopus paradoxus*	+		
		Carex arenaria	+	*Cladonia sp.*	+		
		Festuca ovina	78%	*Hypnum jutlandicum*	+		
		Festuca tenuifolia	+	*Pseudoschleropodium purum*	2%		
		Galium saxatile	3%	*Rhytidiadelphus squarrosus*	+		
		Glechoma hederacea	1%				
		Luzula campestris	1%				
		Ornithopus perpusillus	+				
		Potentilla erecta	+				
		Rumex acetosella	+				
		Senecio sp.	+				
		Trifolium repens	+				
		Urtica dioica	+				
		Veronica arvensis	+				
Total	+	Total	94%	Total	2%	Bare ground	4%

Icklingham Plains, Breckland

Site: Icklingham Area A Management: Sheep grazing.
Comments: Acidic/neutral grassland with restricted drainage.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Agrostis capillaris	1%	*Campylopus introflexus*	1%		
Agrostis stolonifera	8%	*Cladonia sp.*	1%		
Anthoxanthum odoratum	12%	*Pseudoschleropodium purum*	5%		
Carex flacca	9%				
Carex hirta	2%				
Carex ovalis	+				
Cerastium fontanum	+				
Cirsium arvensis	1%				
Cirsium vulgare	+				
Crepis capillaris	+				
Festuca ovina	12%				
Festuca rubra	2%				
Galium saxatile	+				
Galium verum	4%				
Hieracium pilosella	5%				
Holcus lanatus	34%				
Lotus corniculatus	1%				
Luzula campestris	+				
Plantago lanceolata	1%				
Rumex acetosella	2%				
Senecio vulgaris	+				
Taraxacum officinale	+				
Trifolium repens	+				
Trisetum flavescens	1%				
Total	93%	Total	7%	Bare ground	1%

Site: Icklingham Area B Management: Sheep grazing.
Comments: Acidic grassland with high lichen cover.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Agrostis capillaris	2%	*Campylopus introflexus*	4%		
Agrostis stolonifera	11%	*Cladonia sp.*	35%		
Alopecurus pratensis	+	*Peltigera rufescens*	+		
Anthoxanthum odoratum	1%	*Pseudoschleropodium purum*	1%		
Calluna vulgaris	4%				
Carex flacca	16%				
Carex ovalis	+				
Erodium cicutarium	+				
Festuca ovina	7%				
Festuca rubra	2%				
Galium saxatile	+				
Galium verum	1%				
Holcus lanatus	9%				
Luzula campestris	+				
Plantago major	+				
Poa pratensis	+				
Rumex acetosella	2%				
Senecio vulgaris	+				
Veronica chameadrys	+				
Total	55%	Total	40%	Bare ground	5%

Site: Icklingham Area C Management: Sheep grazing.
Comments: Acidic grassland with heather and lichen.

Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover		
Agrostis stolonifera	6%	*Campylopus introflexus*	3%		
Anthoxanthum odoratum	7%	*Cladonia sp.*	33%		
Calluna vulgaris	25%	*Pseudoschleropodium purum*	1%		
Carex flacca	11%				
Festuca ovina	11%				
Galium saxatile	+				
Galium verum	1%				
Holcus lanatus	5%				
Rumex acetosella	+				
Veronica chameadrys	+				
Total	66%	Total	37%	Bare ground	3%

Lower Hollesley Heath, Suffolk Sandlings

Site: Lower Hollesley 2c Management: Grazing introduced 1994
Comments: Heather replacing acidic grassland but with some invasion by bracken and bramble.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Pteridium aquilinum*	4%	6%
	Rubus fruticosus	-	2%
	Total	4%	8%
Dwarf shrub/herb	*Calluna vulgaris*	19%	62%
	Erica cinerea	36%	1%
	Galium saxatile	+	-
	Rumex acetosella	+	-
	Stellaria media	+	-
	*Fine grasses (including *Festuca ovina & Agrostis capillaris*)	10%	+
	Total	65%	63%
Lichens/bryophytes	(Composite category)	+	3%
Bare ground		25%	27%

Site: Lower Hollesley 2g Management: Grazing introduced 1994
Comments: Heather replacing acidic grassland.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Pteridium aquilinum*	+	-
	Quercus petraea	-	+
	Total	+	+
Dwarf shrub/herb	*Calluna vulgaris*	19%	36%
	Carex arenaria	+	-
	Erica cinerea	6%	22%
	Galium saxatile	14%	2%
	Rumex acetosella	10%	-
	*Fine grasses (including *Festuca ovina & Agrostis capillaris*)	37%	14%
	Total	86%	74%
Lichens/bryophytes	(Composite category)	1%	10%
Bare ground		4%	2%

Site: Lower Hollesley 6c Management: Grazing introduced 1994.
Comments: Area burnt in 1976. Regenerating heather and gorse invasion.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Betula* sp.	+	1%
	Pinus sylvestris	+	+
	Pteridium aquilinum	-	+
	Ulex gallii	-	13%
	Total	+	14%
Dwarf shrub/herb	*Calluna vulgaris*	36%	81%
	Erica cinerea	4%	+
	Rumex acetosella	+	-
	Total	40%	81%
Lichens/bryophytes	(Composite category)	20%	5%
Bare ground		-	2%

Site: Lower Hollesley 9b Management: Bracken sprayed in 1989. Grazing introduced in 1994.
Comments: Heather expanding at expense of *Agrostis capillaris* and *Festuca ovina*.

	Species	Cover in 1985	Cover in 1994
Dwarf shrub/herb	*Calluna vulgaris*	20%	57%
	Erica cinerea	1%	26%
	Euphrasia officinalis	+	-
	Galium saxatile	10%	-
	Holcus lanatus	+	-
	Polygala serpyllifolia	4%	-
	Rumex acetosella	6%	-
	*Fine grasses (including *Festuca ovina* & *Agrostis capillaris*)	46%	3%
	Total	87%	86%
Lichens/bryophytes	(Composite category)	13%	19%
Bare ground		1%	7%

Upper Hollesley Heath, Suffolk Sandlings

Site: Upper Hollesley 1c Management: Sheep grazed and scrub clearance.
Comments: Scrub clearance has allowed heather expansion, though acidic grassland has declined.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Betula* sp.	24%	-
	Pinus sylvestris	+	1%
	Pteridium aquilinum	+	-
	Total	24%	15%
Dwarf shrub/herb	*Calluna vulgaris*	29%	82%
	Carex pilulifera	+	-
	Erica cinerea	1%	-
	Galium saxatile	2%	-
	Rumex acetosella	5%	-
	*Fine grasses (including *Festuca ovina* & *Agrostis capillaris*)	14%	+
	Total	51%	82%
Lichens/bryophytes	(Composite category)	2%	47%
Bare ground		1%	2%

Site: Upper Hollesley 2b Management: Sheep grazed, cut 1988.
Comments: Heather expanding and excluding *Erica cinerea*.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Betula* sp.	+	-
	Pinus sylvestris	1%	-
	Pteridium aquilinum	+	-
	Total	1%	-
Dwarf shrub/herb	*Calluna vulgaris*	71%	98%
	Erica cinerea	5%	+
	Total	76%	98%
Lichens/bryophytes	(Composite category)	1%	36%
Bare ground		+	+

Site: Upper Hollesley 3b Management: Sheep grazed.
Comments: Some expansion of scrub and colonization by mosses.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Betula* sp.	+	4%
	Pinus sylvestris	+	1%
	Pteridium aquilinum	4%	3%
	Total	4%	8%
Dwarf shrub/herb	*Calluna vulgaris*	54%	64%
	Erica cinerea	-	+
	Galium saxatile	1%	1%
	Rumex acetosella	1%	-
	*Fine grasses (including *Festuca ovina* & *Agrostis capillaris*)	4%	-
	Total	60%	65%
Lichens/bryophytes	(Composite category)	12%	40%
Bare ground		2%	-

Sutton Heath, Suffolk Sandlings

Site: Sutton Heath 1b Management: Sheep grazed. Bracken controlled 1989.
Comments: Bracken control has contributed to an increase in cover by heather and fine grasses.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Betula* sp.	1%	-
	Pinus sylvestris	+	-
	Pteridium aquilinum	5%	-
	Total	6%	-
Dwarf shrub/herb	*Calluna vulgaris*	8%	58%
	Chamerion angustifolium	-	1%
	Rumex acetosella	23%	+
	*Fine grasses (including *Festuca ovina & Agrostis capillaris*)	+	11%
	Total	31%	70%
Lichens/bryophytes	(Composite category)	10%	4%
Bare ground		28%	15%

Site: Sutton Heath 4c Management: Sheep grazed.
Comments: Little change between surveys.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Pinus sylvestris*	+	1%
	Total	+	1%
Dwarf shrub/herb	*Calluna vulgaris*	90%	99%
	Total	90%	99%
Lichens/bryophytes	(Composite category)	10%	7%
Bare ground		+	+

Site: Sutton Heath 6b Management: Sheep grazed.
Comments: Bracken encroachment has reduced cover of *Agrostis capillaris* and *Festuca ovina*.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Pteridium aquilinum*	42%	60%
	Total	42%	60%
Dwarf shrub/herb	*Calluna vulgaris*	20%	19%
	Carex arenaria	-	+
	Galium saxatile	2%	2%
	Rumex acetosella	1%	7%
	*Fine grasses (including *Festuca ovina* & *Agrostis capillaris*)	13%	4%
	Total	36%	32%
Lichens/bryophytes	(Composite category)	4%	13%
Bare ground		7%	2%

Sutton Common, Suffolk Sandlings

Site: Sutton Common 4b Management: Sheep grazed and cut in 1989.
Comments: Some increase in heather cover.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Betula* sp.	+	-
	Pteridium aquilinum	18%	23%
	Total	18%	23%
Dwarf shrub/herb	*Calluna vulgaris*	30%	56%
	Carex arenaria	+	2%
	Galium saxatile	1%	-
	Rumex acetosella	4%	1%
	*Fine grasses (including *Festuca ovina & Agrostis capillaris*)	6%	3%
	Total	41%	62%
Lichens/bryophytes	(Composite category)	1%	15%
Bare ground		10%	5%

Site: Sutton Common 7b Management: Sheep grazed.
Comments: Increase in heather and mosses at the expense of bare ground.

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Pteridium aquilinum*	7%	4%
	Total	7%	4%
Dwarf shrub/herb	*Calluna vulgaris*	52%	86%
	Carex arenaria	-	+
	Total	52%	86%
Lichens/bryophytes	(Composite category)	2%	23%
Bare ground		17%	-

Site: Sutton Common 16a Management: Sheep grazed and bracken control.
Comments: Decline in heather and increase in cover of fine grasses

	Species	Cover in 1985	Cover in 1994
Scrub/bracken	*Pteridium aquilinum*	20%	1%
	Total	20%	1%
Dwarf shrub/herb	*Calluna vulgaris*	56%	37%
	Carex arenaria	-	+
	Galium saxatile	1%	+
	Rumex acetosella	+	3%
	*Fine grasses (including *Festuca ovina* & *Agrostis capillaris*)	1%	20%
	Total	58%	60%
Lichens/bryophytes	(Composite category)	1%	9%
Bare ground		6%	11%

Purdis Heath, Suffolk Sandlings

Site: Purdis Heath - mean of compartments 2d, 4a & 4c-e Management: None.
Comments: Heather in good condition.

Scrub/bracken		Dwarf shrub/herb		Bryophyte			
Species	Cover	Species	Cover	Species	Cover		
Betula sp.	+	*Calluna vulgaris*	83%	*Campylopus introflexus*	13%		
Quercus robur	+	*Chamerion angustifolium*	+	*Cladonia sp.*	2%		
Rubus fruticosus	+	*Erica cinerea*	4%	*Pseudoschleropodium purum*	10%		
Ulex gallii	+	*Festuca ovina*	1%				
		Galium saxatile	+				
		Rumex acetosella	+				
Total	+	Total	88%	Total	25%	Bare ground	1%

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