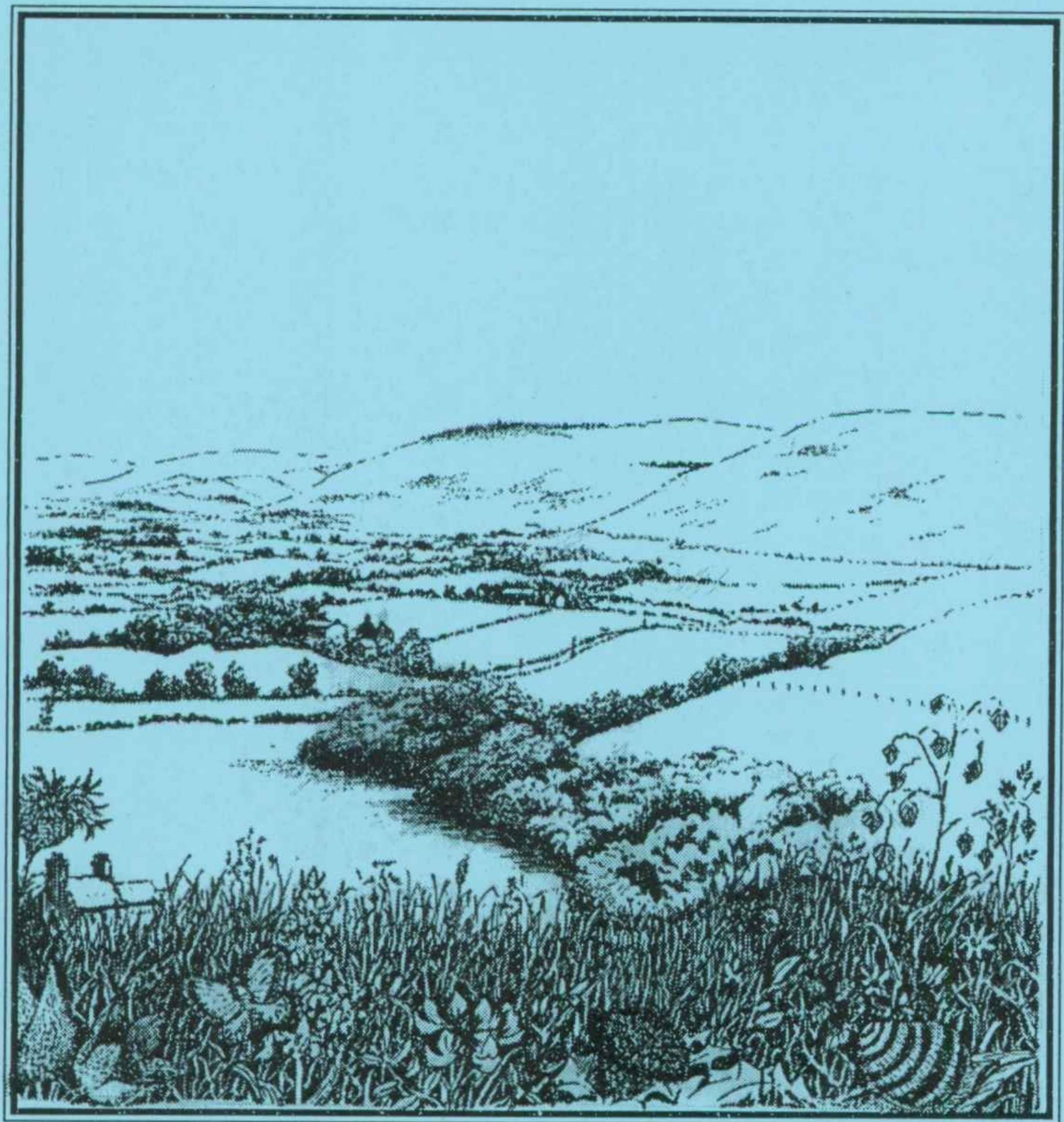
Department of the Environment



Current status and prospects for threatened habitats in England

Part 2
Calcareous grassland landscapes

ITE/ERM/UCPE contract report
to the
Department of the Environment

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Part 2

Calcareous grassland landscapes

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CONTRACT

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EXECUTIVE SUMMARY

Survey

1. In 1992, the Department of the Environment commissioned a research project to investigate the threatened habitats occurring within the landscape types included in the original Countryside Stewardship Scheme, of which calcareous grassland was one. The general aim of the project was to build on the work of the Countryside Survey 1990, to examine in more detail the distribution and quality of these habitats within the landscape types in England. This forms a basis against which future ecological changes, resulting from changing policies or specific initiatives, may be compared and measured.

2. The first step was to define the current geographical extent, and potential future extent, of the calcareous grassland landscape type. The broad geographical extent of the existing and potential areas was determined by geological characteristics (solid and drift) and altitude. The resulting database of 1 km squares was called the 'calcareous grassland mask'.

3. The next step was to characterise the calcareous grassland mask in terms of ecology, landscape features and archaeology. The 1 km squares were stratified according to limestone type (soft or hard) and designation status (designated or non-designated). Squares in these four strata were then randomly sampled, and land cover, vegetation in quadrats, landscape features and historical features were recorded. Historic features were also collected from existing archaeological datasets and archives.

Current status

4. Just 1.6% of the calcareous grassland mask area was estimated to be calcareous grassland habitat. This habitat comprised a range of vegetation types from maritime and bogs, through a range of grassland types, to vegetation becoming dominated by woody species; 59% of the calcareous grassland mask contained one or more designation type, but 90% of calcareous grassland habitats was designated. A greater proportion of the hard limestone areas in the mask were designated (65%) than in the more extensive soft limestone areas (56%).

5. In addition to the core calcareous grassland vegetation, areas of other grassland categories that might have been modified from calcareous grassland (modified calcareous grassland) were identified. Other land uses such as woodland and more intensive agriculture have been long modified but may still contain elements of a recognisable calcareous grassland flora.

	Area (ha)
Calcareous grassland habitat	41 300
Modified calcareous grassland vegetation types	750 000
Calcareous grassland mask	2 634 300

6. Objective measures of vegetation (recorded in quadrats) have been related to quality criteria, to provide an empirical evaluation of the quality of calcareous grassland vegetation in different parts of the calcareous grassland landscape. Using at least two separate measures of each of the quality criteria, the four survey strata were ranked. Based on quadrat information, calcareous grassland in the designated soft limestone stratum ranked highest for 13 of the 17 measures, and the designated hard limestone stratum was the highest in the other four (including three measures of diversity). This confirms the relationship between designated land and 'good-quality' calcareous grassland.

7. From examination of historic records, the calcareous grassland mask was shown to contain features from all historic periods, although representation of the Early Medieval period is sparse. The frequency of features was higher in designated than in non-designated strata. It is not possible to say whether designation status has helped to preserve sites or whether, by contrast, designated sites have been subject to more intensive examination.

8. It was recognised that, without time-series data, it was difficult to assess the effect of designation. It was not known, for example, whether correlations between 'good' areas of calcareous grassland and some form of designation were because the designation had been effective, or whether the designation was made because of the quality of the calcareous grassland. However, this study provides for the first time an essential baseline, necessary to conduct future monitoring of the effectiveness of designations.

Threats

9. Calcareous grasslands are relatively insensitive to the acidifying effects of acid deposition. During the period 1989–91, only 18% of all areas within the calcareous grassland mask was in exceeded areas (ie where the pollutant deposition exceeds the weathering rate of the soil), with higher exceedance rates in the north (hard limestone areas). In lowland England as a whole, the soil acidity critical load was exceeded in 57% of the total area.

10. Under current emissions reduction scenarios, none of the calcareous grassland mask would be at threat from acid deposition.

11. Average atmospheric deposition of nitrogen (NO_x and NH_x) in calcareous grassland areas is 21 kg nitrogen ha^{-1} yr^{-1}, which is similar to that received by other parts of lowland England (19 kg nitrogen ha^{-1} yr^{-1}). High N deposition occurs mainly in the northern hard limestone areas, where 42% of the area receives more than 25 kg nitrogen ha^{-1} yr^{-1}.

12. These rates of atmospheric N deposition are low compared to average agricultural inputs and there is no experimental information describing the long-term effects of these rates on calcareous grasslands in Britain. However, it is likely that the low rates of atmospheric N will have a significant effect on community composition in calcareous grasslands, with gradual nutrient enrichment leading to a loss of plant species diversity.

13. Other threats to calcareous grassland include:
    - landtake for arable use, urban expansion, mineral extraction and road building;
    - fragmentation as a result of encroachment associated with all of the above;
    - changes to land use and practices on adjoining lands, particularly afforestation and agricultural intensification;
    - recreational use of surviving commons.

Prospects

14. To consider what vegetation changes may take place under different scenarios of perceived threats, the study has made use of the 'Competitors: Stress-tolerators: Ruderals' (C-S-R) classification of functional types, and the TRISTAR2 model which predicts vegetation change in response to environmental and/or management change scenarios.

15. Most of the 'core' calcareous grassland vegetation is composed of stress-tolerator and competitor/stress-tolerator/ruderal species. The remaining vegetation plot types are representative of all other combinations of functional types.

16. The TRISTAR2 model calculated the predicted change in abundance of the functional types, under each of six specimen change scenarios, and an index of vulnerability was produced. The calcareous grassland mask consists of a heterogeneous grouping of calcareous grassland, grassland and woodland vegetation, all of which are relatively unproductive. In general, differences in vulnerability are small but some of the coarser and taller grassland classes appear to be among the most vulnerable. Other, wetter grassland classes are under very little threat. The core calcareous grassland and woodland classes occupy an intermediate position.

17. The results from the field survey and the outputs from the vegetation change and atmospheric impact models have been considered in the light of current policy measures. Calcareous grassland is a valuable habitat, dominated by a non-climax vegetation type. Because the vegetation is non-climax, intervention is required to prevent calcareous grassland turning into scrub/woodland; calcareous grassland therefore requires management to maintain its condition. The survey results indicate that, of the area within the

calcareous grassland mask (26 343 km²), about 1 140 000 ha may at one time have been calcareous grassland and is still in a land use which could revert (eg forestry or agriculture). About 750 000 is 'modified' grassland, which has the greatest potential for restoration.

18. Working from the *Biodiversity Action Plan* draft objectives as a starting point, it would appear feasible to establish the following objectives:
    - to maintain and enhance all extant areas of unimproved calcareous grassland – an estimated total of 41 300 ha;
    - to restore and enhance poor semi-natural or improved grasslands – from the total area of 750 000 ha across the country, targeting thin soils with low nutrient levels adjacent to existing calcareous grasslands;
    - to re-create calcareous grasslands by reversion of small areas of arable or chalk where it would have other benefits;
    - to improve the management of chalk woodlands.

19. If such targets are seen as being realistic, it is recommended that they are achieved by extending existing schemes, offering incentives for restoration and management on private land and implementing re-creation on agricultural land and woodland, where appropriate.

20. To ensure that the benefits of these measures are retained in the long term, and transferred to other areas, it is also essential that effective management approaches are identified and publicised, and that awareness of the value of calcareous grassland habitats is raised.

Chapter 1 INTRODUCTION: PURPOSE AND CONTEXT OF THE REPORT

1.1 Policy background

1.1.1 Despite much concern over the loss of semi-natural habitats in recent decades, there are inadequate levels of information as to the location and status of some rare and important habitats on a national scale. This information is becoming available through thematic and local surveys and is essential if assessments are to be made of the likely impacts of changing policies (eg Common Agricultural Policy, Habitats Directive, Biodiversity Action Plan) or of current incentive schemes (eg Countryside Stewardship) on the distribution and quality of these habitats.

1.1.2 To add to knowledge and understanding in these areas, the Department of Environment (DOE) commissioned a research project to investigate the threatened habitats occurring within the landscape types included in the original Countryside Stewardship Scheme. These are:

i. lowland heath landscapes
ii. chalk and limestone grasslands landscapes
iii. upland landscapes
iv. coastal landscapes
v. river valleys and waterside landscapes

1.1.3 These landscape types, together with their constituent habitats (see Box 1), are seen as areas which have suffered serious losses and degradation of habitats in the past and appear to be still under threat. They are perceived as having great value for wildlife, landscape, history and amenity/public enjoyment.

1.1.4 The general aim of the project was to build on the work of the Countryside Survey 1990 and examine in more detail the distribution and quality of threatened habitats within the landscape types in England. This examination forms a basis against which future scenarios of change, resulting from changing policies or specific initiatives, may be measured and compared. The project has also attempted to develop a methodology for measuring change at the national level; it reviews current policy instruments affecting threatened habitats and considers prospects for the future.

1.2 Research context

1.2.1 Countryside Survey 1990 (CS1990), a project carried out by ITE, jointly funded by NERC, DOE and the former Nature Conservancy Council, was developed from earlier surveys of GB and included field surveys of land cover, landscape features and vegetation quadrats. It also included soil surveys of all sample squares and was linked to a project mapping the land cover of GB using satellite imagery (Barr *et al.* 1993).

1.2.2 For the Countryside Survey 1990 fieldwork, a standard sample unit of 1 km x 1 km square has been used. Squares visited in the earlier surveys (1978 and 1984) were surveyed in 1990 and an additional 124 squares were added to the sample, giving a total of 508 squares.

1.2.3 Although the 1978, 1984 and 1990 Countryside Surveys provide comparatively

Box 1.1

In the context of this project, the calcareous grassland **landscape type** is a conceptual term for geographical area(s) in which calcareous grassland occurs or has occurred, historically, and includes other land cover types (eg farmland) which form mosaics with calcareous grassland. The **mask** is a cartographic term which, in this project, is a map which includes both the calcareous grassland landscape type and areas which have the potential to be included in the landscape type. Individual **habitats**, such as calcareous grassland, scrub woodland and other types of grassland, occur within the landscape type.

up-to-date information on general changes in the British countryside, the sample-based system was not designed to yield data on rarer, or localised, habitats. Thus, there was a need for information about these habitats which are perceived to be under threat, or which represent areas of concern to the Department. This Report describes work undertaken on the calcareous grassland landscape type.

1.3 Objectives

1.3.1 The objectives for each landscape type were to:

i. determine the distribution of the landscape type in England;
ii. survey the habitats (including major land cover types and ecological features such as hedgerows) and historic features within each landscape type;
iii determine, on a regional basis and in relation to current designations, the composition of each landscape type in terms of the quantity and quality of the surveyed features;
iv. develop models to predict the effect of environmental and management changes on the distribution and quality of the landscape types and their constituent habitats;
v. in the light of the above, make recommendations on ways in which policy instruments may be refined to further protect, enhance or re-establish the habitats which characterise each landscape type; and
vi. establish a baseline and develop a methodology for measuring change in these habitats which is sufficiently robust and precise to assess the effectiveness of policies, at a national (England) scale.

1.4 General approach

1.4.1 To meet the objectives of this project, a consortium was assembled which brought together the ecological and modelling knowledge and skills of ITE and the NERC Unit of Comparative Plant Ecology (UCPE) with the policy-related expertise of Environmental Resources Management (ERM). Giving additional support, in relation to historical aspects, was the Archaeological Unit of the University of Lancaster.

1.4.2 The general approach used by the research team can be summarised Figure 1.1.

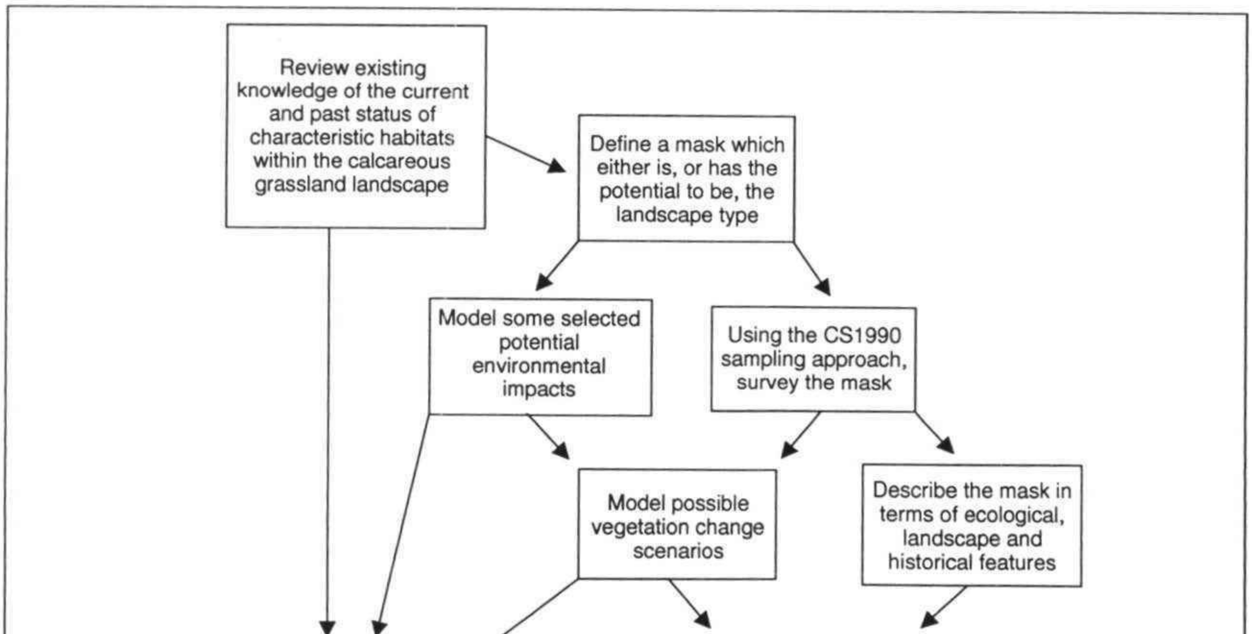


Figure 1.1 General approach used by the research team

1.5 Structure of the Report

1.5.1 The task of compiling this Report was undertaken jointly by members of the research team. The structure of the Report reflects the overall approach, as shown in Figure 1.1, with steps in the research being reported as separate Chapters. The final Chapter brings together the main conclusions from each phase of the work and gives a summary of the project, in relation to the objectives.

Chapter 2 BACKGROUND: THE IMPORTANCE OF CALCAREOUS GRASSLAND

2.1 Introduction

2.1.1 This Chapter is based on a review of existing literature and gives a general definition of calcareous grassland and its distribution within England. It describes its distinctive ecological, scenic, recreational and historical characteristics, and explains why calcareous grassland is important in a national context. The evolution of calcareous grassland and the factors important to its maintenance are discussed. Trends for change and threats to the calcareous grassland resource are briefly reviewed, and the need for conservation and enhancement is discussed.

2.2 Calcareous grassland – a general definition

2.2.1 Calcareous grassland in England is an open landscape occurring on thin, well-drained soils containing calcium carbonate. It is dominated by fine grasses and small flowering plants, many of which are rare. Its survival is dependent upon grazing, without which reversion to scrub and woodland would occur. Within the British Isles, different types of calcareous grassland occur on different types of limestone rock, the principal division being between the chalk grasslands on soft limestones in south-eastern England and the limestone grasslands occurring on harder limestones in the north and west of Britain. Calcareous grasslands were once much more extensive than they are today, and perhaps only 5% remains. The main concentrations are in the Cotswolds, South Downs, Wiltshire, Chilterns, limestone pavements in the Pennines and coastal cliffs. A very high proportion of that which remains is designated – mainly Areas of Outstanding National Beauty (AONBs), National Parks (especially in hard limestone areas), and Sites of Special Scientific Interest. This is discussed in greater detail in Chapter 4.

2.3 Calcareous grassland as an ecological resource

2.3.1 Calcareous grassland is a type of vegetation dominated by grass species, which develops on soils formed by the weathering of limestone rocks. The grassland that develops on calcareous soils is vegetationally distinct from that of neutral soils (called mesotrophic grassland) or acid soils (called calcifugous grassland).

2.3.2 True calcareous grasslands characteristically occur on well-drained soils. They do not occur on wet calcareous soils in poorly drained sites (where they are replaced by calcareous mires and fen vegetation types), or in montane areas with high rainfall, low temperatures and low rates of evapotranspiration (where they are replaced by upland calcareous mires and montane vegetation types). Most calcareous grasslands are poorly supplied with macronutrients (especially nitrogen and phosphorus), and are accordingly dominated by stress-tolerant plant species.

2.3.3 Within the British Isles, different types of calcareous grasslands occur on different types of limestone rock. Although the principal division is between soft southern and harder northern limestones, some areas of limestone blur this south-east/north-west separation, including the chalk of the Yorkshire Wolds in the extreme east of Yorkshire, the Oolitic limestones of the Dorset coast and the Cotswolds, the Devonian limestones of south Devon, and the carboniferous limestones of the Mendips and the Bristol area.

2.3.4 The National Vegetation Classification (Rodwell 1992) recognises eight types of essentially lowland calcareous grassland with 31 distinct subcommunities, two upland types with eight distinct subcommunities, and four strictly montane types with four subcommunities. The main community types are shown in Table 2.1.

2.3.5 Calcareous grasslands are among the most species-rich plant communities in Britain and northern Europe. Willems (1990) estimated that about 700 plant species occur in European calcareous grasslands, of which 200 are bryophytes and lichens. Within Britain the large number of plant species occurring in calcareous grassland constitutes a substantial percentage of the total native flora (perhaps 10–20%). Not only do very large numbers of species occur overall, but many species are represented in small areas of turf (ie high species diversity as well as high species richness). Chalk downland turf often contains 30 or even 40 species per square metre, and almost no other types of vegetation in Britain contain more (though a few may contain as many, eg some calcareous mires).

2.3.6 Many of the plant species found in calcareous grassland are scarce native species of high nature conservation importance. A total of 77 protected or listed species occurs in calcareous grasslands, of which 50 are restricted to calcareous grassland (Keymer & Leach 1990). They include many species which are additionally notable for their attractiveness and cultural associations, including several species of orchid (eg the *Red Data Book* species lizard orchid (*Himantoglossum hircinum*), military orchid (*Orchis militaris*) and monkey orchid (*O. simia*), and the 'Nationally scarce' species man orchid (*Aceras anthropophorum*), musk orchid (*Herminium monorchis*) and burnt orchid (*Orchis ustulata*)).

2.3.7 In addition, calcareous grasslands (especially the climatically warmer South Downs) provide habitats for many invertebrates, including ants and a large number of butterflies which are confined to this habitat and are scarce or localised in Britain. These include the adonis blue (*Lysandra bellargus*), Lulworth skipper (*Thymelicus acteon*), silver spotted skipper (*Hesperia comma*), chalkhill blue (*Lysandra coridon*) and marble white (*Melanargia galathea*).

2.3.8 Calcareous grasslands similar to those in Britain are to be found over much of central and northern Europe, wherever geological and climatic conditions permit. Indeed, many of the plants and insects which are rare or threatened in Britain are fairly widespread across Europe. However, their rarity in England makes them a nationally important resource. The internationally valuable calcareous grasslands with atlantic influences in

Table 2.1 Calcareous grassland and related communities in the National Vegetation Classification

Lowland	CG1	*Festuca ovina–Calluna vulgaris* grassland	S/SW coasts England Wales
	CG2	*Festuca ovina–Avenula pratensis* grassland	England/Wales limestones
	CG3	*Bromus erectus* grassland	Widespread England
	CG4	*Brachypodium pinnatum* grassland	Scattered England
	CG5	*Bromus erectus–Brachypodium pinnatum* grassland	Scattered England
	CG6	*Avenula pubescens* grassland	Scattered England
	CG7	*Festuca ovina–Hieraceum pilosella–Thymus praecox/pulegioides* grassland	Scattered mainly S England
	CG8	*Sesleria albicans–Scabiosa columbaria* grassland	NE England only
Upland	CG9	*Sesleria albicans–Galium sterneri* grassland	N/NW England only
	CG10	*Festuca ovina–Agrostis capillaris–Thymus praecox* grassland	Scattered British uplands
Montane	CG11	*Festuca ovina–Agrostis capillaris–Alchemilla alpina* grass–heath	Mainly Scottish uplands
	CG12	*Festuca ovina–Alchemilla alpina–Silene acaulis* dwarf herb community	Scottish mountain summits
	CG13	*Dryas octopetala–Carex flacca* heath	NW Scotland lowlands
	CG14	*Dryas octopetala–Silene acualis* ledge community	Scottish Highlands

Scotland are beyond the scope of this study, which looks only at England.

2.4 Calcareous grassland as a scenic resource

2.4.1 Calcareous grassland is found in a number of scenically different types of landscape. Often on steep scarp slopes, such areas provide dramatic viewpoints over surrounding downland and traditional sheep grazing landscapes. In other areas, chalk grassland is on gentler slopes and provides views over undulating wolds. In yet other areas, harder limestones feature caves, swallow holes and characteristic limestone pavements. The grasslands themselves are usually warm and sheltered containing colourful, sweetly scented plants such as wild thyme (*Thymus praecox*), marjoram (*Origanum vulgare*) and orchids and many fast-moving butterflies. The landscape is usually a mosaic of other land cover types which adds detail and interest to vistas. These include ancient woodlands and hanger woods, agricultural land, hedges and scrub, as well as features such as stone walls, barns and small stone villages amid pasture and water meadows.

2.4.2 Many calcareous grassland landscapes are in AONBs and National Parks. Some of the calcareous landscapes epitomise what many consider to be the 'true English landscape'. The Cotswolds are an example of this with the scarp slopes, rolling downs and wolds, country villages, and a mosaic of arable, grassland, and scrub.

2.4.3 The various calcareous landscapes have inspired many writers, artists, composers and architects, including William Morris and Vaughan Williams (Cotswolds), Shelley and John Nash (Chilterns), Tennyson and Peter de Wint (Lincolnshire Wolds), and Gilbert White and Myles Birket Foster (east Hampshire Downs).

2.5 Calcareous grassland as a recreational resource

2.5.1 Calcareous grassland is widely used for recreation. Many areas are especially popular because of their historic remains, and can attract large numbers of visitors. Chalk grassland is also popular with walkers and picnickers as a result of the wide vistas it provides and easy walking conditions. These vistas are often above scarp foot settlements, such as Cheltenham and Gloucester, and they therefore provide a valuable retreat for town dwellers.

2.5.2 The landscape is also ideal for horse riding and cycling, especially as there are many long-distance trails over the Downs, such as the Cotswolds Way, the Ridgeway and the South Downs Way. Coastal calcareous areas are popular recreational areas for walking and also for abseiling and rock climbing sports.

2.5.3 The chalk downlands are visited by the increasing number of naturalists, especially in spring and early summer when flowers and butterflies are visible.

2.6 Calcareous grassland as an historical resource

2.6.1 Calcareous grasslands are ancient landscapes created and shaped by human farming activity. Archaeologically, they are amongst the most important land cover types, as there have been no tree roots to disturb remains and minimal soil disturbance. In addition, the formation of grassland often involved setting aside large areas of landscape; thus, whole areas have been preserved providing information about the setting, extent and inter-relationships of sites. Furthermore, monuments under established grassland can often be seen as surface features at ground level. They are therefore an integral part of the landscape and are especially useful as an educational resource.

2.6.2 High, well-drained soils have always been popular as areas for settlement, and settlement remains represent the most diverse and chronologically wide-ranging archaeological evidence in grassland areas. The earliest earthworks are the causewayed enclosures of Neolithic date (eg Knap Hill, Wiltshire). Hillforts are among the most impressive of the later prehistoric period and many are now situated in areas of established grassland. Later prehistoric and Roman settlements are well represented in higher areas where stone was the major building material. During the 12–14th centuries there was widespread desertion of the chalk uplands, which can be seen by the many medieval villages which remain in the Cotswolds, the Wiltshire Downs and the Yorkshire Wolds. This desertion had many causes, including the civil war and expansion of monastic granges which was followed by the black death. In addition, large-scale depopulation took place after 1450 when the increased demand for wool by the cloth trade led to large areas being put to pasture. The wealth which sprung from the wool trade during the medieval period allowed many fine vernacular buildings of local stone to be built.

2.6.3 Other archaeological remains found in calcareous grassland include roads, fields and agricultural features, boundaries and ritual monuments. Some of the ancient tracks on chalk grassland remain today, such as the Berkshire Ridgeway. Famous ritual monuments on calcareous grassland include Stonehenge and the Rollright stones. In addition, there are the famous chalk figures including the Uffington White Horse (Oxfordshire) and the Long Man (Wiltshire).

2.7 The evolution of calcareous grassland

2.7.1 An understanding of the evolution of calcareous grassland is important to its conservation and enhancement. Authoritative accounts of calcareous grassland history are given in Rackham (1986) and, to some extent, by Darvill in his consideration of grassland as a whole (1987), upon which the following account is based.

2.7.2 The creation of calcareous grassland is thought to have commenced around 5500 BC when the first large-scale tree clearances began to take place. Such grasslands would have occurred naturally in forest clearings and on coastal sites, but would not have been widespread before this time. The rate of calcareous grassland formation would have increased with the greater demand to graze animals. Two distinct grazing patterns would have been established in most areas: meadow, which was allowed to grow and then cut as hay for winter fodder, and pasture where livestock were left to graze between April and December. In addition, livestock were widely grazed on the higher ground during the day and folded on arable land overnight. This process led to a removal of nutrients from the chalk grassland (through animal dung) and helped to create the nutrient-stressed systems that remain.

2.7.3 Formation of grassland increased to around 4% meadow and around 20% pastoral by the time of the black death when many areas reverted to woodland as the reduced population no longer needed such large areas. Expansion then occurred again with irrigation around 1500. After 1700, seeding of grasslands began and with it the decline in the quality of chalk grasslands. With the mechanisation of farming, many grasslands were ploughed up for agriculture in the early 19th century. This process was re-introduced during the Second World War, when further advances in farming – such as the use of herbicides, pesticides and fertilizers – served to reduce the quality of much of what remained.

2.8 The dynamics of calcareous grassland

2.8.1 The preceding descriptions show that calcareous grassland is natural in the sense that the plants are wild and not sown, but it is man-made in the sense that it would revert to woodland in the absence of grazing management.

2.8.2 The maintenance of species richness in unimproved calcareous grassland depends in part upon freedom from disturbance and the long continuance of traditional grazing management. Once a grassland has been disturbed it may never fully regain its original character, as certain species are peculiar to sites that have remained undisturbed for centuries, eg pasque flower (*Pulsatilla vulgaris*) (Rackham 1986). Wells *et al.* (1976) studied the Porton Ranges in Wiltshire, and found that chalk grasslands disturbed by medieval and Napoleonic ploughing could be distinguished by species absences from those areas that had never been ploughed; those less than 130 years old could easily be recognised. However, on the other hand, there is some evidence that important assemblages of lichen only occur on sites which have been disturbed in the last 100 years (Gilbert 1993).

2.8.3 The grassland of ancient monuments on chalk is often especially species-rich, presumably because it has never been disturbed (Wells 1985; Rackham 1986), and some species are confined to prehistoric monuments, rather than medieval monuments. It should be noted, however, that there are some very valuable sites where calcareous grassland development began during the Middle Ages after periods of disturbance, eg former quarries at Barnack in Northamptonshire. In these cases a dissected topography and thin soils may play a part in providing conditions that are especially suitable for rare chalk species.

2.8.4 Calcareous grasslands depend on certain conditions of stress and disturbance for their survival. The important conditions are as follows:

- soils with high pH (over 7.0) due to the presence of free calcium (not other minerals or salinity) – a form of stress;
- soils with low macronutrient status, especially low nitrogen and phosphorus – a form of stress;
- the regular removal of plant material by grazing – a form of disturbance;
- in many but not all cases (especially chalk grasslands in the south-east of England and limestone grasslands in the south-west of England), very free-draining soils giving rise to summer drought – a form of stress.

2.8.5 These conditions are largely maintained by grazing. Calcareous grasslands are sensitive to small increases in available macronutrients, so the continual removal of plant material by grazing is of primary importance.

2.8.6 In the absence of grazing, calcareous grasslands may become invaded by scrub. About 20 woody species are involved. Chalk scrub is especially species-rich compared to other scrub types because it contains a number of species having south-eastern geographical distribution patterns in Britain, though it is species-poor compared to the grassland it replaces. Soils beneath chalk scrub become eutrophicated, with increased levels of nitrogen and phosphorus. Clearance of scrub does not therefore lead to the re-establishment of chalk grassland, but may lead to invasion by coarse grass species and the establishment of tall herb communities (Grubb & Key 1975).

2.8.7 Scrub can be managed by cutting. However, if this is not followed up by effective grazing, it may have the effect of coppicing the scrub so that it returns with increased vigour. Coppicing is often carried out too late in successional development, and secondary woodland plants rather than calcareous grassland plants flourish. If cutting is to be used, then it is best done in places where scrub development is not so far advanced that the grassland plants have been eliminated.

2.8.8 Coarse grasses are another problem for calcareous grasslands, especially tor-grass (*Brachypodium pinnatum*) in chalk grasslands in south-eastern Britain and upright brome (*Bromopsis erecta*) in south-eastern chalk grasslands, but also false brome (*Brachypodium sylvaticum*) in chalk and limestone grasslands throughout most of Britain. These species move the bulk of the grassland biomass into a zone 10–30 cm above the ground (as compared with 0–10 cm in species-rich calcareous grassland turf), and shade out other species, leading to species-poor brome-dominated swards.

2.8.9 The spread of tor-grass during this century has been widely documented, and variously explained in terms of the breakdown of traditional grazing management, myxomatosis, burning, and the increased atmospheric deposition of nitrogen. The key problem seems to be that brome is unpalatable to most agricultural livestock, so that, once some temporary breakdown in traditional grazing management has triggered the invasion, the situation is hard to retrieve, and a complicated grazing/management regime has to be designed.

2.9 Trends for change in calcareous grassland

2.9.1 Large areas of calcareous grassland have been lost over the last 300 years, and substantial losses of the surviving calcareous grassland have occurred within the last 50 years. Much of the information about this loss is either anecdotal or derived by extrapolation from studies dealing with grasslands in general (Keymer & Leach 1990).

Loss of calcareous grassland

2.9.2 During the 20th century calcareous grasslands have been lost to landtake mainly for the reasons listed below.

- Ploughing up for arable or improved pasture remains by far the most significant cause of loss, especially as most calcareous grasslands remain in agricultural ownership.

- Mineral extraction is a significant factor in some areas, and continues to cause small but significant losses of the better calcareous grasslands which may be poorly protected where mineral extraction permissions were issued soon after the Second World War. However, abandoned hard chalk and limestone quarries also provide habitats for calcareous grassland species, and in areas where almost all of the original grassland has been lost to agriculture they may benefit the calcareous grassland resource. Old quarries are a very important nature conservation resource in some areas, eg Rutland, the Yorkshire Wolds (Davis 1979, 1982; Jefferson 1984).

- Conifer plantations have been established on some steep slopes in chalk and limestone areas, and, because conifers cause soil acidification, these plantations are generally inimical to calcareous grassland plants.

- Building development and roads account for a small proportion of calcareous grassland loss.

2.9.3 Nature Conservancy Council (Keymer & Leach 1990) surveys suggested that between 1968 and 1980 the loss of calcareous grassland was about 60% due to ploughing or agricultural improvement, about 30% due to scrub encroachment, 6% due to forestry, and 1% to development.

2.9.4 As can be seen, the main cause of loss has been agriculture. Second World War ploughing and post-1945 agricultural intensification accounted for the substantial loss of the grassland that survived into the 20th century. Between 1968 and 1980 alone, perhaps 20% of the remaining chalk grassland disappeared according to Nature Conservancy Council surveys (Keymer & Leach 1990). In Hertfordshire only 250 ha of the once-extensive Chiltern grasslands survived (unimproved) in 1940; over half of this disappeared by 1985 (Sawford 1990).

2.9.5 Even in districts with large exposures of calcareous rocks, unimproved calcareous grasslands are today largely confined to steep scarp slopes where arable cultivation is impossible. This applies especially to chalk grassland (Keymer & Leach 1990), and it is true of counties with huge expanses of chalklands, eg Wiltshire (Gillam 1993). It is almost certainly to some extent true for northern and western calcareous grasslands as well (though in these areas improved pasture rather than arable would have replaced the unimproved grassland). In a few places, especially Wiltshire (Gillam 1993), military land uses have preserved chalk grassland on less steep slopes, as on Salisbury Plain and Porton Down.

2.9.6 In counties with small exposures of calcareous rocks, the situation is even more marked. In Leicestershire, where there was never much limestone grassland, the few substantial limestone grassland sites remaining in 1933 were lost to ploughing, forestry and airfields. Long-established habitats for calcareous grassland plants are now confined to the edges of disused airfields, a few road verges and railways, but quarries provide by far the greatest amount of suitable habitat (Primavesi & Evans 1988) for such species.

2.9.7 Obviously if the landscape is ploughed up or built on it reduces its aesthetic appeal. Large areas will turn from green to brown, and skyscapes will be interrupted. In addition, archaeological remains may be ploughed and destroyed. Another major effect of such landtake is on the amenity value of the land. This is especially acute where the last remaining fragments of chalk grassland are destroyed near towns.

Fragmentation

2.9.8 The fragmentation and isolation of surviving calcareous grasslands are as much a concern as their loss. Nature Conservancy Council surveys suggest that, even in counties with extensive chalklands, fragmentation is severe. In Dorset only 12.6% of chalk grassland sites (174 surveyed) were over 40 ha (Keymer & Leach 1990). In counties with lesser exposures of calcareous rocks fragmentation is greater. In Lincolnshire no sites (55 surveyed) were over 10 ha, and 75% were under 1 ha. In counties like Leicestershire (discussed above) fragmentation must be even more extreme.

2.9.9 Fragmentation is important for many reasons, but especially because it can impede management. Fragmentation again affects all aspects of calcareous grassland conservation value. The integrity of the habitat, the sense of openness and interconnectedness, the wide open space for recreation, and the historic value are all reduced. Ecological values are particularly affected.

2.9.10 The principal concerns relate to the loss of biodiversity. Recent studies of island theory (Shafer 1990), minimum viable populations (Soulé 1987), metapopulation ('populations of populations' which constitute the presence of a species in a geographical area) (Gilpin & Hanski 1991), and 'landscape ecology' (which studies the relationship between landscape structure and living things) (Forman & Godron 1986) place this issue upon a firm footing. Another important class of concerns relates to edge effects, which are related to loss of biodiversity. The more important aspects are listed below.

- Fragmentation may have long-term consequences for the maintenance of species diversity within calcareous grassland. Essentially plants and animals have a reduced chance of migrating between isolated patches of grassland, and this increases the chance that species will become extinct within any given patch.

- Fragmentation may lead to a drain on populations of species in surviving fragments of grassland. Emigrating individuals succumb to inhospitable environments. Wildlife corridors (eg road verges) may ameliorate this effect, but blind corridors leading out of patches of grassland may exacerbate it (Selman & Doar 1992).

- There may be loss of genetic diversity within species confined to isolated habitat patches. Besides constituting loss of biodiversity in itself, this may in turn increase local extinction probabilities for species.

- Increased edge to the grassland habitats will change the relative importance of ecological processes taking place at the grassland boundary.

- Fragmentation may exacerbate conflicts in nature conservation priorities, and may make it harder to manage isolated patches which are difficult to reach.

Changes in land management

2.9.11 Changes in land management, notably a reduction in traditional grazing, have had adverse effects upon the ecological value and open character of calcareous grassland. A large part of the surviving calcareous grassland resource is under immediate threat from scrub encroachment. This situation can always be traced to lack of grazing, but often the problem is that grazing alone is not sufficient to restore the situation once coarse grasses (especially tor-grass) and woody species have started to invade.

2.9.12 Many calcareous grasslands are still used for agriculture. Though the best sites in southern Britain are increasingly managed primarily for nature conservation, large areas of calcareous grassland in the north and west are managed as pasture in private ownership. Because calcareous grasslands depend upon grazing management, any changes in agricultural policy could have severe effects upon the calcareous grassland resource. The most relevant agricultural activities are listed below.

The use of fertilizers and selective herbicides and seeding The addition of fertilizers, whether artificial or organic, allows competitive grass species to dominate the calcareous grassland sward, eliminating the wealth of broadleaved herbs that are the characteristic feature of unimproved calcareous grasslands. The aerial spraying of fertilizers and herbicides damaged many calcareous grasslands on otherwise uncultivatable slopes during the 1960s, and this remains a threat to some of the finest chalk grasslands. Any restrictions on fertilizer use will alleviate the threat to the calcareous grassland resource, both directly and indirectly by affecting the incidence of eutrophicating runoff.

Herbicide use Again, any restrictions will alleviate the threat to the calcareous grassland resource, both directly and indirectly by affecting the incidence of spray drift.

Ploughing Any restriction may give scope for re-creating calcareous grasslands.

Stocking rates Any changes in agricultural subsidies and quotas may have 'knock-on' effects on the quality of surviving chalk grassland.

Recreational pressures

2.9.13 Many calcareous grasslands are heavily used for recreation. While recreational use may provide an incentive for the conservation of grassland where the old agricultural regime has passed away, it may also exacerbate deterioration. Reasons for deterioration include physical disturbance and soil compaction (from parking, walking, cycling, horse riding and motorcycle scrambling) and dogs (which can disturb stock and cause eutrophication). In addition, there may be public resistance to management measures, especially scrub clearance.

2.9.14 On the whole, calcareous grassland turf is more tolerant of trampling than any other vegetation type in Britain. However, some calcareous grassland, especially viewpoint sites, experience such heavy use by the public that soil erosion is still a problem (eg Box Hill in Surrey). Fertilizer application alters the composition of calcareous grasslands in ways that make them less resistant to trampling, and in the Marlborough Downs erosion is associated with areas that were sprayed with fertilizers from the air during the 1960s and 1970s (Gillam 1993).

2.9.15 Recreational pressures result not only in damage to calcareous grassland habitats, but may bring significant visual intrusion and degradation of the recreational resource itself. In addition, they may lead to disturbance of buried archaeological features.

Atmospheric pollution

2.9.16 Acid deposition has little effect upon calcareous grasslands, where the high pH soils are more than capable of neutralising such deposition. Sulphur deposition probably has little effect at all, while the deposition of nitrogen may have nutrient but not pH effects.

2.9.17 A large body of literature links the spread of tor-grass (and to a lesser upright brome) in The Netherlands with increased deposition of atmospheric nitrogen (Bobbink & Willems 1987, 1988; Bobbink, Bik & Willems 1988). These coarse grasses seem to be able to utilise the nitrogen at low levels of available phosphorus, and therefore out-compete the other calcareous grassland species. There is some experimental evidence to show that the levels of nitrogen deposition prevailing in The Netherlands (in excess of 50 kg ha^{-1}) are sufficient to account for the spread of tor-grass. These levels are not matched in Britain, but the historical epidemiology of tor-grass increase in Britain is not inconsistent with an explanation in terms of increased nitrogen deposition (Bell 1994).

2.9.18 The main effects of such deposition are still unclear but would mainly affect the ecological value of calcareous grassland.

Climate change

2.9.19 Because many characteristic species of calcareous grasslands require warm dry summers, it might be supposed that global warming would favour these more distinctive elements in the calcareous grassland flora. On the other hand, wetter summers would not favour these plants. A run of warm summers was invoked to explain the northwards spread of the lizard orchid in Britain during the 1930s and 1940s, long before climatic warming was identified as an issue.

2.9.20 The potential effects of global warming are still unclear but any impacts are likely to be concentrated on calcareous grassland as an ecological resource.

2.10 Conservation, restoration and re-creation of calcareous grassland

2.10.1 This Section considers what potential there is to conserve, restore or even re-create calcareous grassland, and looks at the measures that are needed to achieve such changes.

Conservation

2.10.2 Although much calcareous grassland is managed for agriculture, a growing area is now managed for nature conservation, or closely related countryside amenity purposes. To a large extent, the methods used in conservation management for calcareous grassland consist of restoring conditions of stress and reinstating ancient grazing practice. The methods most commonly used are as follows:

- grazing – by sheep mainly if the grassland is fairly near its optimal condition;
- scrub removal if there is encroachment; ideally, this should be combined with tight grazing control so as to prevent the effects of coppicing the scrub;
- nutrient removal – eg turf stripping for badly degraded sites.

2.10.3 Calcareous grasslands are sensitive to small increases in available macronutrients. In calcareous grasslands the continual removal of plant material by grazing is of primary importance.

2.10.4 Sheep grazing was the traditional form of management on most calcareous grasslands, and is widely presumed to be the best form of grazing for its maintenance today. Where the turf has suffered no degradation, this may well true, but where incipient scrub invasion is in progress – as is the case on most southern English calcareous grasslands – mixed grazing may be better. Where the aim of grazing is the restoration of species-rich swards in seriously degraded areas, then altogether different forms of grazing may be required. Oates (1993) gives an illuminating account of the grazing activities of different animals.

2.10.5 To summarise experience to date, it seems that a balanced grazing regime is best for most calcareous grasslands where some incipient degradation of the turf is in progress. Sheep and cattle together will effect control of the better grasslands, while ponies are especially appropriate where tor-grass is a problem (but perhaps more widely as an alternative to cattle); primitive sheep are appropriate in controlling open scrub. Goats may be needed to deal with more serious scrub invasion.

2.10.6 Management of grassland is important to prevent a move to scrub. Such a move can be very hard to restore as calcareous grassland may not return if it is cleared, because of soil eutrophication. Chalk scrub may be of modest nature conservation importance in its own right. It may support important populations of invertebrates and birds, especially where there is a close patchwork of scrub and grassland. This presents a problem for nature conservation managers, because they may be pressured to preserve chalk scrub alongside chalk grassland. Such a combination is difficult to manage as scrub is highly invasive. Cutting scrub has been widely used as a nature conservation tool. Though occasionally effective, it has often been disastrous (Oates 1992).

2.10.7 The spread of coarse grasses is another issue for grassland management. They spread vegetatively and quickly form large patches. The key problem seems to be that tor-grass is unpalatable to most agricultural livestock, so that once some temporary breakdown in traditional grazing management has triggered invasion, then the situation is hard to retrieve, and a complicated grazing/ management regime will have to be designed.

2.10.8 A newly recognised threat to some high-quality calcareous grasslands is rabbit (*Oryctolagus cuniculus*) grazing. On parts of the North Downs and the Chilterns, rabbit populations have returned to pre-myxomatosis levels, and considerable alterations are taking place in the turf locally (Oates 1992). Large bare patches are formed, some eutrophication may occur around latrine areas, and unpalatable plants spread, eg ground-ivy (*Glechoma hederacea*) in Wiltshire (Gillam 1993). Whilst the relaxation of rabbit grazing has been widely identified as the trigger that caused massive scrub invasion on chalk downlands in the 1950s, it now seems that not all rabbit grazing is desirable.

2.10.9 As well as restoring the habitat on calcareous landscapes, it is also possible to restore landscape features such as stone walls and barns which have fallen into disrepair. Public access may also be encouraged, especially to newly restored vistas and land around ancient monuments.

Re-creation

2.10.10 Re-creation of calcareous grassland on suitable soils is both possible and desirable and may be easiest on former arable land. Although high-quality calcareous grassland may take hundreds of years to re-create, if at all, it is still possible to re-create something similar, containing a number of chalk species and of use to some invertebrates, within a relatively short timeframe (eg 10–20 years; Gibson, Watt & Brown 1987; Gibson & Brown 1991, 1992). The success of such restoration will depend on many factors, such as the proximity of surviving calcareous grassland, the former use of the land and survival of a seedbed, as well as the way in which it is managed and the weather.

2.10.11 Although the ecological benefits of restoration are clearly not as high as those of preserving good-quality existing chalk grassland, the landscape and amenity benefits are rapid and can be concentrated in those areas which need most help. This may be in areas near to towns which have little open space and few remaining fragments of calcareous grassland.

2.11 Summary

2.11.1 Calcareous grassland is a vegetation type found only on limestone soils and dominated by a diverse and rich range of small herbs and fine grasses. Many of the plants and the invertebrates they support are rare and declining in the UK, and the complete plant/ invertebrate system is impossible to re-create once lost or damaged. This grassland has been created and is maintained by the human practice of grazing animals. In the absence of grazing, such grassland would revert to woodland.

2.11.2 The landscape within which calcareous grassland is found is particularly valued for its scenic qualities. Features such as scarp, downland and wolds all provide long views over surrounding land. There is also a characteristic mix of countryside features and uses which perhaps typifies the English landscape. These scenic qualities make calcareous grassland a valuable amenity landscape, especially as there are so many long-distance paths and bridleways on the Downs.

2.11.3 From a historical perspective there are many well-preserved and easily viewed ancient monuments in calcareous grassland, including barrows and deserted medieval villages.

2.11.4 An understanding of the evolution and dynamics of calcareous grassland is essential to its conservation and enhancement. Concern over its continuing loss, fragmentation and deterioration has led to a range of studies related to the impacts of land use and environmental agents of change, and to research into how calcareous grassland can be conserved, restored and re-created. Management schemes so far have concentrated on the conservation of the best-surviving areas of calcareous grassland habitat, especially because damaged and degraded calcareous grassland may never be capable of being restored from an ecological point of view. However, in terms of future policy formulation, restoration and re-creation of calcareous grassland may be equally relevant, because of the potential to generate wider scenic, amenity and historical benefits.

2.11.5 This is the background to the present study. The remainder of the Report attempts for the first time to create a national definition of existing and potential calcareous grassland, to assess its extent and quality and threats to its survival, and hence to inform policy-makers.

Chapter 3 DEFINING THE CALCAREOUS GRASSLAND MASK

3.1 Introduction

3.1.1 Although a description of calcareous grassland has been derived (Section 2.2), data have not been collected in a consistent manner to allow the definitive national distribution of calcareous grassland to be mapped. At the outset of this project, the available information had not been comprehensively compiled, although the English Nature data were being brought together with a view to mapping distributions in England. However, the information available forms a useful check against the geographical information system procedures described below.

3.2 Defining the calcareous grassland mask

3.2.1 The calcareous grassland mask (see Box 1.1) was based on a sample of 1 km squares in England containing existing and potential areas of calcareous grassland habitat. This database, and the landscape map derived from it, was derived by using a geographical information system (GIS) to combine data on geology and drift deposits to identify areas of England with characteristics suitable for supporting these grassland habitats. The rationale and methodology behind the derivation of the database are described in this Section.

3.2.2 The criteria used to develop the database were that it should:

- cover areas of existing calcareous grassland and areas with potential to become calcareous grassland;
- be based on the 1 km square National Grid framework.

3.2.3 Areas with potential to become calcareous grassland were included to allow for the possibility of these habitats becoming more common in the future. These grasslands were once extensive in some parts of the country, but changes in land use have led to the disappearance and fragmentation of the habitat. However, it is possible that this decrease may not continue and that, in some areas of England, calcareous grasslands could begin to increase. Vestiges of calcareous grasslands can still be found in other land cover types, such as pastures and roadside verges, and with changes in land use and agricultural practice some of these areas may change back to good-quality chalk or limestone grassland. In addition, a widespread interest in grassland re-creation within such schemes as Countryside Stewardship and Environmentally Sensitive Areas also offers the financial means for direct re-creation of calcareous grasslands, even in areas which are currently arable or improved grassland and which have no remaining species characteristic of calcareous grassland.

3.2.4 The steps taken to define the 1 km map of calcareous grassland landscapes ('the calcareous mask') were:

i. to agree a working definition of calcareous grassland;
ii. to develop criteria for identifying areas of potential calcareous grassland;
iii. to obtain the datasets relevant to the criteria developed in (ii), and use GIS technology to identify and map 1 km squares in England which already support or have some potential to support the calcareous grassland types defined in (i);
iv. to validate the map and, if necessary, modify procedures (i)–(iii);
v. to produce a database of potential calcareous landscape areas for use in other parts of the project and for inclusion in the DOE's Countryside Information System.

3.3 Calcareous grassland potential

3.3.1 Areas of potential calcareous grassland were identified by using a combination of data on solid geology and quaternary deposits. Solid geology provides a good coarse area boundary definition as the light, friable, well-

Figure 3.1 The chalk and limestone mask for England
Left – chalk=black, oolitic limestone=dark green, massive limestone= pale green
Right – designated areas = black

drained soils which characterise chalk grassland areas are dependent to a large extent on the underlying geology. Simplified digitised versions of the 1:625 000 British Geological Survey solid geology and quaternary maps (drift geology) of Britain were employed. Using these data, a 1 km resolution map was defined by:

i. identifying 1 km squares dominated by marine limestones, oolitic and friable limestones, and metamorphic limestones;
ii. modifying the map, using quaternary drift deposits (excluding loess) to exclude squares where the rocks are overlain with non-calcareous soils;
iii. expanding the area defined in (ii) by adding any adjacent 1 km squares containing steep slopes – this step was taken improve the coverage of sites found on escarpments;
iv. excluding squares with more than 75% urban land (as measured from the 1:250 000 Ordnance Survey maps).

3.3.2 Work has been carried out to validate the calcareous grassland mask through comparisons with other information. A description of this work is given in Appendix 1; the overall conclusion is that, although there are some mismatches between the calcareous grassland mask and other datasets, the fit was judged to be acceptable for the purposes of this project.

3.4 The calcareous grassland mask – outputs

3.4.1 The calcareous grassland mask covers 26 555 1 km squares in England (Figure 3.1). The National Grid references of these squares are available as a dataset, eg for use in the DOE's Countryside Information System.

3.4.2 These data have been used as the framework for the field sampling programme described in Chapter 4 and the modelling of atmospheric inputs described in Chapter 6.

Chapter 4 ECOLOGICAL CHARACTERISTICS OF THE CALCAREOUS GRASSLAND MASK

4.1 Introduction

4.1.1 The methods used to define the calcareous grassland mask are described in Chapter 3. This Chapter describes the field survey which was completed in order to characterise the mask in terms of ecological components, such as land cover, landscape features and vegetation.

4.2 Sampling strategy

4.2.1 The calcareous grassland mask was stratified to ensure that the sample of surveyed squares was representative, and to allow comparison between calcareous grassland landscapes in different parts of the country, and between calcareous grassland types in designated and non-designated areas. The four strata are:

i. designated, hard limestone
ii. designated, soft limestone
iii. non-designated, hard limestone
iv. non-designated, soft limestone

4.2.2 'Hard' and 'soft' limestone were defined according to geology types extracted from geological maps (see Chapter 3). For the purposes of the project, the hard limestones were taken to include the Silurian, Devonian and Carboniferous limestones, and the soft limestones the Permian and Jurassic limestones and the Cretaceous chalk. The soft limestones occur largely in the south and east, where soils have been improved to provide large areas of intensive agriculture. The hard limestones are found mostly in the north; they are associated with less intensive livestock production. In areas of high rainfall, the soils are often leached and do not bear typical calcareous vegetation.

4.2.3 'Designated' refers to the presence in all or part of a 1 km square of one of the following designations, according to a database compiled by ITE in 1988:

- Site of Special Scientific Interest (SSSI),
- National Nature Reserve (NNR),
- National Park (NP),
- Area of Outstanding National Beauty (AONB),
- Heritage Coast (HC),
- Green Belt (G Belt),
- Environmentally Sensitive Area (ESA).

These designations have varied objectives and were defined on the basis of different criteria, ranging from the conservation of rare species to landscape value. Some cover small homogeneous areas such as NNRs, whilst others are large and varied, like National Parks. They are administered by a range of bodies including English Nature, the Countryside Commission, the Ministry of Agriculture, Fisheries and Food, wildlife conservation trusts and local authorities.

4.2.4 The presence of a 1 km square in the designated strata indicates that at least some part of the square has at least one designation – in interpreting the following results it should be remembered that not all of the square is necessarily designated, so the area of the designated strata, and areas of land cover types within it, may be over-estimates. This is mainly relevant to designations which affect small areas, eg SSSIs. Further, some designations are not directly related to the calcareous nature of the vegetation.

4.2.5 The sampling unit, as for Countryside Survey 1990, is a 1 km square. Within each stratum, 1 km squares were chosen at random for field survey. A total of 43 squares were surveyed in 1993, from the calcareous grassland mask. A further 49 squares surveyed during Countryside Survey 1990 fell within the calcareous grassland mask; data have been extracted from these squares, and incorporated into the analysis. In addition, 13 heath, 11 upland and 24 coastal squares from surveys of other threatened habitats fell within the calcareous grassland mask; quadrat data from these squares have been used in producing vegetation classifications (see para 4.4.2) to improve the representation of these vegetation types, but have not been included in the quantitative analysis of quality measures, as they were not part of the original sample.

4.2.6 The results from the sample squares have been used to calculate estimates for the calcareous grassland mask as a whole. They are also presented as subtotals for the combined designated, non-designated, hard and soft limestone strata. These subtotals, and the overall total for the defined calcareous grassland mask are derived from the sample by weighting according to stratum area. The area of land in each stratum, and the number of sample squares in each, is shown in Table 4.1.

Table 4.1 The number of squares in the calcareous grassland mask and the number in the field survey sample

Strata designation	Lime-stone	Area of land km²	%	Number of sample km squares 1990	1993	Total	%
Designated	Hard	4630	*18*	10	11	21	*23*
	Soft	10751	*41*	25	15	40	*43*
Non -designated	Hard	2429	*9*	4	9	13	*14*
	Soft	8533	*32*	10	8	18	*20*
Total		*26343*	*100*	*49*	*43*	*92*	*100*

4.3 Field survey

4.3.1 Land cover was recorded at 16 points on a grid within each field survey square, rather than mapping the whole square as in Countryside Survey 1990 (Barr *et al.* 1993). Each grid point was accurately located on the ground and the land cover of the parcel of land (ie area of relatively homogeneous land cover) in which each point fell was recorded (code numbers were described in a field handbook). The nearest field boundary (within 100 m of each grid point) was also recorded.

4.3.2 For the squares which had already been recorded as part of the CS1990 survey, the same approach was used in that a grid of 16 points was placed over a map of each square and relevant data were extracted from associated databases.

4.3.3 Quadrats were recorded to provide quantitative botanical information about the areas in the sample squares which support, or could support, calcareous grassland. All the plant species present in the quadrats were recorded, together with cover estimates. These quadrats were permanently marked, to provide a baseline for future monitoring. Three different types of quadrats were recorded.

Main plots: 2 m x 2 m quadrats were recorded at up to five randomly chosen grid points, to provide a representative sample of semi-natural vegetation. If the vegetation at these points was intensively managed (arable or intensive grassland which had been reseeded or heavily fertilized), then no quadrat was recorded.

Habitat plots: five 2 m x 2 m quadrats were also recorded in each survey square, in the less common habitats which were not represented by the main plots. The use of these targeted plots ensured that, if any unimproved calcareous grassland occurred in the survey square, then it was recorded within a quadrat.

Verge plots: five 10 m x 1 m plots were recorded on road or track verges. The plot was placed parallel to the road to record the metre strip of verge nearest to the road, but, where the verge was more than 2 m wide, additional species were also recorded in the second metre, beyond the first, to include species which were not mown as often. Two of the verge plots

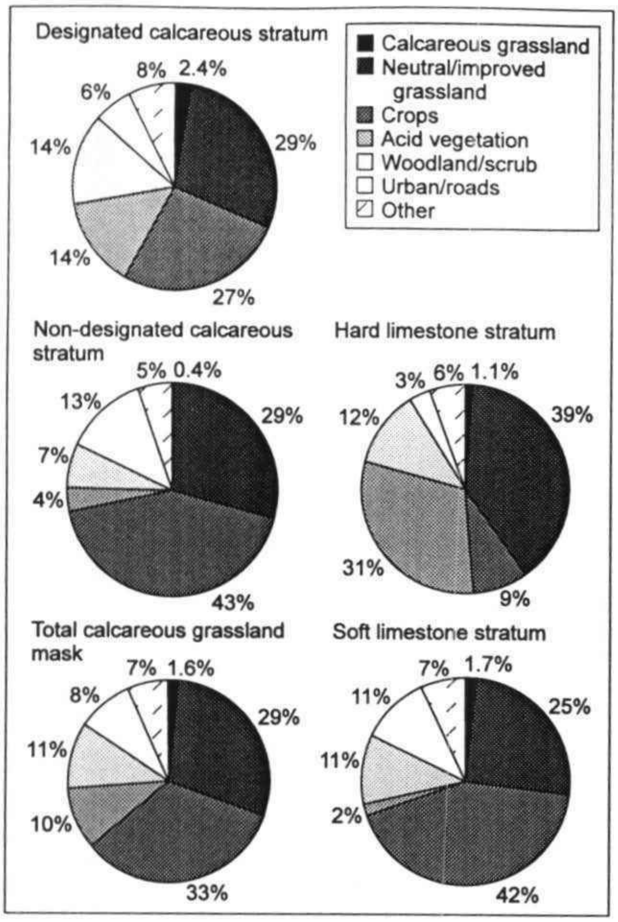


Figure 4.1 Estimates of the percentage area of each land cover type in the calcareous grassland mask, based on description of land cover at the 16 grid points in each sample square

were randomly located, the other three were placed so as to ensure tracks, minor roads, and major roads were all sampled.

4.3.4 Main plots, habitat plots and verge plots were also recorded in Countryside Survey 1990. In 1990, the main plots were 200 m², but an inner 2 m x 2 m nested quadrat was recorded separately and information from this inner plot has been extracted to supplement data from the 1993 plots.

4.3.5 Care was given to maintaining quality in field recording and to minimising variation between surveyors. A field handbook was produced to provide a reference source for surveyors in the field, and a training course was run.

4.4 Field survey results: land cover

4.4.1 The land cover at 16 grid points in each 1 km sample square has been used to estimate the area of each land cover type in the four strata (Figure 4.1). Land cover has been aggregated into 15 types for presentation here, but aggregations into more or fewer categories are possible.

The land cover estimates for each stratum and for combined strata are given in Appendix 2.

4.4.2 About 1.6% of the calcareous grassland mask was defined as true calcareous grassland (defined as including a high proportion of plant species associated with calcareous soils), and 90% occurred in designated strata. Soft limestone was much more extensive in England than hard limestone, so it was expected that a greater area of calcareous grassland would be recorded on chalk and friable limestone. However, calcareous grassland also occupies a greater proportion of soft limestone area, 1.7% compared to 1.1% of the hard limestone. Thus, although a greater proportion of the soft limestone area is intensively managed (see below), it still contains a higher proportion of calcareous grassland than the hard limestone, which, although being less intensively managed, is often heavily leached and so does not always support calcareous vegetation.

4.4.3 Crops made up 42% of the soft limestone strata, compared with 9% of the hard limestone areas; this reflects the more intensive agricultural management practised on chalk in the lowlands compared to the hard limestone areas, which are mostly upland. Crops were more common in the non-designated, compared to the designated, strata (43% to 27%) for both limestone types, but this difference was most apparent on the hard limestone (22% to 2%).

4.4.4 Neutral or improved grassland made up 25% of the soft limestone area, compared to 39% of the hard limestone strata. There was little difference in the proportion found in the designated and non-designated strata. Crops and neutral/improved grass taken together make up 47% of the hard limestone areas, compared to 68% of the soft limestone areas, reflecting the more intensive agricultural management in the lowland areas.

4.4.5 Acid vegetation occurred mainly on the hard limestone: 89% of the acid grass/bracken, 100% of the moorland grass, 100% of bogs. The exception was the heathland category, of which 52% occurred on the soft limestone – this included some of the heath areas of East Anglia where acid soils overlay calcareous geology. High

Table 4.2 Abundance of boundaries in the calcareous grassland mask

Strata	% of points without boundaries	% of points with boundaries
Designated hard	29	71
Designated soft	44	56
Non-designated hard	14	86
Non-designated soft	23	77
Total	*32*	*68*

proportions (*c* 80%) of the acid vegetation types occurred within designated strata.

4.4.6 Woodland/trees and scrub made up approximately 10% of both soft and hard limestone landscapes, and were more common in the designated strata. Urban land and rail/road/tracks made up a more significant element of the soft limestone landscapes (11%) compared to the hard limestone areas (3%), and were more common in the non-designated strata.

4.5 Field survey results: boundaries

4.5.1 The proportion of different boundary types recorded in the calcareous grassland mask is shown in Figure 4.2. The proportion of points with and without a boundary within 100 m is shown in Table 4.2. More detailed figures are given in Appendix 2. Field boundaries were more common in the hard limestone landscapes and in the designated areas; this may reflect field size and/or the presence of urban land. Fences were by far the most frequent boundary type; in hard limestone areas they were often

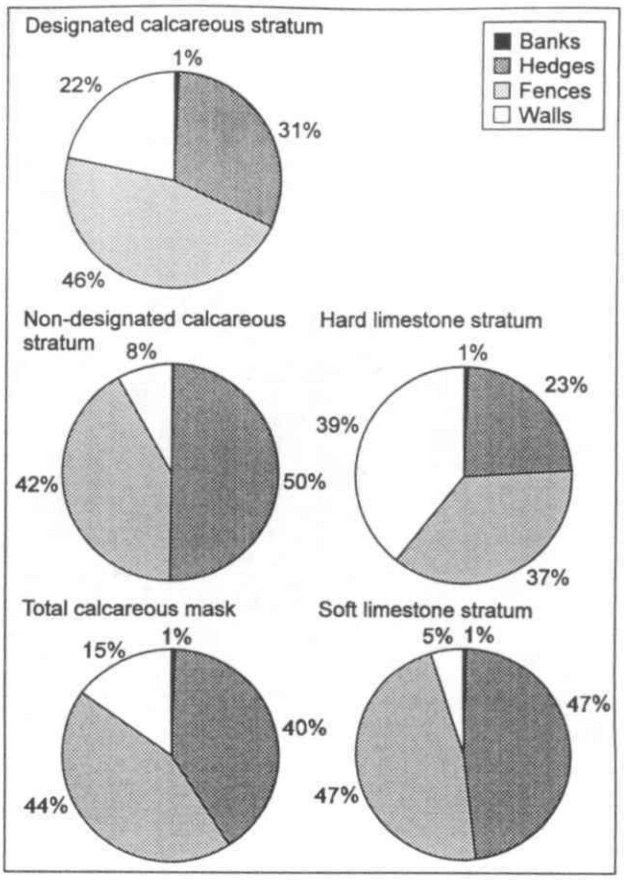


Figure 4.2 Proportion of boundary types in the calcareous grassland mask

associated with walls, in the soft limestone areas with hedges.

Summary of land cover and boundary results

4.5.2 Figure 4.3 shows the proportion of land cover types estimated to be in designated and non-designated areas, and on hard and soft limestone. The designated strata

Table 4.3 Comparison of land cover estimates for the calcareous grassland mask with those for England as a whole

Land cover	Calcareous grassland mask Area (km²)	SE	%	England Area (km²)	SE	%
Calcareous grass	413	122	1.6	415	208	0.3
Neutral/improved grass	7624	747	28.9	36728	3050	29.1
Recreational grass	369	150	1.4	2127	432	1.7
Crops	8756	875	33.2	43878	6175	34.8
Unmanaged grass/tall herbs	444	100	1.7	1699	174	1.3
Acid grass/bracken	863	217	3.3	2907	513	2.3
Moorland grass	895	247	3.4	2833	627	2.2
Heathland/bog	807	371	3.1	5818	1236	4.6
Waterside	168	70	0.6	2651	832	2.1
Woodland/trees	2608	424	9.9	12620	1512	10.0
Scrub	304	90	1.2	621	83	0.5
Rail/road/track	938	170	3.6	3466	227	2.7
Structures/curtilage	1384	378	5.3	8981	1252	7.1
Other	770	156	2.9	1348	589	1.1
Total	*26343*	*4117*	*100.0*	*126092*	*16910*	*100.0*

Calcareous grassland mask land cover estimates are based on information from 16 grid points in key habitat sample squares
Estimates for England are based on habitat maps from CS1990 sample squares

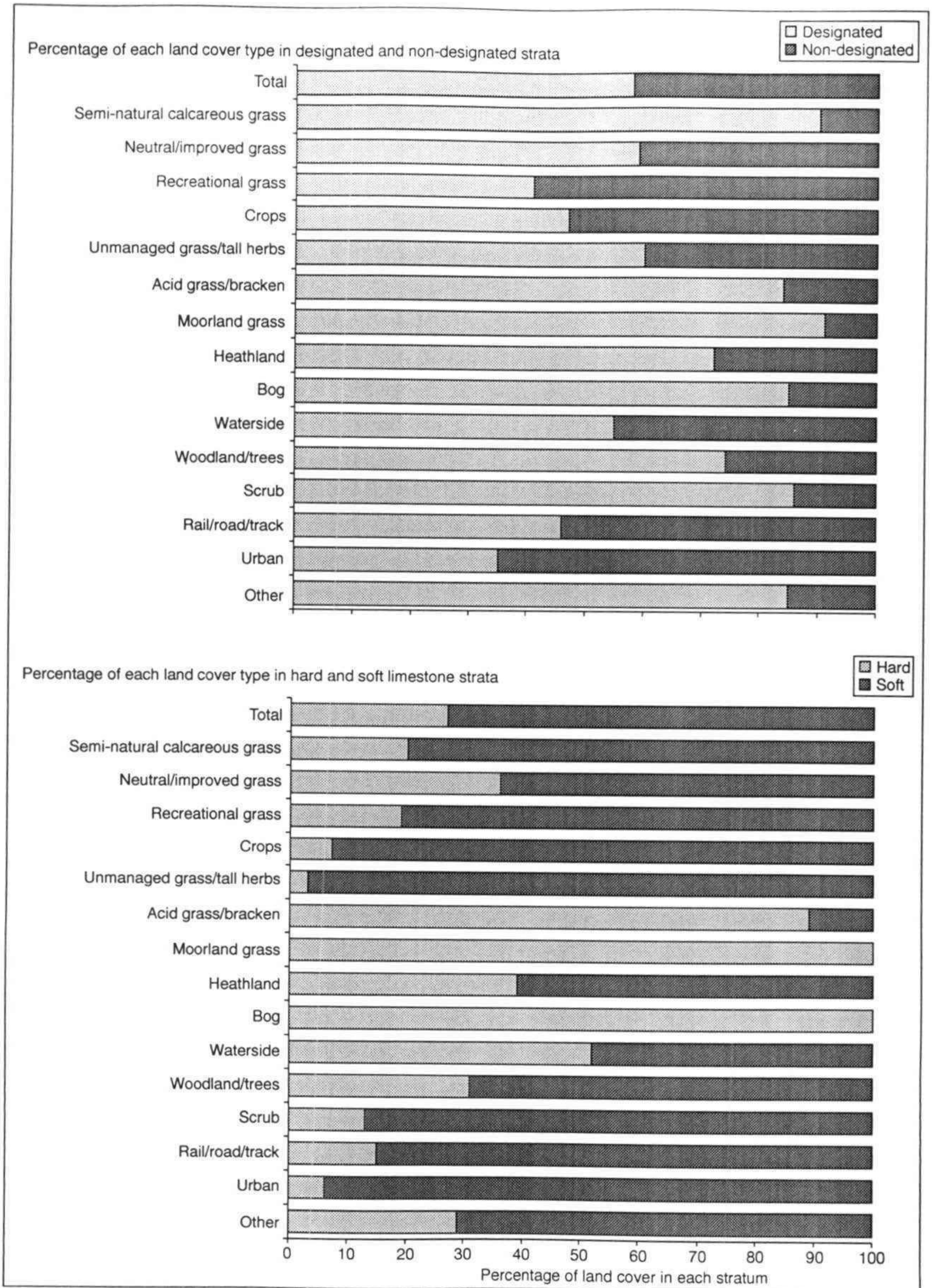


Figure 4.3 Percentage of land cover types in the calcareous grassland mask

include 90% of the calcareous grassland and also have a greater proportion of other semi-natural habitats, eg acid grassland, heathland, and woodland. The non-designated strata have more non-vegetated land, eg built-up land and communication routes. The hard limestone strata have a much greater proportion of acid upland vegetation types, eg moorland grass and bog, whilst the soft limestone areas have more crops, lowland grassland and woodland.

4.5.3 There are above-average amounts of calcareous grassland in the mask compared with England as a whole, but all other cover types occur in similar proportions (Table 4.3).

4.6 Vegetation sampling and analysis

4.6.1 The land cover data (as described in Section 4.3) represent the major vegetation categories and provide a baseline against which quantitative estimates of change can be made. To examine the more subtle changes that may take place as a result of new management or changing environmental conditions, the balance of vegetation species within the major land cover types needs to be recorded. To do this, species were recorded within quadrats. Two broad types of analysis have been carried out: first, quadrats have been analysed according to the species they contain, and, second, the species have been analysed according to their frequency of occurrence in quadrats.

Analysis of quadrats: 'structural types' and plot classes'

4.6.2 Quadrats were recorded from 60 of the sample squares; in the other 45 sample squares the grid points did not fall on vegetation which met the criteria for recording quadrats, ie it was arable or non-acid grassland (para 4.3.3). In some of these squares, lowland heath was present but was not recorded at any of the 25 grid points. The absence of lowland heath at grid points from such a high proportion of the survey squares may reflect the distribution characteristics of lowland heath which occurs in large blocks in relatively few areas of the country. A sampling scheme based on a 1 km square resolution, while appropriate for the mask as a whole, picks up few areas of lowland heath.

Table 4.4 Calcareous grassland mask 'plot classes'
A classification derived from a multivariate analysis of quadrat data (using TWINSPAN)

Principal gradient score	Plot class	Name
115	PCA	Fertile grassland, with annual weeds
127	PCB	Fertile grassland, overgrown, often shaded
156	PCC	Calcareous woodland, eutrophic, often woodland edge
156	PCD	Tall, coarse grassland, open
165	PCE	Eutrophic grassland, often neglected
171	PCF	Intensive grassland, Lolium-dominated, often disturbed
175	PCG	Eutrophic grassland, overgrown, tall herbs, often shaded/wet
201	PCH	Fertile grassland, short, often disturbed
208	PCI	Calcareous woodland, mainly ash
212	PCJ	Neutral/basiphilous grassland, tall with herbs
215	PCK	Neutral/basiphilous grassland, short, mown or grazed
227	PCL	Basiphilous/calcareous grassland, tussocky with herbs
266	PCM	Basiphilous woodland, more open, grassy
284	PCN	Neutral permanent pasture
286	PCO	Calcareous grassland, short-turf, grazed, with small herbs
292	PCP	Neutral grassland, semi-improved, grazed or mown
305	PCQ	Neutral grassland, unimproved, light/no grazing, some shading
309	PCR	Marsh/rushy pasture
337	PCS	Neutral/acid woodland, bramble-dominated
369	PCT	Northern calcareous
378	PCU	Northern, damp pasture, often with flushing/streamsides
427	PCV	Acid grassland, often rushy
491	PCW	Dry grassland/heath
498	PCX	Bracken/dry heath, often shaded
545	PCY	Moorland grass, moist
593	PCZ	Mossy heath, often planted with Sitka spruce (*Picea sitchensis*)
655	PCAA	Mire
672	PCBB	Wet heath/bog
*	PCCC	Mostly saltmarsh

Plot classes including unimproved calcareous grassland vegetation are shaded. See Appendix 2 for more information on plot classes
* Saltmarsh plots were excluded from the analysis

4.6.3 Two types of analysis have been carried out using the quadrat data: allocating the quadrats to structural vegetation types, and classifying quadrats into plot classes.

4.6.4 The quadrats have been aggregated according to vegetation type, based on quadrat descriptions, into broad groups called 'structural types':

- Verges
- Calcareous grassland
- Neutral/improved grassland
- Unmanaged grassland/tall herbs
- Acid grass/dry heath
- Wet heath/bogs
- Marsh/flushes
- Aquatic/streamsides
- Trees/scrub/hedges
- Woodland/glades

4.6.5 The quadrats have also been classified statistically into 'plot classes' based on species composition (using a standard multivariate technique, TWINSPAN) (Table 4.4). This classification has been produced using data from all the calcareous survey squares from 1990 and 1993. In addition, quadrat data from squares surveyed in the upland and coastal landscapes have also been included, where they overlap with the calcareous grassland mask, in order to provide more replicates of coastal and upland calcareous vegetation. The effects of including quadrats of different sizes have been investigated (main plots from 1990 squares are 200 m^2, those from 1993 squares are 4 m^2, all habitat plots are 4 m^2, verge plots are 10 m^2); the differences between quadrats of different size are less than the differences between the vegetation types, and it was concluded that the best classification arose from including the maximum amount of information. Further details of the plot classes are given in Appendix 2.

Analysis of species : 'habitat indicator groups' and 'species groups'

4.6.6 Species have been allocated to **'habitat indicator groups'**, based on expert knowledge of individual species ecology, to identify the extent to which the species are associated with calcareous grassland (Box 4.1).

Box 4.1

Calcareous grassland species,
eg *Cirsium acaule, Plantago media*
Base-rich grassland species,
eg *Lotus corniculatus, Trisetum flavescens*
Neutral grassland species,
eg *Dactylis glomerata, Trifolium repens*
Damp grassland species,
eg *Deschampsia cespitosa, Filipendula ulmaria*
Acid vegetation species,
eg *Potentilla erecta, Galium saxatile*
Woodland species,
eg *Glechoma hederacea, Fraxinus excelsior*
Scrub/woodland edge species,
eg *Rubus fruticosus, Crataegus monogyna*
Weed and alien species,
eg *Urtica dioica, Cirsium arvense*
Maritime species,
eg *Elymus pycanthus, Halimione portulacoides*
Marsh and aquatic species,
eg *Juncus articulatus, Stellaria alsine*

4.6.7 A multivariate statistical classification into **'species groups'** has been produced which groups species with similar distributions across the quadrat dataset, using DECORANA and Ward's Minimum Clustering. The rare species (frequency <2%) have been excluded from the classification, because there is insufficient information to allow them to be allocated correctly. The quadrats from woodland, grassland and acid vegetation plot classes (see para 4.4.3) have been analysed separately, species groups being produced for each of the three habitats. This has been done because some species occur in more than one of these habitat types and are associated with different species in the different situations. The species groups are listed in Table 4.5, along with the individual species which occur most frequently.

4.6.8 Species from the 'calcareous grassland habitat indicator group' have been identified as being sensitive to particular threats (based on expert knowledge of species ecology), ie species which quickly disappear in the presence of:

i. succession, ie colonisation by tree species resulting in scrub or woodland,
ii. eutrophication, resulting from deposition, runoff, or application of fertilizers.

The presence of species from these 'sensitivity indicator groups' implies that the vegetation in which they occur has not been subject to these pressures.

Assessment of vegetation quality

4.6.9 These classifications of quadrats and species will be used to describe the types of vegetation in the four strata, and to compare them in terms of selected quality criteria.

4.6.10 The use of quality criteria to provide a comparative assessment of sites by other studies is discussed in Appendix 2 (Box A2.1). In this project, objective measures of vegetation have been related to quality criteria, to provide an empirical evaluation of the quality of heathland vegetation in different parts of the heathland landscape. Each criterion emphasises a particular aspect of quality, but they do inter-relate, and should not be considered as mutually exclusive. The following discussion of vegetation in terms of quality criteria is based on species information from quadrats, and makes use of the classifications described above (Section 4.4). The following quality criteria are considered in turn: size, diversity, naturalness, representativeness, rarity, fragility and potential value.

4.7 Vegetation quality: size/ abundance

4.7.1 Large size is usually considered a positive quality, for a number of reasons. Each species has a minimum area (or resource) which is necessary to maintain a viable population. There is a relationship

Table 4.5 Species groups derived from the calcareous grassland mask quadrat data (derived from a multivariate analysis of the quadrat data, using DECORANA)

Species group	Description	Typical species
Grassland		
G1	Eutrophic coarse grassland species	*Arrhenathrum elatius, Elymus repens*
G2	Annual weeds in *Lolium*-dominated grassland	*Lolium perenne, Plantago major, Poa annua*
G3	Basiphilous shaded grassland species	*Rubus fruticosus, Potentilla reptans, Glechoma hederacea*
G4	Neutral managed grassland species	*Poa trivialis, Cirsium arvense, Phleum pratense*
G5	Moist tall herb grassland species	*Lathryus pratensis, Filipendula ulmaria*
G6	Tall calcareous grassland species	*Medicago lupilina, Bromopsis erecta*
G7	Managed grassland species from heavy soils	*Agrostis stolonifera, Holcus lanatus, Ranunculus repens*
G8	Grazed/mown mesotrophic grassland species	*Dactylis glomerata, Festuca rubra, Taraxacum* agg.
G9	Semi-improved neutral grassland species	*Trifolium repens, Cerastium fontanum, Agrostis capillaris*
G10	Heavily-grazed calcareous grassland species	*Prunella vulgaris, Senecio jacobaea, Carex flacca*
G11	Grazed calcareous grassland species	*Lotus corniculatus, Briza media, Ranunculus bulbosus*
G12	Mildly acid marsh species	*Cirsium palustre, Calliergon cuspidatum*
G13	Acid flush species	*Juncus effusus, Cardamine pratensis*
G14	Grazed low-nutrient grassland species	*Festuca ovina, Veronica officinalis*
Woodland		
W1	Calcareous species	*Rubus fruticosus, Fraxinus exelsior, Hedera helix*
W2	Calcareous species, on clays	*Fagus sylvatica, Melica uniflora,*
W3	Disturbed eutrophic species, on humus-rich soils	*Urtica dioica, Galium aparine, Geum urbanum*
W4	Woodland clearing species	*Agrostis stolonifera, Holcus lanatus, Rosa* sp.
W5	Woodland edge species, disturbed	*Dactylis glomerata, Taraxacum* agg., *Veronica chamaedrys*
W6	Basiphilous species, on heavy soils	*Mercurialis perennis, Hyacinthoides non-scripta*
W7	Mildly acid species, on gleys	*Viola riviniana/reichenbachiana, Quercus* sp., *Dryopteris dilatata*
W8	Mildly acid species, on brown earths, often moist	*Holcus mollis, Silene dioica*
W9	Acid species	*Oxalis acetosella, Digitalis purpurea, Stellaria holostea*
Acid vegetation		
A1	Scrub/bracken/shade-tolerant species	*Pteridium aquilinum, Rumex acetosella*
A2	Acid grassland species	*Festuca ovina, Galium saxatile, Agrostis capillaris*
A3	Moss/lichen heath species	*Lophocolea bidentata, Cladonia cholorophaea*
A4	Moorland species	*Deschampsia flexuosa, Vaccinium myrtillis, Pleurozium schreberi*
A5	*Sphagnum* lawn species	*Sphagnum recurvum, Aulocomnium palustre*
A6	Mire species	*Polytrichum commune, Juncus squarrosus, Carex nigra, Molinea caerulea*
A7	Blanket bog species	*Calluna vulgaris, Eriophorum angustifolium, Eriophorum vaginatum*

Species groups including unimproved calcareous grassland species are shaded

Table 4.6 The mean number of main plots and verge plots, per square, in the calcareous grassland mask, by strata

Strata	Mean no. of main plots per square	Mean no. of verge plots per square
Designated hard	4.38	3.14
Designated soft	1.80	4.93
Non-designated hard	2.92	5.00
Non-designated soft	1.39	5.00
Combined designated	2.58	4.39
Combined non-designated	1.73	5.00
Combined hard	3.88	3.78
Combined soft	1.62	4.96
Total	*2.22*	*4.64*

These figures represent the mean number of quadrats per square, including those squares where no quadrats were recorded. Figures for combined strata are weighted by stratum size

between area and species diversity affected by population size, extinction and immigration rates. Large sites provide a buffered 'edge' between the central core of the site and adjacent land, which helps to protect the core from disturbance, runoff, spray drift, etc. Larger sites usually (but not always) contain a greater range of environments, reflected in a greater diversity of species. In the lowlands of England, where semi-natural habitats tend to be highly fragmented, size is likely to be an important criterion. Not only the size of individual units of calcareous grassland need to be considered, but also the extent of associated semi-natural vegetation.

Average area of semi-natural vegetation per 1 km square

4.7.2 Overall, more calcareous grassland vegetation (ie meeting the criteria for recording quadrats) was found in squares in the designated strata compared to those in the non-designated strata (Table 4.6). However, there were differences between the strata and between plot types. The number of main plots gives an indication of the area of land in the calcareous grassland mask which is not intensively managed. The Table shows that more vegetation met the criteria for recording plots in the hard limestone areas than in the soft ones; this is related to the larger areas of semi-natural vegetation, often in unenclosed areas, on the hard limestone (see Section 4.3). There are also more plots recorded in the designated strata, again related to the larger areas of semi-natural vegetation in these areas. The mean number of verge plots recorded per square, in each stratum, gives an indication of the prevalence of tracks and roads in each stratum. More verge plots were recorded in squares on soft limestone, and in non-designated strata.

Variation in the area of semi-natural vegetation, and calcareous grassland, per km square

4.7.3 Figure 4.4 shows the frequency distribution for the number of main plots (randomly located) recorded in each km square (out of a maximum of five), in each stratum. This gives an indication of the proportion of each square which was arable or intensive grassland, and so did not meet the criteria for recording quadrats. The maximum five plots were recorded in most squares in the designated hard stratum, reflecting the scarcity of intensively managed land in these areas (see Section 4.3). In the soft limestone areas fewer main plots were recorded, reflecting the greater areas of arable and intensive grassland.

Association between calcareous grassland and other vegetation types

4.7.4 Table 4.7 shows the number of main and habitat plots recorded on calcareous grassland (defined using the structural

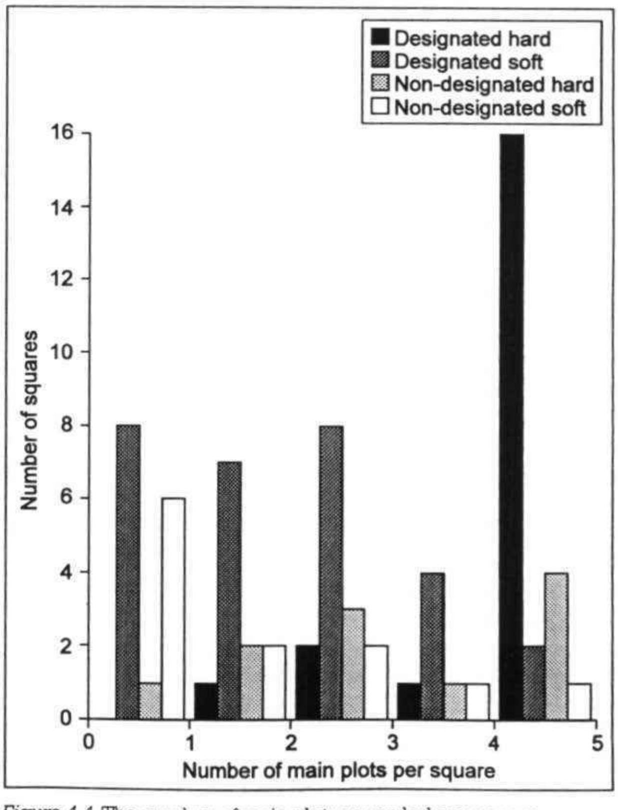


Figure 4.4 The number of main plots recorded per square

Table 4.7 Number of main and habitat plots recorded in calcareous grassland (structural classification)

Strata	No. of survey squares	Squares with main plots in calcareous grassland No. of squares	%	No. of plots	Squares with habitat plots in calcareous grassland No. of squares	%	No. of plots
Designated hard	21	2	*10*	2	5	*24*	10
Designated soft	40	6	*15*	9	20	*50*	36
Non-designated hard	13	0	*0*	0	2	*15*	2
Non-designated soft	18	1	*6*	1	3	*17*	4
Combined designated	61	8	*13*	11	25	*41*	46
Combined non-designated	31	1	*3*	1	5	*16*	6
Combined hard	34	2	*6*	2	7	*21*	12
Combined soft	58	7	*12*	10	23	*40*	40
Total	*92*	*9*	*10*	*12*	*30*	*33*	*52*

classification – see para 4.4.1). Only 12 (of a possible 1104 = 1%) of the randomly located main plots fell on to calcareous grassland. This demonstrates the scarcity of this vegetation type, despite the large area where the geology and soils are suitable. The use of the non-random habitat types ensured a better representation; 52 habitat plots were recorded on calcareous grassland, from 30 sample squares. Of the squares in which quadrats were recorded on calcareous grassland, 83% contained a designation, 77% were on soft limestone. There appears to be no significant relationship between the presence of calcareous grassland in a square and the presence of woodland. However, on hard limestone, there was an inverse relationship between the presence of acid vegetation and calcareous grassland.

Relative abundance of structural types

4.7.5 Table 4.8 shows the mean number of quadrats in each structural type for each stratum. Figure 4.5 shows the mean number of main plots and habitat plots recorded in each type of calcareous grassland mask. 'Calcareous grassland' was recorded most frequently in the designated and soft strata, by both main plots and habitat plots. A higher proportion of habitat plots was recorded in calcareous grassland compared to main plots, showing that it was often present in fragments too small to be recorded by randomly located plots; this reflects the scarcity and largely fragmented distribution of unimproved calcareous grasslands within the much larger areas of suitable geology.

4.7.6 More common were the 'neutral/improved grassland' quadrats, especially in the hard and non-designated strata. 'Unmanaged

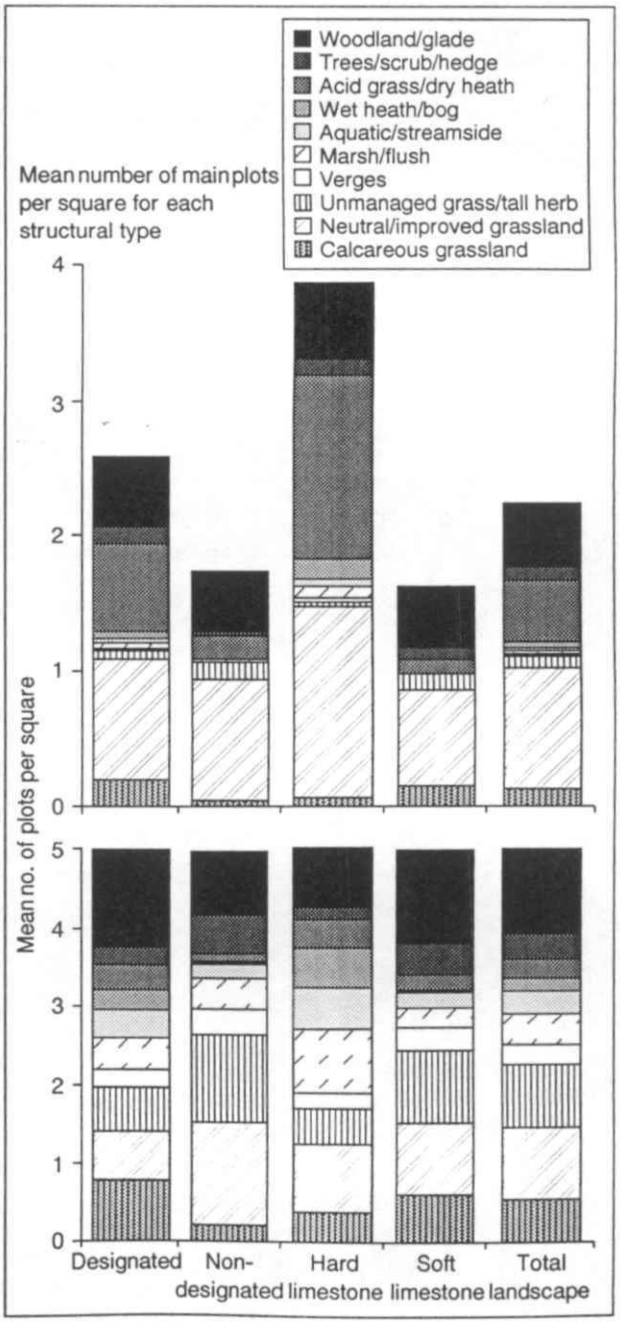


Figure 4.5 Abundance of structural types in the calcareous grassland mask

Table 4.8 Mean number of quadrats per square in each structural type, for each strata of the calcareous grassland landscape

	Designated				Non-designated				Combined											
	Hard		Soft		Hard		Soft		Designated		Non-des		Hard		Soft		Total	
Structural type	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Main plots (4 m²)																		
Calcareous grassland	0.10	*2*	0.23	*13*	0.00	*0*	0.06	*4*	0.19	*7*	0.04	*2*	0.06	*2*	0.15	*9*	0.13	*6*
Neutral/improved grassland	1.38	*32*	0.68	*38*	1.46	*50*	0.72	*52*	0.89	*34*	0.89	*51*	1.41	*36*	0.70	*43*	0.89	*40*
Unmged grass/tall herb	0.05	*1*	0.08	*4*	0.00	*0*	0.17	*12*	0.07	*3*	0.13	*8*	0.03	*1*	0.12	*7*	0.09	*4*
Verges	0.05	*1*	0.00	*0*	0.00	*0*	0.00	*0*	0.01	*0*	0.00	*0*	0.03	*1*	0.00	*0*	0.01	*0*
Marsh/flush	0.14	*3*	0.00	*0*	0.00	*0*	0.00	*0*	0.04	*2*	0.00	*0*	0.09	*2*	0.00	*0*	0.03	*1*
Aquatic/streamside	0.10	*2*	0.00	*0*	0.00	*0*	0.00	*0*	0.03	*1*	0.00	*0*	0.06	*2*	0.00	*0*	0.02	*1*
Wet heath/bog	0.19	*4*	0.00	*0*	0.08	*3*	0.00	*0*	0.06	*2*	0.02	*1*	0.15	*4*	0.00	*0*	0.04	*2*
Acid grass/dry heath	1.67	*38*	0.20	*11*	0.77	*26*	0.00	*0*	0.64	*25*	0.17	*10*	1.36	*35*	0.11	*7*	0.45	*20*
Trees/scrub/hedge	0.19	*4*	0.13	*7*	0.00	*0*	0.06	*4*	0.14	*5*	0.04	*2*	0.12	*3*	0.09	*6*	0.10	*5*
Woodland/glade	0.52	*12*	0.50	*28*	0.62	*21*	0.39	*28*	0.51	*20*	0.44	*25*	0.56	*14*	0.45	*28*	0.48	*22*
Total	*4.38*	*100*	*1.80*	*100*	*2.92*	*100*	*1.39*	*100*	*2.58*	*100*	*1.73*	*100*	*3.88*	*100*	*1.62*	*100*	*2.22*	*100*
Habitat plots (4 m²)																		
Calcareous grassland	0.48	*10*	0.90	*18*	0.15	*3*	0.22	*4*	0.77	*15*	0.21	*4*	0.37	*7*	0.60	*12*	0.54	*11*
Neutral/improved grassland	0.52	*10*	0.65	*13*	1.54	*31*	1.22	*25*	0.61	*12*	1.29	*26*	0.87	*17*	0.90	*18*	0.90	*18*
Unmged grass/tall herb	0.29	*6*	0.68	*14*	0.77	*15*	1.22	*25*	0.56	*11*	1.12	*23*	0.45	*9*	0.92	*19*	0.79	*16*
Verges	0.14	*3*	0.25	*5*	0.31	*6*	0.33	*7*	0.22	*4*	0.33	*7*	0.20	*4*	0.29	*6*	0.26	*5*
Marsh/flush	0.95	*19*	0.18	*4*	0.54	*11*	0.33	*7*	0.41	*8*	0.38	*8*	0.81	*16*	0.25	*5*	0.40	*8*
Aquatic/streamside	0.67	*13*	0.23	*5*	0.23	*5*	0.17	*3*	0.36	*7*	0.18	*4*	0.52	*10*	0.20	*4*	0.28	*6*
Wet heath/bog	0.71	*14*	0.05	*1*	0.15	*3*	0.00	*0*	0.25	*5*	0.03	*1*	0.52	*10*	0.03	*1*	0.16	*3*
Acid grass/dry heath	0.38	*8*	0.30	*6*	0.31	*6*	0.06	*1*	0.32	*6*	0.11	*2*	0.36	*7*	0.19	*4*	0.24	*5*
Trees/scrub/hedge	0.05	*1*	0.30	*6*	0.31	*6*	0.56	*11*	0.22	*4*	0.50	*10*	0.14	*3*	0.41	*8*	0.34	*7*
Woodland/glade	0.81	*16*	1.45	*29*	0.69	*14*	0.83	*17*	1.26	*25*	0.80	*16*	0.77	*15*	1.18	*24*	1.07	*22*
Total	*5.00*	*100*	*4.98*	*100*	*5.00*	*100*	*4.94*	*100*	*4.98*	*100*	*4.96*	*100*	*5.00*	*100*	*4.96*	*100*	*4.97*	*100*
Verge plots (10 m x 1 m)																		
Verges	3.14	*100*	4.93	*100*	5.00	*100*	5.00	*100*	4.39	*100*	5.00	*100*	3.78	*100*	4.96	*100*	4.64	*100*

The means for the combined strata (ie subtotals and total) are weighted by stratum area

grassland/tall herb' was most common in the non-designated soft stratum. 'Marsh/flush' and 'aquatic/streamside' vegetation was most commonly recorded in the habitat plots, as these habitats are usually too small and scarce to be recorded in random plots.

4.7.7 'Acid grass/dry heath' and 'wet heath/bog' were mostly associated with the hard limestone areas. 'Woodland/glades' were frequently recorded by both main and habitat plots, especially in the soft designated stratum.

Summary of size/abundance as a quality criterion

4.7.8 The key points are that unimproved calcareous grassland was recorded infrequently (only 1% of the random main plots), even in areas with suitable soils and geology. Most unimproved calcareous grassland occurred in designated areas; although there was some in non-designated squares, it tended to be in small fragments. Although a higher proportion of the hard limestone areas was not subject to intensive agricultural practices, there was still a lower proportion of calcareous grassland present than in the more intensively used soft limestone areas. True calcareous grassland is scarce and fragmented.

4.8 Vegetation quality: diversity

4.8.1 Diversity can be expressed both as the variety of vegetation types and the number of plant species within a site, thus reflecting the range of variation in physical variables, as well as the species richness associated with each vegetation type. The number of 'plot classes' present indicates the diversity of different vegetation types or habitats; the number of 'species groups' recorded is used to assess the species richness. The number of species recorded in quadrats is not reported because it cannot be directly related to quality, without taking account of the types of species present; for example, high species number may reflect either a 'high'-quality site or one which includes ruderal species. (See para 4.9.6 for discussion of species groups).

Number of different plot classes

4.8.2 Table 4.9 uses the classification of quadrats into 'plot classes' to consider the range of vegetation present in each 1 km

Table 4.9 Mean number of different plot classes recorded per square, by strata

	Designated				Non-designated				Combined									
	Hard		Soft		Hard		Soft		Designated		Non-des		Hard		Soft		Total	
	Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean	
Plot class group	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Main plots (4 m²)																		
Woodland (PCs: C,I,M,S)	0.24	*9*	0.40	*29*	0.62	*25*	0.28	*24*	0.35	*20*	0.35	*24*	0.37	*14*	0.35	*27*	0.35	*21*
Calcareous grassland (PCs: L,O,T)	0.29	*11*	0.15	*11*	0.08	*3*	0.06	*5*	0.19	*11*	0.06	*4*	0.22	*9*	0.11	*8*	0.14	*9*
Other grassland (PCs: A,B,D-H,J,K, N,P-R,U)	1.00	*38*	0.68	*49*	1.14	*46*	0.83	*71*	0.77	*44*	0.91	*63*	1.05	*41*	0.74	*57*	0.82	*50*
Acid vegetation (PCs: V,W,X,Y,Z,AA, BB)	1.05	*40*	0.18	*13*	0.62	*25*	0.00	*0*	0.44	*25*	0.14	*9*	0.90	*35*	0.10	*8*	0.31	*19*
Maritime (PCCC)	0.05	*2*	0.00	*0*	0.00	*0*	0.00	*0*	0.01	*1*	0.00	*0*	0.03	*1*	0.00	*0*	0.01	*1*
Total	*2.62*	*100*	*1.40*	*100*	*2.46*	*100*	*1.17*	*100*	*1.77*	*100*	*1.45*	*100*	*2.56*	*100*	*1.30*	*100*	*1.64*	*100*
Habitat plots (4 m²)																		
Woodland (PCs: C,I,M,S)	0.57	*15*	0.85	*23*	0.69	*17*	0.72	*18*	0.77	*21*	0.72	*18*	0.61	*16*	0.79	*21*	0.75	*20*
Calcareous grassland (PCs: L,O,T)	0.48	*13*	0.55	*15*	0.54	*13*	0.50	*12*	0.53	*15*	0.51	*13*	0.50	*13*	0.53	*14*	0.52	*14*
Other grassland (PCs: A,B,D-H,J,K, N,P-R,U)	1.47	*40*	1.88	*52*	2.31	*57*	2.72	*67*	1.75	*48*	2.63	*65*	1.76	*46*	2.25	*59*	2.12	*55*
Acid vegetation (PCs: V,W,X,Y,Z,AA, BB)	1.19	*32*	0.28	*8*	0.54	*13*	0.11	*3*	0.55	*15*	0.21	*5*	0.97	*25*	0.20	*5*	0.41	*11*
Maritime (PCCC)	0.00	*0*	0.08	*2*	0.00	*0*	0.00	*0*	0.05	*1*	0.00	*0*	0.00	*0*	0.04	*1*	0.03	*1*
Total	*3.71*	*100*	*3.63*	*100*	*4.08*	*100*	*4.06*	*100*	*3.65*	*100*	*4.06*	*100*	*3.84*	*100*	*3.82*	*100*	*3.82*	*100*
Verge plots (10 m x 1 m)																		
Woodland (PCs: C,I,M,S)	0.00	0	0.15	*4*	0.23	*6*	0.11	*4*	0.11	*4*	0.14	*4*	0.08	*3*	0.13	*4*	0.12	*4*
Calcareous grassland (PCs: L,O,T)	0.14	7	0.23	*6*	0.31	*8*	0.06	*2*	0.20	*6*	0.12	*4*	0.20	*7*	0.15	*4*	0.17	*5*
Other grassland (PCs: A,B,D-H,J,K, N,P-R,U)	1.91	91	3.20	*89*	2.92	*77*	2.94	*95*	2.81	*90*	2.93	*90*	2.26	*85*	3.09	*92*	2.86	*90*
Acid vegetation (PCs: V,W,X,Y,Z,AA, BB)	0.05	2	0.00	*0*	0.31	*8*	0.00	*0*	0.01	*0*	0.07	*2*	0.14	*5*	0.00	*0*	0.04	*1*
Maritime (PCCC)	0.00	0	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*
Total	*2.10*	*100*	*3.58*	*100*	*3.77*	*100*	*3.11*	*100*	*3.13*	*100*	*3.26*	*100*	*2.67*	*100*	*3.37*	*100*	*3.18*	*100*

These figures represent the mean number of plot classes per square, including those squares where no plots were recorded
The figures for combined strata are weighted by stratum area

square, ie the higher the mean number of different plot classes present, the greater the variety of semi-natural vegetation. For the main plots, the proportions of plot classes are directly related to the relative abundance of vegetation types. Data from the main plots suggest that grassland plot classes contributed 59% of the diversity, but this proportion was lower in the designated and hard strata. The greatest variety of grassland plot classes occurred on the hard limestone, whilst those on soft limestone were more uniform. There were considerably more calcareous grassland plot classes (PCL – basiphilous/calcareous grassland, tussocky with herbs, PCO – calcareous grassland, short-turf, grazed, with small herbs, and PCT – northern calcareous grassland) present in the designated squares. On the hard limestone, acid vegetation types contributed much to the variety within squares, particularly in designated areas where 40% of the plot classes were of acid vegetation types. On the soft limestone, woodlands were more important as a source of additional diversity. Overall, the hard limestone areas showed significantly greater diversity of plot classes, because they included acid vegetation. Within each limestone type, there was slightly more diversity in designated areas. However, the differences between designated and non-designated sites were considerably smaller than the differences between limestone types.

4.8.3 The habitat plots were targeted towards the less abundant vegetation types, particularly calcareous grassland, where this was not sufficiently common to be recorded in main plots. Therefore, greater diversity is apparent amongst the habitat plots compared to the main plots. This is especially so for the soft limestone squares, whose habitat plots show very nearly as many plot classes present per square as the hard limestone areas. This suggests that there is a similar range of vegetation types in the soft limestone squares as in the hard limestone areas, but far fewer are sufficiently abundant to be recorded by random plots, ie the soft limestone squares are more fragmented, with small patches of some less common vegetation types. The number of calcareous grassland plot classes was very similar for all strata, but habitat plots in other grasslands show greater diversity in the non-designated strata than in the designated strata, perhaps because the latter contain fewer of the more intensively managed types.

4.8.4 The verge plots are mostly classified as grassland (95%). There were more different calcareous grassland plot classes present in the designated and hard strata. Verges in squares from the designated soft stratum have more grassland plot classes than seen in grassland main plots, ie they are more diverse than the fields. (For more detailed discussion of individual plot classes, see Section 4.9).

Number of different species groups

4.8.5 Table 4.10 uses the classification of species into 'species groups' to consider the range of different types of species present in each square. For the main plots, the proportions of species groups are directly related to their relative abundance in the squares. When all species groups are considered, the greatest diversity for main plots occurs in the squares on hard limestone, where there are nearly twice as many species groups represented in the average square. The number of calcareous grassland species groups (G6,G10,G11) was very similar across the four strata. For other grassland species groups, the difference between hard and soft limestone is greater than the difference between designated and non-designated squares, although, within each limestone type, there are more species groups present in designated squares.

4.8.6 The habitat plots were targeted towards the less abundant vegetation types, particularly calcareous grassland, where this was not sufficiently common to be recorded in main plots. Therefore, greater diversity is apparent amongst the habitat plots compared to the main plots, especially for the soft limestone squares, whose habitat plots show very nearly as many species groups present per square as the hard limestone areas. This suggests that there is a similar range of species groups in the soft limestone squares as in the hard limestone areas, but far fewer are sufficiently abundant to be recorded by random plots; ie the soft limestone squares are more fragmented with small patches of some less common vegetation types. This is the same pattern as shown above for plot classes (para 4.7.5), suggesting not only that a similar variety of vegetation types occurs in the soft limestone squares, but also that the range of species they contain is only slightly less diverse. There are slightly more calcareous grassland species groups present in the designated squares, but little difference between the hard and soft limestone strata.

4.8.7 The verge plots are mostly composed of grassland species although they do have some woodland and acid species. In terms of grassland species groups, they are more diverse than the main plots (ie the fields), especially on the soft limestone. There is little difference in the number of calcareous grassland species groups across the strata. (For more detailed discussion of individual species types see Section 4.9).

Summary of diversity as a quality criterion

4.8.8 There was a greater range of vegetation types (plot classes), and more different types of species (species groups) in the hard limestone squares than in the soft limestone ones; ie in terms of the main land cover types, the soft limestone areas appear more uniform. However, the habitat plots show little difference between hard and soft limestone in the range of plot classes and species groups present, indicating that a similar range is present in the soft limestone areas, but in many cases are much more restricted in extent. Neither of these measures provides information specifically on the quality of calcareous grassland. Comparison of species number in calcareous grassland plots is very similar between strata, which might imply that they are of similar quality. However, before this can be assessed, the types of species involved need to be considered.

Table 4.10 Mean number of different species groups per square for each stratum

Plot type	Species group type	Designated Hard	Designated Soft	Non-designated Hard	Non-designated Soft	Combined Des	Combined Non-des	Combined Hard	Combined Soft	Total
Main plots (4 m²)	Calcareous grassland (G6,10,11)	1.0	0.7	0.8	0.6	0.8	0.7	0.9	0.7	0.7
	Other grassland (G1-5,7-9,12-14)	5.7	3.5	4.2	3.2	4.1	3.5	5.2	3.4	3.9
	Woodland (W1-9)	0.9	1.9	1.9	1.0	1.6	1.2	1.3	1.5	1.4
	Acid vegetation (A1-7)	3.0	0.4	1.5	0.0	1.2	0.3	2.5	0.2	0.9
Total		*20.1*	*11.6*	*17.2*	*9.9*	*14.2*	*11.5*	*19.1*	*10.8*	*13.1*
Habitat plots (4 m²)	Calcareous grassland (G6,10,11)	2.1	2.0	1.6	1.8	2.0	1.7	1.9	1.9	1.9
	Other grassland (G1-5,7-9,12-14)	8.1	7.7	8.8	8.3	7.8	8.4	8.4	7.9	8.0
	Woodland (W1-9)	3.0	4.0	3.6	2.6	3.7	2.8	3.2	3.3	3.3
	Acid vegetation (A1-7)	3.4	0.7	1.4	0.2	1.5	0.4	2.7	0.5	1.1
Total		*24.4*	*21.5*	*24.3*	*21.3*	*22.4*	*22.0*	*24.4*	*21.4*	*22.2*
Verge plots (10 m x 1 m)	Calcareous grassland (G6,10,11)	1.3	1.6	1.9	1.3	1.5	1.4	1.5	1.4	1.4
	Other grassland (G1-5,7-9,12-14)	6.4	7.9	9.0	7.6	7.4	7.9	7.3	7.8	7.7
	Woodland (W1-9)	0.0	0.9	1.8	0.7	0.6	0.9	0.6	0.8	0.8
	Acid vegetation (A1-7)	0.1	0.0	1.2	0.0	0.0	0.3	0.5	0.0	0.1
Total		*16.1*	*19.5*	*22.9*	*18.9*	*18.4*	*19.8*	*18.4*	*19.2*	*19.0*

These figures represent the mean number of species groups recorded per square, including those squares where no plots were recorded. The figures for combined strata are weighted by stratum size

4.9 Vegetation quality: naturalness

4.9.1 'Natural' is a term sometimes applied to vegetation which is considered to be unmodified by human influence – it cannot be strictly applied to any habitat in England, certainly not to a subclimax habitat such as grassland. However, in this context, naturalness is used as a measure of the extent of modification or disturbance away from the optimum required to maintain an area as calcareous grassland. Too little 'modification' will allow succession to scrub and woodland; too much will move the vegetation towards species-poor, improved grassland. Such modification or disturbance is indicated by the presence of species which are not normally associated with calcareous grassland, eg rye-grass (*Lolium perenne*), which in a calcareous context would indicate eutrophication, or a woodland species, eg hawthorn (*Crataegus monogyna*), which might indicate that lack of grazing is allowing scrub development. It is clearly not only the presence of such species but their relative abundance or cover which provide useful measures of 'naturalness'.

Numbers of habitat indicator species

4.9.2 The classification of species into 'habitat indicator groups' examines the extent to which vegetation recorded in quadrats is dominated by plant species associated with calcareous grassland, as opposed to those mainly found in neutral/improved grasslands or woodlands (Table 4.11).

4.9.3 In the main plots, the number of species from habitat indicator groups is directly related to their relative abundance in the squares. The results demonstrate the scarcity of 'calcareous grassland species'; only 3% of records from the main plots were of species from this group. They were most common in the designated soft limestone stratum. The 'base-rich species' are those which are associated with alkaline soils but which tolerate lower pH conditions than the more extreme calcicoles. These were also most common in the designated soft limestone stratum. So, although the mean species number per quadrat was lower on the soft limestone, there were a higher proportion of calcicolous and basic species. However, the sample of main plots on which this comparison is based is small and may not be representative. The results are reinforced by the figures from the habitat plots which show the same pattern, ie a higher proportion of calcicolous and basic species in the designated soft limestone stratum.

4.9.4 The most prevalent habitat indicator group in the main plots is the 'neutral grassland species'; this accounts for 45% of the species records, although it is less frequent in the designated strata. 'Acid vegetation species' are strongly represented on the hard limestone, whilst 'woodland species' are more significant in soft limestone strata. 'Weeds and aliens' are more common in the non-designated strata.

4.9.5 The habitat plots have a slightly higher proportion of calcicolous and basic

Table 4.11 Mean number of species per plot in each habitat indicator group

Habitat indicator groups	Designated				Non-designated				Combined									
	Hard		Soft		Hard		Soft		Designated		Non-desig		Hard		Soft		Total	
	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Main plots (4 m²)																		
Calcareous grassland	0.2	*1*	0.7	*6*	0.1	*0*	0.1	*1*	0.6	*4*	0.1	*1*	0.1	*1*	0.5	*3*	0.4	*3*
Base-rich grassland	0.6	*3*	1.3	*10*	0.6	*4*	0.9	*6*	1.1	*7*	0.8	*5*	0.6	*4*	1.1	*8*	1.0	*6*
Neutral grassland	6.8	*40*	5.4	*42*	7.9	*48*	7.8	*51*	5.8	*41*	7.8	*50*	7.2	*42*	6.5	*46*	6.6	*45*
Damp grassland	0.7	*4*	0.2	*2*	0.6	*4*	0.6	*4*	0.4	*3*	0.6	*4*	0.7	*4*	0.4	*3*	0.5	*3*
Acid vegetation	6.4	*38*	1.0	*7*	4.8	*29*	0.8	*5*	2.6	*18*	1.7	*11*	5.9	*35*	0.9	*7*	2.2	*15*
Woodland	0.9	*5*	1.4	*11*	0.8	*5*	1.7	*11*	1.2	*9*	1.5	*10*	0.9	*5*	1.5	*11*	1.4	*9*
Scrub/woodland edge	0.4	*2*	1.3	*10*	0.4	*2*	0.9	*6*	1.0	*7*	0.8	*5*	0.4	*2*	1.1	*8*	0.9	*6*
Weed and alien	0.9	*5*	1.7	*13*	1.2	*7*	2.3	*15*	1.4	*10*	2.1	*13*	1.0	*6*	2.0	*14*	1.7	*11*
Maritime	0.1	*0*	0.0	*0*	0.0	*0*	0.0	*0*	0.0	*0*	0.0	*0*	0.0	*0*	0.0	*0*	0.0	*0*
Marsh and aquatic	0.1	*1*	0.1	*1*	0.2	*1*	0.2	*1*	0.1	*1*	0.2	*1*	0.1	*1*	0.1	*1*	0.1	*1*
Total	*17.1*	*100*	*12.9*	*100*	*16.4*	*100*	*15.3*	*100*	*14.2*	*100*	*15.6*	*100*	*16.9*	*100*	*14.0*	*100*	*14.8*	*100*
Habitat plots (4 m²)																		
Calcareous grassland	0.5	*2*	1.0	*6*	0.3	*1*	0.3	*2*	0.9	*4*	0.3	*1*	0.4	*2*	0.7	*4*	0.6	*3*
Base-rich grassland	1.4	*6*	1.9	*11*	1.4	*7*	1.2	*7*	1.8	*9*	1.3	*7*	1.4	*6*	1.6	*9*	1.6	*8*
Neutral grassland	7.9	*34*	6.4	*36*	7.9	*39*	7.0	*42*	6.8	*35*	7.2	*41*	7.9	*36*	6.7	*39*	7.0	*38*
Damp grassland	1.7	*7*	0.5	*3*	1.2	*6*	0.6	*4*	0.9	*4*	0.8	*4*	1.5	*7*	0.6	*3*	0.8	*4*
Acid vegetation	5.8	*25*	1.1	*6*	3.1	*15*	0.7	*4*	2.5	*13*	1.3	*7*	4.9	*22*	0.9	*5*	2.0	*11*
Woodland	2.3	*10*	1.6	*9*	2.0	*10*	1.4	*8*	1.9	*10*	1.5	*9*	2.2	*10*	1.5	*9*	1.7	*9*
Scrub/woodland edge	1.0	*4*	1.6	*9*	1.2	*6*	1.6	*10*	1.4	*7*	1.5	*9*	1.1	*5*	1.6	*9*	1.5	*8*
Weed and alien	0.9	*4*	3.0	*17*	2.0	*10*	3.2	*19*	2.4	*12*	2.9	*17*	1.3	*6*	3.1	*18*	2.6	*14*
Maritime	0.0	*0*	0.1	*0*	0.0	*0*	0.0	*0*	0.1	*0*	0.0	*0*	0.0	*0*	0.1	*0*	0.0	*0*
Marsh and aquatic	1.7	*7*	0.5	*3*	1.1	*6*	0.6	*3*	0.9	*4*	0.7	*4*	1.5	*7*	0.5	*3*	0.8	*4*
Total	*23.2*	*100*	*17.7*	*100*	*20.2*	*100*	*16.6*	*100*	*19.4*	*100*	*17.4*	*100*	*22.2*	*100*	*17.2*	*100*	*18.5*	*100*
Verge plots (10 m x 1 m)																		
Calcareous grassland	0.3	*1*	0.3	*1*	0.3	*1*	0.1	*1*	0.3	*1*	0.1	*0*	0.3	*1*	0.2	*1*	0.2	*1*
Base-rich grassland	1.6	*5*	1.1	*5*	1.2	*5*	0.7	*4*	1.3	*5*	0.8	*4*	1.4	*5*	1.0	*5*	1.1	*5*
Neutral grassland	14.7	*50*	9.6	*44*	10.7	*45*	9.4	*50*	11.2	*47*	9.7	*48*	13.3	*48*	9.5	*47*	10.6	*48*
Damp grassland	0.9	*3*	0.3	*1*	0.8	*3*	0.2	*1*	0.5	*2*	0.3	*1*	0.9	*3*	0.3	*1*	0.4	*2*
Acid vegetation	2.3	*8*	0.4	*2*	2.7	*11*	0.3	*2*	0.9	*4*	0.8	*4*	2.4	*9*	0.3	*1*	0.9	*4*
Woodland	1.4	*5*	3.3	*15*	2.9	*12*	2.0	*11*	1.3	*5*	1.1	*6*	1.6	*6*	1.1	*1*	1.2	*6*
Scrub/woodland edge	1.9	*6*	1.7	*8*	1.7	*7*	1.2	*6*	1.8	*8*	1.3	*6*	1.8	*7*	1.5	*7*	1.6	*7*
Weed and alien	6.0	*20*	6.7	*31*	4.5	*19*	6.1	*32*	6.5	*27*	5.7	*28*	5.4	*20*	6.4	*31*	6.2	*28*
Maritime	0.1	*0*	0.1	*0*	0.0	*0*	0.0	*0*	0.1	*0*	0.0	*0*	0.1	*0*	0.0	*0*	0.0	*0*
Marsh and aquatic	0.2	*1*	0.1	*0*	0.2	*1*	0.1	*1*	0.1	*0*	0.1	*1*	0.2	*1*	0.1	*0*	0.1	*0*
Total	*29.3*	*100*	*21.6*	*100*	*24.0*	*100*	*18.9*	*100*	*23.9*	*100*	*20.0*	*100*	*27.5*	*100*	*20.4*	*96*	*22.3*	*100*

grassland species than the main plots, reflecting the more targetted sampling strategy. They also have more records from the less abundant vegetation types, eg 'marsh and aquatic species'.

4.9.6 The verge plots are dominated by the grassland groups, but also have a high proportion of 'weed and alien species' compared to the main and habitat plots, reflecting the greater disturbance to which they are subjected.

Frequency of calcareous species

4.9.7 Table 4.12 shows the 'calcareous grassland species' which were recorded in each stratum. Some species were found in all strata, eg meadow oat-grass (*Avenula pratensis*) and hoary plantain (*Plantago media*). Some are associated with hard limestone, eg vernal sandwort (*Minuartia verna*) and limestone bedstraw (*Galium sterneri*), others with the soft limestone, eg kidney vetch (*Anthyllis vulneria*) and tor-grass.

4.9.8 Of the 38 calcareous and base-rich grassland species, most (92%) were found in the designated, soft limestone stratum and just over half (55%) in the non-designated, soft limestone stratum. Far fewer of these species occurred in the hard limestone strata, 37% and 32% in the designated and non-designated strata respectively.

Summary of naturalness as a quality criterion

4.9.9 Calcareous and base-rich grassland species were most common and formed the highest proportion of species records in designated, soft limestone areas, suggesting that this is where some of the least modified calcareous grasslands occur. Soft limestones were generally richer in these species than hard limestone areas.

Table 4.12 Records of 'calcareous grassland species'

Calcareous grassland species		% of plots in which species recorded			
		Designated		Non-designated	
		Hard	Soft	Hard	Soft
Anacamptis pyramidalis	Pyramidal orchid		0.4	0.6	
Anthyllis vulneraria	Kidney vetch		0.4		0.5
Asperula cynanchica	Squinancywort	0.4	2.8		
Avenula pratensis	Meadow oat-grass	2.7	4.1	2.4	1.5
Blackstonia perfoliata	Yellow-wort	0.8	1.1	0.6	
Brachypodium pinnatum	Tor-grass		2.4		1.5
Bromopsis erecta	Upright brome	1.1	9.6		4.9
Calamintha ascendens	Common calaminth		0.2		
Campanula glomerata	Clustered bellflower		1.7		
Carduus nutans	Musk thistle	0.4	1.1		
Carex humilis	Dwarf sedge		0.6		
Cirsium acaule	Dwarf thistle	0.4	5.8		
Coeloglossum viride	Frog orchid		0.2		
Ctenidium molluscum	Plumy crested feather moss	2.3	0.6	2.4	
Echium vulgare	Viper's-bugloss		0.2		
Erophila verna	Common whitlowgrass	1.1	0.2	1.8	
Filipendula vulgaris	Dropwort	0.8	1.3		0.5
Galium sterneri	Limestone bedstraw	1.5	0.0	0.6	
Helianthemum nummularium	Common rock-rose	2.3	3.4		0.5
Hippocrepis comosa	Horseshoe vetch		1.1		
Homalothecium lutescens	Moss	1.1	3.0	1.8	1.5
Inula conyza	Ploughman's-spikenard		1.1	1.8	
Koeleria macrantha	Crested hair-grass	3.8	5.1	2.4	1.5
Koeleria sp	Hair-grass	0.4			
Linum catharticum	Fairy flax	6.8	6.6	4.8	1.0
Listera ovata	Common twayblade		0.6	0.6	
Minuartia verna	Vernal sandwort	0.4		0.6	
Neckera crispa	Moss	0.4	0.2		
Onobrychis viciifolia	Sainfoin		0.2		
Origanum vulgare	Marjoram	2.3	2.6		0.5
Ornithopus perpusillus	Bird's-foot		0.2		
Phyteuma orbiculare	Round-headed rampion		1.1		
Plantago media	Hoary plantain	1.1	2.8	1.2	2.5
Sanguisorba minor	Salad burnet	3.4	9.2	2.4	1.5
Scabiosa columbaria	Small scabious		3.2		
Senecio integrifolius	Field fleawort		0.2		
Sesleria albicans	Blue moor-grass	1.5			
Thesium humifusum	Bastard toadflax		0.6		
Total no. of species		*21*	*35*	*14*	*12*

4.10 Vegetation quality: representativeness

4.10.1 Representativeness involves using a classification of the range of vegetation being considered in order to allow comparison of examples of the same type. It is used to ensure that examples of the full range of types present within a region are conserved, as well as giving emphasis to those which are 'typical'. The range of vegetation present is described here using the classification of quadrats into 'plot classes', and of species into 'species groups'.

Relative abundance of plot classes

4.10.2 The relative abundance of each plot class within the four strata, as recorded in the main plots, habitat plots and verge plots, is given in Appendix 2. These results are summarised in Table 4.13, in which the plot classes have been aggregated to aid interpretation. However, it must be remembered that the names given to these plot classes and aggregates are simplifications for groups which may contain considerable variety. Hence, the three plot classes which include calcareous grassland (PCL – basiphilous/calcareous grassland, tussocky with herbs, PCO – calcareous grassland, short-turf, grazed, with small herbs, and PCT – northern calcareous grassland) also include grasslands which are transitional with neutral and acid grasslands. Using this grouping, calcareous grasslands make up 9% of main plots overall, compared to the

Table 4.13 The percentage of plots in plot class groups, by strata

Plot classes	Plot class group	Designated Hard	Designated Soft	Non-designated Hard	Non-designated Soft	Combined Designated	Combined Non-des	Combined Hard	Combined Soft	Combined Total
Main										
C,I,M,S	Woodland	7.6	29.2	21.1	24.0	17.8	22.5	11.1	27.2	19.4
A,B,D,E-H	Fertile grassland	1.1	25.0	7.9	24.0	12.4	17.9	2.8	24.1	14.9
J,K,N,P-R,U	Neutral grassland	34.8	18.1	39.5	44.0	26.4	42.2	35.8	28.4	32.0
L,O,T	Calcareous grassland	7.6	12.5	2.6	8.0	10.1	6.4	6.2	10.5	9.0
V-BB	Acid vegetation	46.7	15.3	29.0	0.0	31.4	11.0	42.3	8.6	24.8
CC	Maritime	2.2	0.0	0.0	0.0	1.2	0.0	1.5	0.0	0.9
A-CC	*Total*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Habitat										
C,I,M,S	Woodland	12.4	27.1	16.9	14.6	22.7	15.1	14.0	21.6	19.3
A,B,D,E-H	Fertile grassland	1.9	32.6	18.5	50.6	23.5	43.3	7.6	40.5	32.0
J,K,N,P-R,U	Neutral grassland	39.0	12.0	36.9	21.4	20.1	24.8	38.4	16.1	22.1
L,O,T	Calcareous grassland	15.2	19.1	15.4	11.2	18.1	12.3	15.4	15.7	15.5
V-BB	Acid vegetation	31.4	6.5	12.3	2.2	14.3	4.4	25.0	4.8	10.5
CC	Maritime	0.0	2.5	0.0	0.0	1.8	0.0	0.0	1.4	1.0
A-CC	*Total*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Verge										
C,I,M,S	Woodland	0.0	4.1	7.7	2.2	3.0	3.4	3.4	3.2	3.3
A,B,D,E-H	Fertile grassland	39.9	76.0	43.1	85.6	67.3	76.0	40.8	79.2	72.4
J,K,N,P-R,U	Neutral grassland	50.7	15.8	26.2	10.0	23.0	13.4	38.7	13.0	18.9
L,O,T	Calcareous grassland	7.7	4.6	16.9	2.2	5.0	5.4	11.8	3.4	5.4
V-BB	Acid vegetation	3.1	0.0	6.2	0.0	0.7	1.4	4.5	0.0	1.1
CC	Maritime	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A-CC	*Total*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

See Appendix 2, Table A2.5 for detailed figures for each plot class

structural classification (Table 4.8) in which they accounted for 6% of main plots; this is because the structural classification used a narrower definition of 'calcareous grassland'. If the plot class classification (TWINSPAN) had been followed through to the next division, tighter plot classes might have resulted; however, there were insufficient quadrats from the calcareous grasslands to do this. The current classification reflects the situation recorded in the field, ie relatively few 'high-quality' calcareous grasslands, and many which had been modified and contained a mixture of calcareous and neutral species, or, on the northern hard limestone, a mosaic of calcareous and acid species, reflecting the leached nature of the soil.

4.10.3 'Woodlands' were particularly important in the designated soft limestone stratum, where 19% of main plots were recorded in woodland (PCC – calcareous woodland, eutrophic, often woodland edge, PCI – calcareous woodland, mainly ash, PCM – basiphilous woodland, more open, grassy, and PCS – neutral/acid woodland, bramble-dominated), the most common type being PCI. PCS woodlands were more common on the hard limestone. In the habitat plots, there were a greater proportion of PCC quadrats, suggesting that, in squares with only small areas of woodland, this was the most common type.

4.10.4 In the main plots (random and therefore representative), 'calcareous grasslands' (PCL – basiphilous/calcareous grassland, tussocky with herbs, PCO – calcareous grassland, short-turf, grazed, with small herbs, and PCT – northern calcareous grassland) were more common on the soft than hard limestone. Within each limestone type, they were more common in designated squares. In the habitat plots (which usually recorded less extensive areas of calcareous grassland), a higher proportion of plots were in these plot classes. In the soft limestone areas there were still more plots in the designated stratum, but in the hard limestone strata, very similar numbers of plots were recorded in designated and non-designated squares.

4.10.5 PCL (the basiphilous/calcareous, tussocky with herb grassland class) was recorded in main plots only in the soft limestone squares, though it was also recorded on hard limestone in verge plots and habitat plots. It was slightly more common in the non-designated strata. PCO (the calcareous short-turf, grazed with small herbs) was recorded only in designated squares in the main plots, where it was more common on the soft limestone. In the habitat plots, it was also most common in the designated soft stratum, but was recorded in the non-designated squares as well. In the verge plots it was most common in the non-designated hard stratum in complete contrast to the main plots. PCT (the 'northern calcareous' grasslands) were recorded only on hard limestone in the main plots and verge plots; they were much more frequent on hard limestone in the habitat plots. PCT in main plots (more extensive areas) and verge plots was more common in the designated squares, but in the habitat plots (smaller patches) was recorded at equal frequency, suggesting that there are greater areas of it in the designated squares, but it can still be found as small patches in the non-designated squares. In verge plots overall, there were fewer examples of the calcareous plot classes (PCL, PCO, PCT) than in the randomly located main plots.

4.10.6 The balance between 'fertile grassland' (PCA – fertile grassland, with annual weeds, PCB – fertile grassland, overgrown, often shaded, PCD – tall, coarse grassland, open, PCE – eutrophic grassland, often neglected, PCF – intensive grassland, rye-grass-dominated, often disturbed, PCG – eutrophic grassland, overgrown, tall herbs, often shaded/wet, PCH – fertile grassland, short, often disturbed) and 'neutral grassland' (PCJ – neutral/basiphilous grassland, tall with herbs, PCK – neutral/basiphilous grassland, short, mown or grazed, PCN – neutral permanent pasture, PCP – neutral grassland, semi-improved, grazed or mown, PCQ – neutral grassland, unimproved, light/no grazing, some shading, PCR – marsh/rushy pasture, PCU – northern, damp pasture, often with flushing/streamsides) differs considerably between strata. Quadrats were not recorded in the most intensive grasslands (heavily fertilized and sown swards) so these are not represented in these figures, but 'fertile grasslands' still represent 15% of main plots recorded. 'Fertile grassland' was far more significant on the soft limestone, where larger areas are suitable for agricultural improvement, but also made up 9% of the quadrats in the non-designated hard stratum. Neutral grasslands were less common in the designated soft stratum, but were present in similar proportions elsewhere.

4.10.7 'Fertile grassland' plot classes are particularly strongly represented in the verge plots, of which they make up 40% of plots on the hard limestone and 79% on soft limestone. There are two types of 'fertile grassland' plot classes, those with short swards which are mown or grazed (PCA – fertile grassland, with annual weeds, PCF – intensive grassland, rye-grass-dominated, often disturbed, PCH – fertile grassland, short, often disturbed), and those with long swards which are under-grazed or neglected (PCB – fertile grassland, overgrown, often shaded, PCD – tall, coarse grassland, open, PCE – eutrophic grassland, often neglected, PCG – eutrophic grassland, overgrown, tall herbs, often shaded/wet). Both types occur in all strata, but are more common in the non-designated and soft ones. Of the 'neutral grassland' plot classes, PCN (neutral permanent pasture) is most common and widespread, whilst PCU (northern damp pasture) is largely restricted to the hard limestone areas.

4.10.8 'Acid vegetation' was mainly recorded on the hard limestone, but also occurred in designated soft limestone squares. Within the hard limestone areas, it was more often recorded in designated squares.

Relative abundance of species groups

4.10.9 Table 4.14 shows the mean number of species per main plot for each species group. This Table indicates the relative abundance of different types of species in quadrats in each stratum. Tables 4.15 and 4.16 give the equivalent information for habitat plots and verge plots. Figures for grassland species groups refer just to grassland plots (as defined by TWINSPAN – see para 4.4.5), those for woodland species groups to woodland plots, and those for acid vegetation species groups to acid vegetation plots.

Grasslands

4.10.10 The species groups most commonly recorded, in main plots, in all strata are 'managed grassland species from heavy soils' (G7), 'grazed/mown mesotrophic grassland species' (G8), and 'semi-improved neutral grassland species' (G9), reflecting the preponderance of managed grassland. The most common calcareous group was 'grazed calcareous grassland

Table 4.14 Mean number of species per main plot, for each species group, by strata

Species group	Description	Designated Hard No.	Designated Hard %	Designated Soft No.	Designated Soft %	Non-designated Hard No.	Non-designated Hard %	Non-designated Soft No.	Non-designated Soft %	Combined Designated No.	Combined Designated %	Combined Non-des'd No.	Combined Non-des'd %	Combined Hard No.	Combined Hard %	Combined Soft No.	Combined Soft %	Total No.	Total %
Grasslands																			
G1	Eutrophic coarse grassland species	0.3	*1*	1.1	*6*	0.4	*2*	1.0	*5*	0.9	*4*	0.8	*4*	0.3	*2*	1.0	*5*	0.9	*4*
G2	Annual weeds species in rye-grass-dominated grassland	1.6	*7*	1.9	*10*	1.5	*7*	2.3	*13*	1.8	*9*	2.1	*11*	1.6	*7*	2.1	*11*	1.9	*10*
G3	Basiphilous shaded grassland species	0.6	*2*	1.3	*7*	0.3	*1*	2.0	*11*	1.1	*5*	1.6	*8*	0.5	*2*	1.6	*8*	1.3	*7*
G4	Neutral managed grassland species	1.6	*7*	1.7	*9*	1.3	*6*	2.1	*12*	1.7	*8*	1.9	*10*	1.5	*6*	1.9	*10*	1.8	*9*
G5	Moist tall herb grassland species	0.2	*1*	0.3	*1*	0.2	*1*	0.2	*1*	0.3	*1*	0.2	*1*	0.2	*1*	0.2	*1*	0.2	*1*
G6	Tall calcareous grassland species	0.1	*0*	1.1	*6*	0.1	*0*	0.4	*2*	0.8	*4*	0.3	*2*	0.1	*0*	0.8	*4*	0.6	*3*
G7	Managed grassland species from heavy soils	3.1	*13*	2.6	*13*	3.1	*15*	2.2	*12*	2.7	*13*	2.4	*13*	3.1	*13*	2.4	*13*	2.6	*13*
G8	Grazed/mown mesotrophic grassland species	5.0	*21*	4.2	*21*	4.7	*23*	3.1	*17*	4.4	*21*	3.5	*19*	4.9	*22*	3.7	*20*	4.0	*20*
G9	Semi-improved neutral grassland species	5.7	*24*	1.9	*10*	5.3	*26*	2.8	*16*	3.1	*15*	3.4	*18*	5.5	*25*	2.3	*12*	3.2	*16*
G10	Heavily-grazed calcareous grassland species	1.0	*4*	0.8	*4*	0.6	*3*	0.6	*4*	0.8	*4*	0.6	*3*	0.8	*4*	0.7	*4*	0.8	*4*
G11	Grazed calcareous grassland species	1.6	*7*	2.1	*11*	0.6	*3*	0.6	*4*	1.9	*9*	0.6	*3*	1.3	*6*	1.4	*8*	1.4	*7*
G12	Mildly acid marsh species	0.7	*3*	0.0	*0*	1.0	*5*	0.4	*2*	0.2	*1*	0.5	*3*	0.8	*3*	0.2	*1*	0.3	*2*
G13	Acid flush species	1.4	*6*	0.2	*1*	1.3	*6*	0.3	*1*	0.6	*3*	0.5	*3*	1.3	*6*	0.2	*1*	0.5	*3*
G14	Grazed low-nutrient grassland species	1.0	*4*	0.4	*2*	0.6	*3*	0.1	*1*	0.5	*3*	0.2	*1*	0.8	*4*	0.2	*1*	0.4	*2*
Total		*23.6*	*100*	*19.5*	*100*	*20.8*	*100*	*18.0*	*100*	*20.7*	*100*	*18.6*	*100*	*22.6*	*100*	*18.8*	*100*	*19.8*	*100*
Woodlands																			
W1	Calcareous woodland species	2.3	*19*	3.9	*22*	1.8	*15*	3.5	*13*	3.4	*21*	3.1	*13*	2.1	*18*	3.7	*17*	3.3	*17*
W2	Calcareous woodland species, on clays	1.0	*8*	1.0	*5*	0.9	*8*	0.5	*2*	1.0	*6*	0.6	*2*	1.0	*8*	0.8	*3*	0.8	*4*
W3	Disturbed eutrophic woodland species, humus-rich soils	0.6	*5*	2.5	*14*	2.8	*24*	6.0	*22*	1.9	*12*	5.3	*22*	1.3	*11*	4.1	*18*	3.3	*17*
W4	Woodland clearing species	1.4	*12*	2.9	*16*	1.8	*15*	5.0	*18*	2.4	*15*	4.3	*18*	4.5	*38*	3.8	*17*	3.2	*17*
W5	Woodland edge species, disturbed	0.6	*5*	1.0	*5*	1.1	*10*	0.8	*3*	0.8	*5*	0.9	*4*	0.8	*6*	0.9	*4*	0.9	*4*
W6	Basiphilous woodland species, on heavy soils	3.1	*26*	3.4	*19*	1.1	*10*	6.5	*24*	3.3	*20*	5.3	*22*	2.5	*21*	4.8	*22*	4.1	*21*
W7	Mildly acid woodland species, on gleys	1.0	*8*	2.2	*12*	0.6	*5*	4.2	*15*	1.9	*12*	3.4	*14*	0.9	*7*	3.1	*14*	2.5	*13*
W8	Mildly acid woodland species, brown earths, often moist	0.4	*4*	0.4	*2*	1.6	*14*	0.2	*1*	0.4	*3*	0.5	*2*	0.8	*7*	0.3	*1*	0.5	*2*
W9	Acid woodland species	1.6	*13*	0.8	*4*	0.0	*0*	0.7	*2*	1.0	*6*	0.5	*2*	1.0	*9*	0.7	*3*	0.8	*4*
Total		*12.0*	*100*	*18.0*	*100*	*11.6*	*100*	*27.3*	*100*	*16.2*	*100*	*23.9*	*100*	*11.9*	*100*	*22.1*	*100*	*19.4*	*100*
Acid vegetation																			
A1	Scrub/bracken/shade-tolerant species	0.6	*4*	2.7	*32*	0.7	*5*	0.0	*0*	2.1	*19*	0.2	*4*	0.7	*4*	1.5	*32*	1.3	*17*
A2	Acid grassland species	5.8	*36*	1.4	*16*	6.6	*41*	0.0	*0*	2.7	*25*	1.5	*41*	6.1	*38*	0.8	*16*	2.2	*28*
A3	Moss/lichen heath species	0.6	*4*	0.0	*0*	0.7	*5*	0.0	*0*	0.2	*2*	0.2	*4*	0.6	*4*	0.0	*0*	0.2	*2*
A4	Moorland species	4.8	*30*	2.3	*27*	4.1	*25*	0.0	*0*	3.0	*28*	0.9	*26*	4.6	*29*	1.3	*27*	2.2	*28*
A5	Sphagnum lawn species	0.8	*5*	0.1	*1*	0.6	*3*	0.0	*0*	0.3	*3*	0.1	*3*	0.7	*4*	0.1	*1*	0.2	*3*
A6	Mire species	2.9	*18*	1.0	*12*	2.2	*14*	0.0	*0*	1.6	*15*	0.5	*13*	2.7	*17*	0.6	*12*	1.1	*14*
A7	Blanket bog species	0.5	*3*	1.1	*13*	1.2	*7*	0.0	*0*	0.9	*9*	0.3	*7*	0.7	*5*	0.6	*13*	0.6	*8*
Total		*16.0*	*100*	*8.6*	*100*	*16.1*	*100*	*0.0*	*0*	*10.8*	*100*	*3.6*	*100*	*16.0*	*100*	*4.8*	*100*	*7.8*	*100*

Table 4.15 Mean number of species records per habitat plot, for each species group, by strata

Species group	Description	Designated Hard No.	Designated Hard %	Designated Soft No.	Designated Soft %	Non-designated Hard No.	Non-designated Hard %	Non-designated Soft No.	Non-designated Soft %	Combined Designated No.	Combined Designated %	Combined Non-des'd No.	Combined Non-des'd %	Combined Hard No.	Combined Hard %	Combined Soft No.	Combined Soft %	Total No.	Total %
Grasslands																			
G1	Eutrophic coarse grassland species	0.5	*2*	1.6	*9*	1.0	*6*	2.1	*14*	1.2	*7*	1.9	*12*	0.7	*3*	1.8	*11*	1.5	*9*
G2	Annual weeds species in rye-grass-dominated grassland	0.4	*2*	1.2	*7*	0.5	*3*	0.8	*6*	1.0	*5*	0.8	*5*	0.5	*2*	1.1	*7*	0.9	*5*
G3	Basiphilous shaded grassland species	1.0	*5*	1.6	*9*	0.7	*4*	1.8	*12*	1.4	*8*	1.5	*10*	0.9	*4*	1.7	*10*	1.5	*8*
G4	Neutral managed grassland species	0.6	*3*	1.0	*6*	1.1	*6*	1.2	*8*	0.8	*5*	1.2	*8*	0.8	*4*	1.1	*7*	1.0	*6*
G5	Moist tall herb grassland species	0.6	*3*	0.4	*2*	0.8	*5*	0.7	*4*	0.4	*2*	0.7	*4*	0.7	*3*	0.5	*3*	0.5	*3*
G6	Tall calcareous grassland species	0.2	*1*	0.9	*5*	0.2	*1*	0.4	*3*	0.7	*4*	0.3	*2*	0.2	*1*	0.7	*4*	0.5	*3*
G7	Managed grassland species from heavy soils	2.3	*11*	1.8	*10*	1.8	*10*	1.6	*11*	1.9	*10*	1.7	*11*	2.1	*10*	1.7	*11*	1.8	*11*
G8	Grazed/mown mesotrophic grassland species	3.5	*17*	3.5	*20*	3.5	*20*	2.9	*19*	3.5	*19*	3.0	*20*	3.5	*17*	3.2	*20*	3.3	*19*
G9	Semi-improved neutral grassland species	4.1	*19*	1.1	*7*	3.0	*17*	1.1	*7*	2.0	*11*	1.5	*10*	3.7	*19*	1.1	*7*	1.8	*11*
G10	Heavily-grazed calcareous grassland species	1.3	*6*	0.9	*6*	0.9	*5*	0.5	*4*	1.1	*6*	0.6	*4*	1.2	*6*	0.8	*5*	0.9	*5*
G11	Grazed calcareous grassland species	2.1	*10*	2.3	*13*	1.5	*9*	1.1	*7*	2.2	*12*	1.2	*8*	1.9	*9*	1.7	*11*	1.8	*10*
G12	Mildly acid marsh species	2.0	*9*	0.3	*2*	1.0	*6*	0.3	*2*	0.8	*4*	0.5	*3*	1.6	*8*	0.3	*2*	0.7	*4*
G13	Acid flush species	1.8	*8*	0.2	*1*	0.9	*5*	0.1	*1*	0.7	*4*	0.3	*2*	1.4	*7*	0.2	*1*	0.5	*3*
G14	Grazed low-nutrient grassland species	1.1	*5*	0.4	*2*	0.6	*4*	0.2	*2*	0.6	*3*	0.3	*2*	1.0	*5*	0.3	*2*	0.5	*3*
Total		*21.4*	*100*	*17.0*	*100*	*17.6*	*100*	*14.7*	*100*	*18.3*	*100*	*15.3*	*100*	*20.1*	*100*	*16.0*	*100*	*17.1*	*100*
Woodlands																			
W1	Calcareous woodland species	2.9	*17*	2.6	*22*	2.9	*15*	3.6	*29*	2.7	*20*	3.5	*25*	2.9	*16*	3.0	*25*	3.0	*22*
W2	Calcareous woodland species, on clays	0.8	*5*	0.6	*5*	0.7	*4*	0.4	*3*	0.6	*5*	0.5	*3*	0.8	*4*	0.5	*4*	0.6	*4*
W3	Disturbed eutrophic woodland species, humus-rich soils	1.2	*7*	3.3	*29*	3.9	*20*	2.8	*22*	2.7	*21*	3.0	*21*	2.2	*12*	3.1	*26*	2.8	*21*
W4	Woodland clearing species	1.5	*9*	1.2	*10*	1.6	*8*	1.6	*13*	1.3	*10*	1.6	*12*	1.6	*9*	1.4	*12*	1.4	*11*
W5	Woodland edge species, disturbed	1.4	*8*	0.4	*4*	2.2	*11*	0.8	*6*	0.7	*5*	1.1	*8*	1.7	*9*	0.6	*5*	0.9	*6*
W6	Basiphilous woodland species, on heavy soils	5.1	*30*	1.8	*16*	4.2	*21*	2.2	*18*	2.8	*21*	2.7	*19*	4.8	*26*	2.0	*17*	2.7	*20*
W7	Mildly acid woodland species, on gleys	1.4	*8*	0.7	*6*	1.0	*5*	0.4	*3*	0.9	*7*	0.5	*4*	1.3	*7*	0.5	*4*	0.7	*5*
W8	Mildly acid woodland species, brown earths, often moist	1.2	*7*	0.6	*5*	2.1	*10*	0.5	*4*	0.8	*6*	0.9	*6*	1.5	*8*	0.6	*5*	0.8	*6*
W9	Acid woodland species	1.6	*9*	0.3	*3*	1.3	*6*	0.1	*1*	0.7	*5*	0.3	*2*	1.5	*8*	0.2	*2*	0.6	*4*
Total		*17.1*	*100*	*11.4*	*100*	*19.9*	*100*	*12.4*	*100*	*13.1*	*100*	*14.1*	*100*	*18.1*	*100*	*11.9*	*100*	*13.5*	*100*
Acid vegetation																			
A1	Scrub/bracken/shade-tolerant species	0.9	*7*	2.5	*21*	0.9	*8*	5.0	*43*	2.0	*17*	4.1	*36*	0.9	*7*	3.6	*31*	2.9	*24*
A2	Acid grassland species	3.9	*30*	3.9	*32*	2.5	*22*	5.5	*48*	3.9	*31*	4.8	*42*	3.4	*27*	4.6	*39*	4.3	*36*
A3	Moss/lichen heath species	0.6	*5*	0.4	*3*	0.6	*6*	0.0	*0*	0.5	*4*	0.1	*1*	0.6	*5*	0.2	*2*	0.3	*3*
A4	Moorland species	3.3	*26*	1.2	*10*	1.6	*14*	1.0	*9*	1.9	*15*	1.1	*10*	2.8	*22*	1.1	*10*	1.6	*13*
A5	Sphagnum lawn species	0.7	*5*	0.4	*3*	2.0	*18*	0.0	*0*	0.5	*4*	0.4	*4*	1.1	*9*	0.2	*2*	0.5	*4*
A6	Mire species	2.1	*16*	2.3	*19*	2.3	*20*	0.0	*0*	2.3	*18*	0.5	*4*	2.2	*18*	1.3	*11*	1.5	*13*
A7	Blanket bog species	1.5	*11*	1.2	*10*	1.5	*13*	0.0	*0*	1.3	*11*	0.3	*3*	1.5	*12*	0.7	*6*	0.9	*8*
Total		*12.9*	*100*	*11.9*	*100*	*11.4*	*100*	*11.5*	*100*	*12.2*	*100*	*11.5*	*100*	*12.4*	*100*	*11.7*	*100*	*11.9*	*100*

Table 4.16 Mean number of species records per verge plot, for each species group, by strata

Species group	Description	Designated				Non-designated				Combined									
		Hard		Soft		Hard		Soft		Designated		Non-des'd		Hard		Soft		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Grasslands																			
G1	Eutrophic coarse grassland species	3.3	*11*	3.8	*18*	2.8	*12*	3.9	*21*	3.6	*16*	3.7	*19*	3.1	*12*	3.8	*19*	3.6	*17*
G2	Annual weeds species in rye-grass-dominated grassland	2.9	*10*	3.4	*16*	2.4	*10*	3.2	*17*	3.3	*14*	3.0	*15*	2.7	*10*	3.3	*17*	3.1	*14*
G3	Basiphilous shaded grassland species	2.9	*10*	2.8	*14*	1.9	*8*	2.2	*12*	2.9	*12*	2.1	*11*	2.6	*10*	2.5	*13*	2.5	*12*
G4	Neutral managed grassland species	2.1	*7*	1.6	*8*	1.3	*6*	1.5	*8*	1.7	*7*	1.5	*7*	1.8	*7*	1.6	*8*	1.6	*7*
G5	Moist tall herb grassland species	1.6	*5*	0.2	*1*	1.1	*5*	0.4	*2*	0.6	*3*	0.5	*3*	1.4	*5*	0.3	*2*	0.6	*3*
G6	Tall calcareous grassland species	0.3	*1*	0.8	*4*	0.2	*1*	0.5	*3*	0.6	*3*	0.4	*2*	0.2	*1*	0.7	*3*	0.6	*3*
G7	Managed grassland species from heavy soils	3.1	*11*	2.1	*10*	2.6	*11*	1.9	*10*	2.4	*10*	2.0	*10*	2.9	*11*	2.0	*10*	2.3	*10*
G8	Grazed/mown mesotrophic grassland species	5.6	*19*	4.2	*20*	4.6	*21*	4.1	*22*	4.7	*20*	4.2	*21*	5.3	*20*	4.2	*21*	4.5	*21*
G9	Semi-improved neutral grassland species	3.2	*11*	0.8	*4*	2.4	*11*	0.7	*4*	1.5	*7*	1.1	*6*	2.9	*11*	0.8	*4*	1.4	*6*
G10	Heavily-grazed calcareous grassland species	0.7	*3*	0.4	*2*	0.5	*2*	0.2	*1*	0.5	*2*	0.3	*1*	0.7	*2*	0.3	*2*	0.4	*2*
G11	Grazed calcareous grassland species	1.4	*5*	0.5	*2*	0.9	*4*	0.1	*0*	0.7	*3*	0.3	*1*	1.2	*5*	0.3	*1*	0.5	*2*
G12	Mildly acid marsh species	0.5	*2*	0.1	*0*	0.5	*2*	0.1	*0*	0.2	*1*	0.2	*1*	0.5	*2*	0.1	*0*	0.2	*1*
G13	Acid flush species	0.6	*2*	0.1	*1*	0.8	*4*	0.1	*0*	0.3	*1*	0.2	*1*	0.7	*3*	0.1	*1*	0.3	*1*
G14	Grazed low-nutrient grassland species	0.7	*2*	0.1	*0*	0.6	*3*	0.0	*0*	0.3	*1*	0.2	*1*	0.7	*2*	0.0	*0*	0.2	*1*
Total		*28.8*	*100*	*20.9*	*100*	*22.6*	*100*	*18.7*	*100*	*23.3*	*100*	*19.5*	*100*	*26.7*	*100*	*19.9*	*100*	*21.7*	*100*
Woodlands																			
W1	Calcareous woodland species	0.0	*0*	4.4	*25*	4.8	*13*	6.5	*25*	3.1	*25*	6.1	*22*	1.7	*13*	5.3	*25*	4.3	*23*
W2	Calcareous woodland species, on clays	0.0	*0*	1.4	*8*	0.6	*2*	0.5	*2*	1.0	*8*	0.5	*2*	0.2	*2*	1.0	*5*	0.8	*4*
W3	Disturbed eutrophic woodland species, humus-rich soils	0.0	*0*	2.5	*14*	6.8	*19*	4.0	*16*	1.8	*15*	4.6	*17*	2.3	*19*	3.2	*15*	2.9	*16*
W4	Woodland clearing species	0.0	*0*	3.4	*20*	3.6	*10*	2.5	*10*	2.4	*20*	2.7	*10*	1.2	*10*	3.0	*14*	2.5	*14*
W5	Woodland edge species, disturbed	0.0	*0*	0.6	*4*	5.4	*15*	3.0	*12*	0.4	*4*	3.5	*13*	1.9	*15*	1.7	*8*	1.7	*9*
W6	Basiphilous woodland species, on heavy soils	0.0	*0*	2.4	*14*	5.6	*16*	5.0	*20*	1.7	*14*	5.1	*18*	1.9	*16*	3.5	*17*	3.1	*17*
W7	Mildly acid woodland species, on gleys	0.0	*0*	1.4	*8*	3.2	*9*	1.0	*4*	1.0	*8*	1.5	*5*	1.1	*9*	1.2	*6*	1.2	*6*
W8	Mildly acid woodland species, brown earths, often moist	0.0	*0*	0.6	*4*	3.2	*9*	1.5	*6*	0.4	*4*	1.9	*7*	1.1	*9*	1.0	*5*	1.0	*6*
W9	Acid woodland species	0.0	*0*	0.6	*4*	2.6	*7*	1.5	*6*	0.4	*4*	1.7	*6*	0.9	*7*	1.0	*5*	1.0	*5*
Total		*0.0*	*0*	*17.3*	*100*	*35.8*	*100*	*25.5*	*100*	*12.1*	*100*	*27.8*	*100*	*12.3*	*100*	*20.9*	*100*	*18.6*	*100*
Acid vegetation																			
A1	Scrub/bracken/shade-tolerant species	1.0	*4*	0.0	*0*	3.3	*19*	0.0	*0*	0.3	*4*	0.7	*19*	1.8	*8*	0.0	*0*	0.5	*8*
A2	Acid grassland species	10.0	*40*	0.0	*0*	7.2	*40*	0.0	*0*	3.0	*40*	1.6	*40*	9.0	*40*	0.0	*0*	2.4	*40*
A3	Moss/lichen heath species	2.5	*10*	0.0	*0*	0.8	*5*	0.0	*0*	0.8	*10*	0.2	*5*	1.9	*9*	0.0	*0*	0.5	*9*
A4	Moorland species	10.0	*40*	0.0	*0*	3.5	*19*	0.0	*0*	3.0	*40*	0.8	*20*	7.8	*34*	0.0	*0*	2.1	*34*
A5	Sphagnum lawn species	0.0	*0*	0.0	*0*	0.2	*1*	0.0	*0*	0.0	*0*	0.0	*1*	0.1	*0*	0.0	*0*	0.0	*0*
A6	Mire species	0.5	*2*	0.0	*0*	2.0	*11*	0.0	*0*	0.2	*2*	0.4	*11*	1.0	*5*	0.0	*0*	0.3	*4*
A7	Blanket bog species	1.0	*4*	0.0	*0*	1.0	*6*	0.0	*0*	0.3	*4*	0.2	*6*	1.0	*4*	0.0	*0*	0.3	*4*
Total		*25.0*	*100*	*0.0*	*0*	*18.0*	*100*	*0.0*	*0*	*7.5*	*100*	*4.0*	*100*	*22.6*	*100*	*0.0*	*0*	*6.1*	*100*

species' (G11) which was found most frequently in the designated soft stratum, but also occurred on hard limestone. On both limestone types, it occurred more commonly in designated squares. The 'heavily grazed calcareous grassland species' (G10) occurred more evenly across the strata, whilst the 'tall calcareous grassland species' (G6) was largely restricted to soft limestone, where it was more common in designated squares.

4.10.11 A similar pattern is seen in the habitat plots. The same three groups are dominant (G7, G8, G9). There are a higher proportion of the calcareous species groups (G10, G11), reflecting the targeted sampling; this is particularly so in the non-designated areas, indicating that the calcareous species are still present in these squares, but in smaller patches. There are also greater proportions of the 'eutrophic coarse grassland species' (G1), suggesting that there are small areas of neglected grassland, particularly in the non-designated squares (which might have potential for calcareous grassland restoration – see Section 4.13).

4.10.12 The verges show a different balance of species groups, although G8 is still predominant. They have higher proportions of the 'eutrophic coarse grassland species' (G1), from verges which are unmanaged or receive very occasional mowing, and the 'annual weed species in rye-grass-dominated grassland' (G2), from verges which are more regularly cut and disturbed. The 'tall calcareous grassland species' (G6) are present in about the same numbers as for the main and habitat plots, but the short calcareous groups, G10 and G11, are less frequent, suggesting that few verges have both suitable soils and management that favours these species. They are present in slightly higher numbers in the hard limestone squares, which might be related to the presence of verges adjacent to unenclosed land which are grazed.

Woodlands

4.10.13 In the main plots, calcareous species (W1, W2) are more common on soft limestone and in designated squares, but are present in all strata. However, in the habitat plots more calcareous species were recorded in the non-designated soft stratum. Verges had more calcareous woodland species in the soft limestone squares. They also had more species associated with woodland clearings and woodland edge (W4, W5).

Acid vegetation

4.10.14 In the main plots acid species were more diverse on hard limestone, where 'acid grassland species' (A2) and 'moorland species' (A4) dominated. On the soft limestone, 'scrub/bracken/shade-tolerant species' (A1) was more frequent. The habitat plots show a similar pattern. Acid vegetation was only recorded in verge plots on the hard limestone, where it was dominated by the 'acid grassland species (A2), and the 'moorland species' (A4).

Summary of representativeness as a quality criterion

4.10.15 The classification into plot classes splits the calcareous grasslands into three types, which have different distributions. The 'northern calcareous' grassland type was more common on hard limestone and in designated areas, whilst the 'basiphilous/ calcareous grassland, tussocky with herbs' was more common on soft limestone, with little difference between designated and non-designated areas. A higher proportion of the 'calcareous short-turf grassland' was in designated areas compared to the other two types.

4.10.16 The classification into species groups produced three types of calcareous grassland species. The 'tall calcareous grassland species' were more common in soft limestone and designated areas. The shorter 'grazed calcareous grassland species' occurred on both soft and hard limestone, but were more often in designated areas. The 'heavily grazed calcareous grassland' occurred in similar low frequencies in all strata.

4.11 Vegetation quality: rarity

4.11.1 The survey strategy employed for this project is designed to record representative examples of calcareous grassland, not rare types or rare species; although they may occur within the sample, it is not possible to make any general statements about their abundance or distribution.

4.11.2 For species rarity, the vascular species recorded have been checked against the

Table 4.17 Mean number of species per plot, for each fragility type, by strata

Threat	Plot type	Designated Hard	Designated Soft	Non-designated Hard	Non-designated Soft	Combined Design'd	Combined Non-des	Combined Hard	Combined Soft	Combined Total
Succession	Main	0.5	1.3	0.6	0.5	1.0	0.5	0.5	0.9	0.8
	Habitat	1.2	1.9	1.1	1.0	1.7	1.0	1.2	1.5	1.4
	Verge	1.1	0.8	1.0	0.3	0.9	0.5	1.0	0.6	0.7
Eutroph-ication	Main	0.6	1.6	0.7	0.9	1.3	0.9	0.6	1.3	1.1
	Habitat	1.5	2.3	1.5	1.2	2.1	1.3	1.5	1.8	1.7
	Verge	1.5	1.2	1.3	0.7	1.3	0.8	1.4	0.9	1.1

Red Data Book list of species, and against the 'Nationally scarce' species list defined in *Guidelines for selection of biological SSSIs* (NCC 1989). Non-vascular plant species have been checked *against Guidelines for the selection of biological SSSIs: non-vascular plants* (Hodgetts 1992). The following *Red Data Book* species were recorded: box (*Buxus sempervirens*), tuberous thistle (*Cirsium tuberosum*), Somerset hairgrass (*Koeleria vallesiana*), and dragon's-teeth (*Tetragonolopus maritimus*).

4.11.3 In addition, several species classified as 'Nationally scarce' were recorded. These were: dwarf sedge (*Carex humilis*), mezereon (*Daphne mezereum*), green-leaved helleborine (*Epipactis leptochilla*), sea heath (*Frankenia laevis*), limestone bedstraw (*Galium sterneri*), sea-buckthorn (*Hippophae rhamnoides*), [moss] *Homalothecium nitens*, wood barley (*Hordelymus europaeus*), lax-flowered sea lavender (*Limonium humile*), vernal sandwort (*Minuartia verna*), yellow bartsia (*Parentucellia viscosa*), spring cinquefoil (*Potentilla tabernaemontani*), bird's-eye primrose (*Primula farinosa*), sea radish (*Raphanus maritimus*), and blue moor grass (*Seslaria albicans*).

4.12 Vegetation quality: fragility

4.12.1 Fragility reflects the degree of sensitivity of vegetation types and species to environmental change. Two types of change have been considered which may adversely affect calcareous grasslands. These are relatively subtle processes which will have a gradual and cumulative effect, as opposed to destructive activities, eg ploughing, which lead to a sudden loss of vegetation.

i. Succession: all grasslands are susceptible to invasion by tree species and succession to woodland if they are not mown or grazed, but this may occur more quickly on some soil types than others, and will be related to the proximity of a seed source.

ii. Eutrophication: this may be at low levels, resulting from runoff from adjacent land or atmospheric deposition, or at high levels from direct application.

4.12.2 Calcareous grassland species which are sensitive to these two processes have been identified; their presence implies that an area remains unaffected, therefore the relative abundance of these species can be used as a measure of quality. Table 4.17 shows a similar pattern for both processes.

4.12.3 In general, there are more species vulnerable to succession in the designated squares, implying that more have been lost from the non-designated squares. In the main plots and habitat plots, there are more of such species on the soft limestone, but this trend is reversed for verge plots.

4.12.4 The figures for eutrophication also suggest that there are more susceptible species in the designated squares. In the main plots and habitat plots, there are more vulnerable species on the soft limestone, but in the verge plots there are more on hard limestone.

4.12.5 It is not possible to determine whether the higher proportions of sensitive species in the designated strata reflect a designation policy targeted at fragile vegetation, or whether they are present because they have been protected by the designation.

4.13 Vegetation quality: potential value

4.13.1 The value of areas which have potential to become calcareous grassland depends on the current vegetation type and on the potential for enhancement and restoration, the latter being affected by all the criteria discussed above.

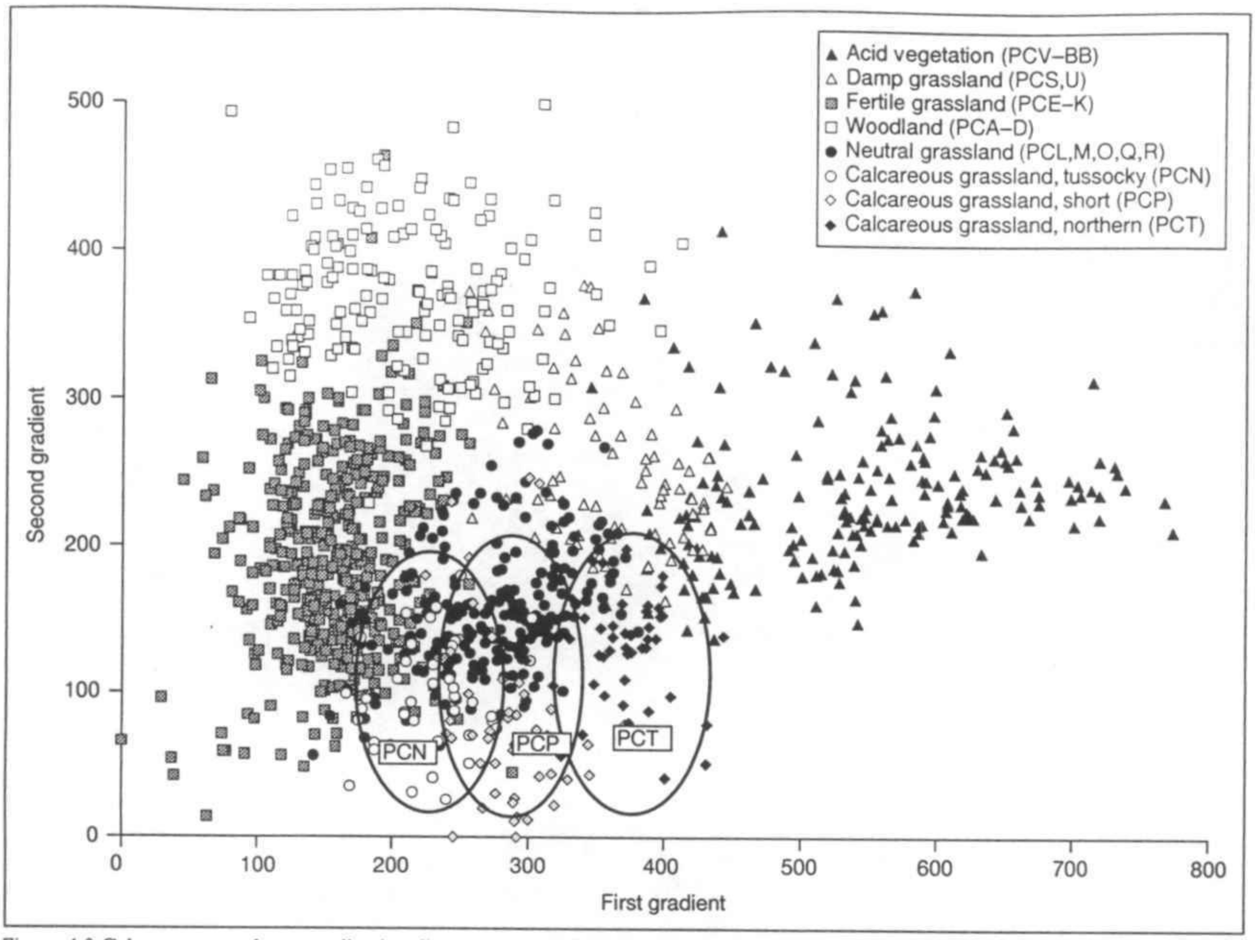


Figure 4.6 Calcareous quadrats – ordination diagram using DECORANA scores

4.13.2 Existing calcareous grassland depends for its maintenance on appropriate management. It can be enhanced by increasing the patch size, incorporating associated habitats, linking patches, and providing buffer zones.

4.13.3 Non-calcareous grassland elements of the 'calcareous grassland mask' can be divided into two types.

i. Land cover types which have received high management inputs and whose vegetation no longer contains any calcareous species (eg arable fields, improved grassland); although calcareous grassland creation may be possible in these situations, the current vegetation and seed bank will not influence the resulting vegetation. The areas of these land cover types available for such calcareous grassland creation schemes are shown in Appendix 2 (although they may not all be on suitable soil types).

ii. Habitats which are derived from calcareous grassland or include calcareous species; if these are on appropriate soils then calcareous grassland restoration may be feasible, and the process will incorporate the plant species present both above-ground and in the seed bank. The effort required to achieve this will depend on the current vegetation, as well as on soil type, past management, and the length of time since calcareous grassland vegetation was dominant.

4.13.4 The relationships between the vegetation types recorded are shown in the ordination diagram in Figure 4.6, on which each quadrat is plotted according to its score on the first and second gradient. The non-calcareous plot classes have been aggregated to simplify presentation. The plot shows some overlap between the calcareous grassland plot classes and those of other grassland types; this is because the calcareous plot classes represent a range of variation, including quadrats which contain only a few calcareous species. There are insufficient quadrats to separate these out into different plot classes. The three plot classes which include calcareous vegetation (PCL – basiphilous/calcareous grassland, tussocky with herbs, PCO – calcareous grassland, short-turf, grazed, with small herbs, and PCT – northern

Table 4.18 Summary of calcareous grassland quality criteria, ranked by strata

Quality criteria	Quality measure	Designated Hard	Designated Soft	Non-des Hard	Non-des Soft
Size	Estimated area of calcareous grassland (land cover definitions)	2	1	4	3
	% of squares with calcareous grassland (structural classification)	2	1	4	3
	No. of calcareous grassland main plots/square (structural classification)	2	1	4	3
Diversity	Mean no. of different calcareous plot classes present - main plots	1	2	3	4
	Mean no. of different calcareous plot classes present - habitat plots	4	1	2	3
	Mean no. of different calcareous species groups present - main plots	1	3	2	4
	Mean no. of different calcareous species groups present - habitat plots	1	2	4	3
Naturalness	Species no./main plot in calcareous habitat indicator group	2	1	3	3
	Species no./habitat plot in calcareous habitat indicator group	2	1	4	2
Representativeness	No. of main plots in calcareous plot classes	1	2	4	3
	No. of habitat plots in calcareous plot classes	3	1	2	4
	Species no./main plot in calcareous species groups	2	1	4	3
	Species no./habitat plot in calcareous species groups	2	1	3	4
Fragility	Species no./main plot for species vulnerable to succession	3	1	2	3
	Species no./habitat plot for species vulnerable to succession	2	1	3	4
	Species no./main plot for species vulnerable to eutrophication	4	1	3	2
	Species no./habitat plot for species vulnerable to eutrophication	2	1	2	4
Number of criteria ranked first		4	13	0	0
Number of criteria ranked second		9	3	5	2
Number of criteria ranked third		2	1	5	9
Number of criteria ranked fourth		2	0	7	6

calcareous grassland) are drawn out across the first gradient, with the northern group nearer to the acid vegetation area of the graph. The taller, tussocky calcareous plot class is at the other end of the first gradient, overlying the fertile and neutral grassland types, whilst the short calcareous grassland plot class is more central and overlies just the neutral grassland group. The plots which are not in calcareous grassland plot classes but which occur in a similar part of the graph may not be on suitable substrates to support calcareous grassland, or they may have been modified by management practices. The calcareous woodlands are completely separated from the calcareous grasslands by the second gradient, suggesting that there is little overlap in species composition.

4.14 Quality criteria – ranking of the calcareous grassland strata

4.14.1 Table 4.18 shows the results of ranking the four strata in terms of the quality measures discussed above. On this basis, the designated soft stratum appears to rank highest in terms of both the amount and the quality of calcareous grassland. The main measure for which this stratum does not rank highest is the number of species per plot (see diversity) – this demonstrates the importance of not assuming that high species number equals high quality, as the plots in this stratum did have the highest number of calcareous species (as defined for habitat indicator groups) and calcareous species groups. The designated hard stratum came second for most quality measures. These results suggest that most high-quality sites are in designated areas, but some in non-designated strata may be of high quality even if they are smaller in size.

4.15 Designations

4.15.1 The above discussion has considered designations as a whole, but clearly different types of designation may have different effects. Table 4.19 shows the

Table 4.19 Number of km squares including designations in the calcareous grassland mask

Designation	Hard limestone No.	Hard limestone *% of stratum*	Soft limestone No.	Soft limestone *% of stratum*	Calcareous grassland mask No.	Calcareous grassland mask *% of mask*
SSSI	1128	*24.4*	2338	*21.7*	3466	*13.1*
NNR	147	*3.2*	188	*1.7*	335	*1.3*
ESA	302	*6.5*	1302	*12.1*	1604	*6.0*
NP	2748	*59.4*	1185	*11.0*	3933	*14.8*
AONB	1509	*32.6*	7163	*66.6*	8672	*32.7*
HC	27	*0.6*	279	*2.6*	306	*1.2*
G Belt	134	*2.9*	1854	*17.2*	1988	*7.5*
Any design	4630	*100.0*	10751	*100.0*	15381	*58.4*

Squares may contain more than one designation, so the last row is not the sum of the above

Table 4.20 Number of survey squares including designations

	Hard limestone		Soft limestone		Calcareous grassland mask	
Designation	No.	*% of stratum*	No.	*% of stratum*	No.	*% of mask*
SSSI	8	*38.1*	13	*32.5*	21	*22.8*
NNR	0	*0.0*	2	*5.0*	2	*2.2*
ESA	5	*23.8*	4	*10.0*	9	*9.8*
NP	15	*71.4*	3	*7.5*	18	*19.6*
AONB	6	*28.6*	30	*75.0*	36	*39.1*
HC	0	*0.0*	2	*5.0*	2	*2.2*
G Belt	0	*0.0*	4	*10.0*	4	*4.3*
Any design	21	*100.0*	40	*100.0*	61	*66.3*

Squares may contain more than one designation, so the last row is not the sum of the above

distribution of the different designations within the calcareous grassland mask. AONBs cover the largest area. National Parks are most common in hard limestone areas, whilst there are more Green Belts and ESAs in soft limestone regions. SSSIs are significant in both.

4.15.2 Analysis of individual designations was not an objective of the project, and was not incorporated into the sampling strategy. The number of sample squares available for each designation allows only limited analysis (Table 4.20). The pattern is repeated for the sample squares, except where small sample numbers led to discrepancies. Thus, National Park is the only designation type to occur frequently in hard limestone areas.

Table 4.21 Overlap between designations for sample squares

Designation combinations							% of designated squares
SSSI							4.8
SSSI						G Belt	1.6
SSSI	NNR			AONB	HC		1.6
SSSI	NNR			AONB			1.6
SSSI	NNR						3.2
SSSI		ESA	NP				1.6
SSSI			NP				8.1
SSSI		ESA		AONB			3.2
SSSI				AONB			11.3
		ESA		AONB			4.8
				AONB		G Belt	1.6
				AONB	HC		1.6
				AONB			33.9
		ESA					1.6
		ESA	NP				4.8
			NP				11.3
						G Belt	3.2

4.15.3 In addition, the situation is complicated by the overlap between designations – Table 4.21. Of the sample squares in the designated strata, 45% have more than one designation.

4.16 Conclusions

4.16.1 The calcareous grassland mask was defined as an area of 26 343 km², of which 58% contained one or more of the specified designations. Of this landscape, just 1.6% (413 km²) was estimated to be calcareous grassland, 90% of which occurred in designated 1 km squares. Analysis of the quadrat data showed that this calcareous grassland included grazed short turf which was rich in herbs, longer tussocky grassland with fewer calcicolous herbs, and northern calcareous grassland associated with the hard limestone areas. It is not possible to determine from the field data how much of the improved grassland occurred in situations amenable to the restoration of calcareous grassland (eg areas of thin soils on slopes).

4.16.2 Given the scarcity of unimproved calcareous grassland, the priority in terms of conservation policy must be to maintain and enhance the existing areas of calcareous grassland through appropriate management. Most existing sites occur within designated areas, but this does not necessarily mean that they are receiving management which is optimal in terms of their ecological interest. Restoration schemes should be concentrated on areas adjacent to existing calcareous grassland, so that there is a source of seed available for colonisation, and so that the core areas are further protected by buffering from other land uses.

Chapter 5 HISTORICAL CHARACTERISTICS OF THE CALCAREOUS GRASSLAND MASK

5.1 Introduction

5.1.1 The archaeological study was designed to provide an 'evaluation of distribution of historic (archaeological) features in the calcareous grassland landscape and of the effectiveness of the designations in protecting these features'. In conjunction with this, the study was intended to examine the task of developing 'recommendations for modification/ enhancement of policies to improve protection of historic features'.

5.1.2 There were three specific aims of the archaeological study:

i. to examine the distribution of archaeological features in the calcareous grassland landscape;
ii. to assess the relationship between features and designations in the calcareous grassland landscape;
iii. to develop recommendations to modify designations to improve the protection of features.

5.2 Methodology

5.2.1 Two distinct types of archaeological data gathering were carried out: from archives and from new survey work. The 'extended national archaeological database' (see below) constitutes the recorded archaeological resource in England and extraction of data from it constituted the major part of the work. Survey work was designed to assess the viability of estimating the percentage of the archaeological resource examined in the sample squares. Within the current project, work was restricted to three sources:

- fieldwork by ITE staff (non-archaeologists);
- selective aerial photography (AP) analysis;
- map interpretation of recent edition Ordnance Survey map extracts supplied by ITE, County Sites and Monuments Records (SMRs) and the National Monuments Record (NMR).

5.2.2 No national standard was known to exist for the recording of the condition of archaeological monuments. It was therefore anticipated that local information, if available, would be difficult to use. However, information was collated within this project and its value was assessed. A work programme is shown in Appendix 3, together with a description of the available archaeological data

5.3 Analysis and results

The distribution of archaeological sites in the calcareous grassland mask

5.3.1 The quantity of archaeological monuments is presented in Table 5.1 (with further details in Appendix 3). These data suggest that the calcareous grassland mask is characterised as follows.

- Prehistoric periods are represented by a scattering of 'find' sites (ie where objects have been found) together with some Bronze Age barrows, some Iron Age settlement sites, and a few early field systems.

- The Roman period is also dominated by find sites, together with a scattering of settlement sites (including burials) and roads.

- Representation of the Early Medieval period is sparse, and includes three barrows.

- The Medieval period includes a small number of settlement sites and field systems.

- The Post Medieval period has a relatively large number of farming, industrial (with a range of extractive industry) and transport sites.

Table 5.1 Quantity of features in the calcareous grassland mask – RCHME* classes by period

	Pre-historic	Palaeo	Meso-lithic	Neo-lithic	Bronze Age	Iron Age	Roman	Early Medieval	Medieval	Post Medieval	Modern	Un-known
Agriculture and subsistence	2		2						6	10		50
Domestic						6	3	1	6	12		5
Civil										3		5
Recreation												1
Garden and parks										1		2
Commemorative												
Religious, ritual and funerary				1	7		6	5	5			19
Commercial												4
Industrial							1		3	26		29
Transport	2						3		3	22		12
Water and drainage									2	2		17
Maritime												
Defence									5		2	
Object	4		2	3	5	4	14	1	1	1		25
Unassigned	2		2		1	4	3	1	1	5		49

* Royal Commission on the Historical Monuments of England

Table 5.2 Quality of features – form groups by period for calcareous grassland mask

Form group	Pre-historic	Palaeo	Meso-lithic	Neo-lithic	Bronze Age	Iron Age	Roman	Early Medieval	Medieval	Post Medieval	Modern	Un-known
A–Structure	1								6	6	1	
B–Ruin									1	3		6
C–Underground										12		
D–Feature									1	10		4
E–Earthwork			4		5	3	5	3	13	5		25
F–Crop/soil	2				1	2			1			20
G–AP	1					1	2		3	6	1	34
H–Find	4		2	3	5	5	14	2	1	1		2
I–Doc/oral	2				2		4	2	6	40		94
J–Exc/rem				1		3	3	1		1		
Unspecified												13

Many of the unspecified sites almost certainly belong to the Post Medieval period and this group follows a similar pattern to the Post Medieval distribution, although with notable additional groupings under religious, ritual and funerary and under water and drainage.

5.3.2 Although some reference to the current condition of monuments is present in some SMR/NMR entries, it is widely variable. The nearest it is possible to get is to look at the recorded 'form' of monuments. However, this examination can only give an indication of the form which monuments currently take. Some monuments of a given form may be stable (eg henges as 'ruins', barrows as 'earthworks'); others of the same form may be rapidly deteriorating (eg many industrial structures as 'ruins').

5.3.3 The number of sites within form groups (aggregations of 20 'forms' into 11 groups – see Appendix 3, Table A3.3) for different archaeological periods (Table 5.2) shows a broad pattern, as might be expected. Structures and ruins are generally of recent date. Earthworks form one of the biggest groups of sites and are most common in the Medieval periods. Crop/soil sites and AP sites appear to be relatively uncommon. Finds as identifiers of sites are relatively plentiful and occur throughout the periods, although they are most important for Prehistoric and Roman sites. Sites identified from documentary sources are also plentiful, although artificially boosted within this dataset by the procedure employed to identify new sites (fieldwork would enable re-allocation by both form group and period of the bulk of these sites). The number of excavated/removed sites appears small, but the unrecorded removal of sites is unquantified.

Designations and archaeological features

5.3.4 Of 398 sites, 246 occur in 26 designated squares (9.5 km^{-2}), with 152 in 16 non-designated squares (9.5 km^{-2}) (Tables 5.3 & 5.4). There is therefore no apparent correlation between designation and density of sites. Sites which are Scheduled Ancient Monuments number 12, which is 3% of the total number of sites in the calcareous grassland dataset, and most of these (all but two) were in areas which were already designated (Table 5.5).

5.3.5 Condition information was, as expected, severely limited. The location of this information within SMR structures is very variable and the information given is to no standard either within or between SMRs. Virtually no information was available on the changing condition of the monuments.

5.4 Discussion

5.4.1 The results of the archaeological study are limited by the inadequacies of the available data. There is clearly a need to review the way in which information about archaeological site condition is recorded, so that recording over future decades will allow such analyses to be undertaken. Indeed, English Heritage is currently funding the Monuments at Risk Survey (MARS) to compile this type of information for a 5% sample area of England, looking at current condition and attempting to gauge changes over the past 50 years (Darvill, Fulton & Bell 1993).

5.4.2 Factors behind the inadequacy of the compiled data include the following.

- The expected variability of SMR data has been confirmed. There is particular variation in the terms used for 'site type' and 'form'. Entries for these fields required standardisation (often difficult to achieve objectively) at the data entry stage. The range in number and types of site represented also varies widely according to the sources used in the creation and enhancement of each SMR. For example, site identification from aerial photographs is common to most SMRs, but the quality and extent of AP coverage, together with the reliability of the identifications, is variable and difficult to quantify.

Table 5.3 Designations – number and mean number of sites per km square by data source and designation

Data source	Designation	Total no. of sites	Mean km^{-2}
SMR/NMR	Yes	190	7.3
	No	88	5.5
Field survey	Yes	56	2.2
	No	64	4.0
Combined sources	Yes	246	9.5
	No	152	9.5

Table 5.4 Number of sites per square for each designation for calcareous grassland

Designation	No. of sites	No. of squares	Sites km^{-2}
G Belt	11	1	11.0
AONB	153	17	9.0
SSSI	116	12	9.7
NP	74	7	10.6
HC	11	2	5.5
NNR	20	2	10.0
ESA	29	4	7.3

Table 5.5 Correlation of SAMs with other designations for calcareous grassland

G Belt	AONB	SSSI	NP	HC	NNR	ESA	No. of sites
							2
	•						5
	•	•			•		5
0	10	5	0	0	5	0	12

- A further problem is the absence of any standards in recorded information about management history of archaeological sites, even though all SMRs have database fields for this information.

- The aerial photography analysis and fieldwork carried out were too limited to be of any real use in estimating the percentage of the total archaeological resource that has been recorded.

- The lack of location data for designations is a problem – the only designations for which we have consistent specific locations are the SAMs.

5.4.3 It is suggested that any attempt at this stage at useful comment on the effects of designations on archaeological sites might be provided by a combination of case studies with a programme of more detailed site identification and subsequent site inspection by experienced archaeologists.

5.4.4 However, the current project has shown that the calcareous grassland mask contains features from all historic periods, although representation of the Early Medieval period is sparse. The frequency of features was higher in designated than in non-designated strata. There appears to be a strong correlation between SAM designation and other types of designation, particularly AONBs. It is not possible to say whether designation status has helped to preserve sites or whether, by contrast, designated sites have been subject to more intensive examination.

5.4.5 From the conclusions of Chapter 4 and the above discussion, it is apparent that designated areas are richer in both 'core' vegetation types and historic features than are non-designated sites.

Chapter 6 PRESSURES FOR CHANGE: ATMOSPHERIC POLLUTION

6.1 Introduction

6.1.1 In Chapter 2 the existing and potential causes of change in calcareous grassland landscapes are summarised, including the effects of atmospheric pollution (para 2.9.16). Atmospheric pollution is considered here in more detail, specifically in terms of acid deposition and nitrogen enrichment.

6.2 Acid deposition

Critical loads

6.2.1 Areas of calcareous grasslands which may be affected by excessive atmospheric acid deposition can be mapped using the 'critical loads' approach, as developed by the Critical Loads Advisory Group (CLAG) under contract to the Department of the Environment (CLAG 1994).

6.2.2 A critical load is defined as a deposition threshold (in this case an atmospheric pollutant) below which long-term damage will not occur. Critical loads maps for soils, which reflect the weathering rate of the soil minerals, show that calcareous soils are in the least sensitive class, with a critical load in the range of 2.0–4.0 kg $H+\ ha^{-1}\ yr^{-1}$ (CLAG 1994). These values can be compared with maps of total sulphur deposition which are based on measurements of wet and dry deposited sulphur compounds and are displayed on a 20 km grid of GB (Hornung *et al.* 1995). The map of 'current' deposition is based on data collected from 1989 to 1991, which when compared with the critical loads value gives an exceedance map showing areas where the deposition exceeds the weathering rate of the soil. This map indicates areas of GB where, in this case, the calcareous grassland mask is most likely to be affected by current sulphur emissions.

6.2.3 The effects of future emission scenarios on sulphur deposition and exceedance can be predicted using a computer model – the Hull Acid Rain Model (HARM). As part of the UNECE Convention on Long-Range Transboundary Pollution (CLRTAP), Britain has agreed to a 70% reduction in sulphur emissions between 1980 and 2005 and an 80% reduction by 2010. The effects of these scenarios compared to the 1989–91 baseline have been evaluated in terms of the proportion of the calcareous grassland mask in areas where the soils' critical loads are exceeded.

Results

6.2.4 Calcareous soils are relatively insensitive to acid deposition and, as a result, they have high critical load values. Taking a critical load value at the low end of the range for calcareous soils (2.0 kg $H+\ ha^{-1}\ yr^{-1}$), only 18% of the squares in the areas covered by the calcareous grassland mask have critical loads which are exceeded by the baseline level (1989–91) of total sulphur deposition (Figure 6.1). The proportion of exceeded squares is higher in the massive limestone

Table 6.1 Areas within the calcareous grassland mask by acid (total sulphur) deposition. Figures in the body of the Table show the percentage of 1 km squares in each area in which acid deposition exceeds the soils' critical load

Scenario	Geology	Calcareous grassland mask		
		Designated	Undesignated	Total
Baseline (1988–91)	Soft limestone: chalk	8%	4%	7%
	Soft limestone: oolitic limestone	19%	11%	14%
	Hard limestone	43%	14%	32%
	Buffer zone (escarpments)	19%	9%	15%
	Total – baseline	18%	8%	14%
70% reduction from 1989–91 baseline	Total	0%	0%	0%

Table 6.2 Inputs of total atmospheric nitrogen to the calcareous grassland mask in England

Region		% of 1 km squares receiving total atmospheric nitrogen: >14 kg ha^{-1} yr^{-1}	>20 kg ha^{-1} yr^{-1}	>25 kg ha^{-1} yr^{-1}
Mask area	Soft limestone	95%	45%	3%
	Hard limestone	87%	62%	42%
	All mask	93%	50%	14%
All England		90%	37%	9%

areas of north-west England (32%) than in the chalk areas (7%) of southern and eastern England (Table 6.1). Squares which contain designations are also at greater risk than those which do not, particularly in areas of massive limestones.

6.2.5 Under a 70% emissions reduction scenario (derived by HARM), the forecast is that no areas of calcareous grassland will receive excessive acid deposition.

6.2.6 The critical load for individual species or assemblages may differ from the site critical load as determined from soils. There is insufficient quantitative information on the effects of sulphur deposition on the fauna and flora of calcareous grasslands to be certain of how damaging acid deposition will be to these ecosystems as a whole. The impacts of acid deposition on calcareous vegetation have been modelled using TRISTAR (TRIangular STrAtegic Rules for British herbaceous vegetation) (Hunt *et al.* 1991), and results from this work are described in Chapter 7.

6.3 Nutrient enrichment – the effects of atmospheric nitrogen inputs

6.3.1 Preliminary data on rates of atmospheric nitrogen (N) deposition are available and have been used to identify areas of calcareous grassland where N deposition rates are particularly high. The nitrogen deposition data are derived from the National Monitoring Network run by the Warren Spring Laboratory, using adjustments for altitude effects and estimates of dry deposition (UK Review Group on Impacts of Atmospheric Nitrogen 1994). The data are for total nitrogen (including wet and dry deposition in reduced and oxidised forms) for 1989–91, interpolated to a 20 km x 20 km grid of Great Britain.

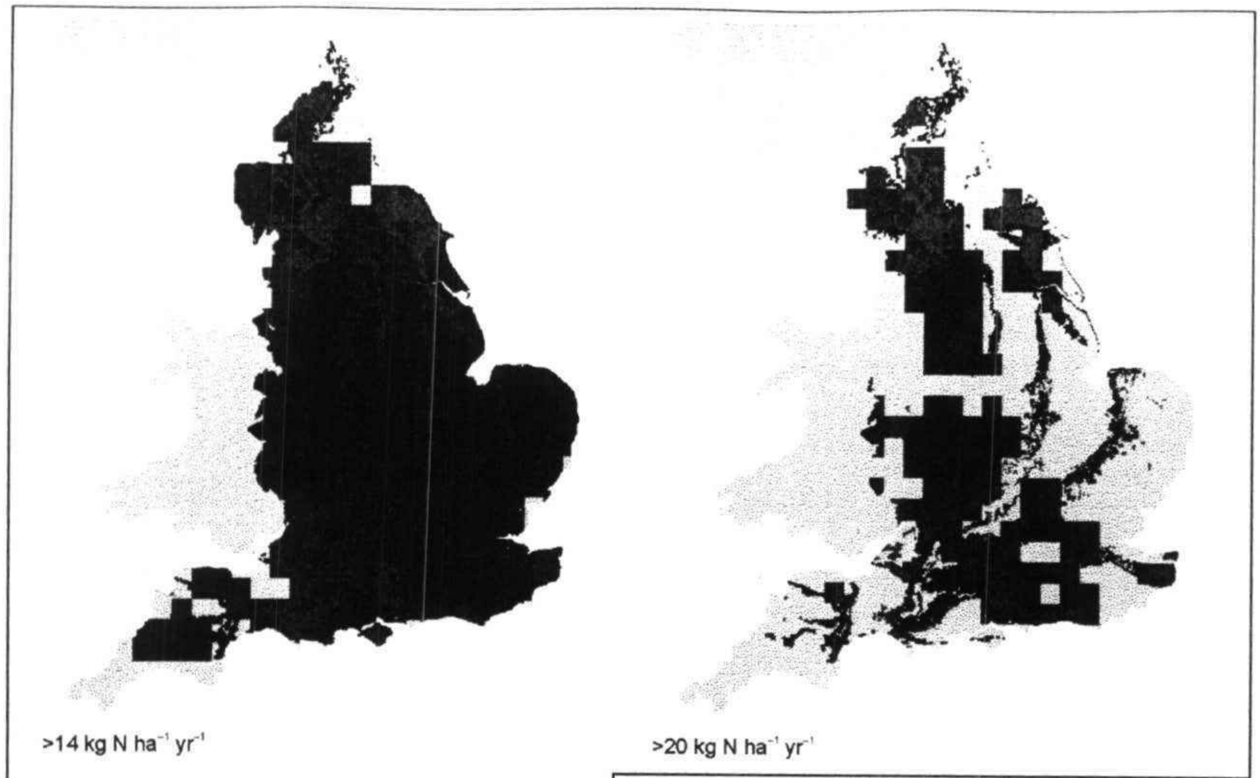
Results

6.3.2 Average atmospheric deposition of nitrogen (eg from nitrogenous gases such as NO_x and NH_x) in calcareous grassland areas is 21 kg nitrogen ha^{-1} yr^{-1}, which is similar to the average for England (19 kg N ha^{-1} yr^{-1}).

6.3.3 These rates of atmospheric N deposition are low compared to average agricultural inputs, but there is a lack of experimental information on the long-term effects of these rates on calcareous grasslands. However, experimental results from grasslands on peat soils in the Somerset Levels (Mountford, Lakhani & Holland 1994) show that the cumulative effect of N rates as low as 25 kg N ha^{-1} yr^{-1} over a period of six years can cause significant changes in plant community composition. It is likely that the low rates of atmospheric N will have a significant effect on community composition in calcareous grasslands, with gradual nutrient enrichment leading to a loss of plant species diversity.

6.3.4 The critical loads for the effects of nitrogen deposition are not well defined at present. Preliminary critical loads for nitrogen in a

Figure 6.1 Impact of acid deposition on chalk and limestone grasslands – exceeded areas (1988–91 baseline) shown in black. Black areas represent chalk and limestone areas receiving over 2 keq total sulphur ha^{-1} yr^{-1} (baseline scenario), ie areas where the critical load of calcareous soils is currently exceeded



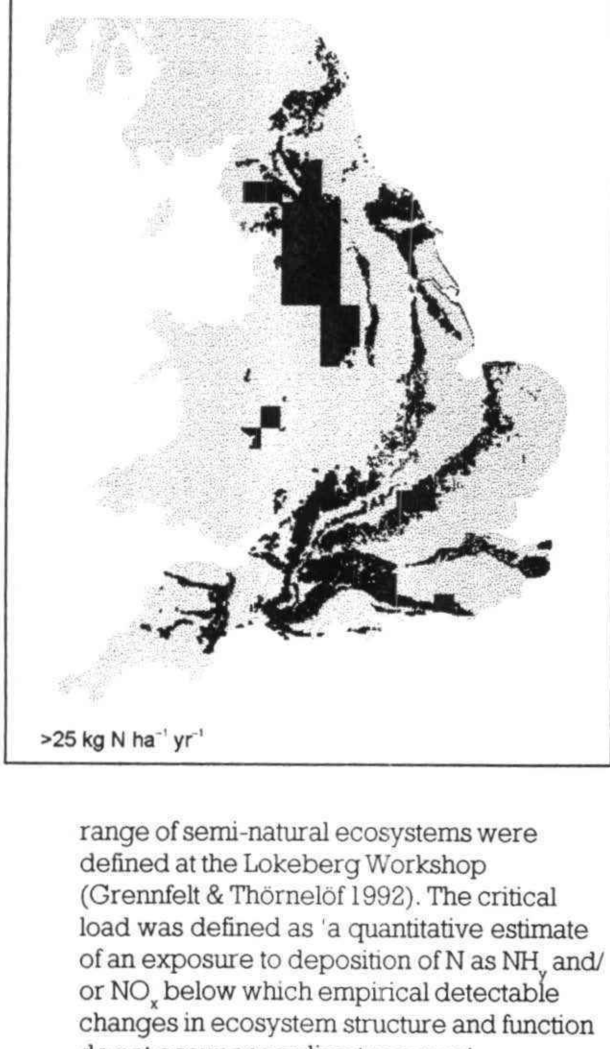


Figure 6.2 Total atmospheric nitrogen inputs on areas of potential chalk and limestone grassland. Exceeded areas shown in light green

range of semi-natural ecosystems were defined at the Lokeberg Workshop (Grennfelt & Thörnelöf 1992). The critical load was defined as 'a quantitative estimate of an exposure to deposition of N as NH_y and/or NO_x below which empirical detectable changes in ecosystem structure and function do not occur according to present knowledge'. For calcareous species-rich grasslands, the critical load was assessed in the range of 14–25 kg N ha^{-1} yr^{-1}. In calcareous grasslands, critical load exceedance would be indicated by increases in tall grass and a decline in diversity. More recent experimental evidence indicates that the critical loads for nitrogen may be much higher than these values, particularly in areas where phosphorus is limiting plant growth rather than nitrogen (Wilson, Wells & Sparks 1995).

6.3.5 In England 90% of 1 km squares receive more than 14 kg N ha^{-1} yr^{-1}, which is the minimum of the critical load range, but only 9% of squares receive in excess of 25 kg N ha^{-1} yr^{-1} – the upper estimate of the critical load. There is therefore considerable uncertainty when it comes to identifying the area at risk from excessive N deposition (Table 6.2).

6.3.6 This uncertainty is also apparent when analysing nitrogen deposition on areas of calcareous grassland. The analysis indicates that the low estimate of areas at risk (ie squares in the calcareous grassland mask receiving total nitrogen in excess of the critical load) is 14% and the high estimate is 93% (Table 6.2, Figure 6.2).

6.3.7 The hard limestone areas of northern England are most at risk from nitrogen deposition; 42% of squares in this category receive more than 25 kg N ha^{-1} yr^{-1}.

6.4 Summary

6.4.1 Calcareous grasslands, by definition, tend to be found on base-rich soils which are relatively insensitive to the effects of acid deposition. Under the UNECE Convention to reduce atmospheric acid deposition by 70% by the year 2005, no areas of the calcareous grassland mask will remain at risk from excessive deposition. There is, however, some uncertainty about the consequences of this scenario for calcareous grassland vegetation. Calcareous grasslands are also at some risk from excessive atmospheric nitrogen deposition. Preliminary data show that they are receiving an average of 21 kg of atmospheric nitrogen ha^{-1} yr^{-1} and that, at this rate, there may be gradual enrichment of calcareous soils leading to a loss of plant species and a change in species towards faster-growing grasses.

6.4.2 These and other potential pressures on the calcareous grasslands of England are considered in the following Chapter, where the effects on vegetation are modelled using techniques developed at the University of Sheffield.

Chapter 7 PREDICTING CHANGES IN CALCAREOUS GRASSLAND VEGETATION

7.1 Introduction

7.1.1 This Chapter describes the development and use of conceptual models to predict the effect of environmental changes, and changes in agricultural management, on the quality of calcareous grassland landscapes.

7.1.2 TRISTAR is an expert-system model which deals with the fundamental environmental and management processes controlling the composition of British herbaceous vegetation. The TRISTAR2 model, developed for this project, is a program which extends this approach specifically into the areas involving climate change scenarios.

7.1.3 TRISTAR2 takes a given specification of an initial steady-state vegetation, adopts some altered environmental and/or management scenario, and then predicts the compositions of the new steady-state vegetation in terms of its component functional types.

7.1.4 Vegetational survey data collected during this study (see Chapter 4) were processed in three distinct phases by means of the TRISTAR2 model. After the final phase, the outputs of the modelling are examined and interpreted.

7.2 Phase I – allocation of functional types

Brief description of methods

7.2.1 The initial steady-state vegetation was specified as a list of abundance of species in each of the survey plots. Each vegetation record has been classified according to both of two sets of criteria:

- the designated status, if any, of the site from which the record was taken, and
- the plant community type into which the vegetation of the quadrat falls.

The basis for the second of these classifications is a TWINSPAN analysis which divides the plots into 28 plot classes as described in Chapter 4 (Section 4.4).

7.2.2 For each plot, one of 19 functional types (see Appendix 4) is then allocated to each of the component species using information from the databases of the Unit of Comparative Plant Ecology (UCPE) at the University of Sheffield. Briefly, two external groups of factors, called 'stress' and 'disturbance', both of which are antagonistic to plant growth, are recognised.

7.2.3 When the four permutations of high and low stress against high and low disturbance are examined, a different primary strategy type emerges in association with each of the three viable contingencies: **competitors** (C) in the case of minimum stress and minimum disturbance, **stress-tolerators** (S) in the case of maximum stress and minimum disturbance, and **ruderals** (R) in the case of minimum stress and maximum disturbance. Intermediate types of C-S-R strategy can be identified (Figure 7.1), each exploiting a different combination of intensity of external stress and disturbance.

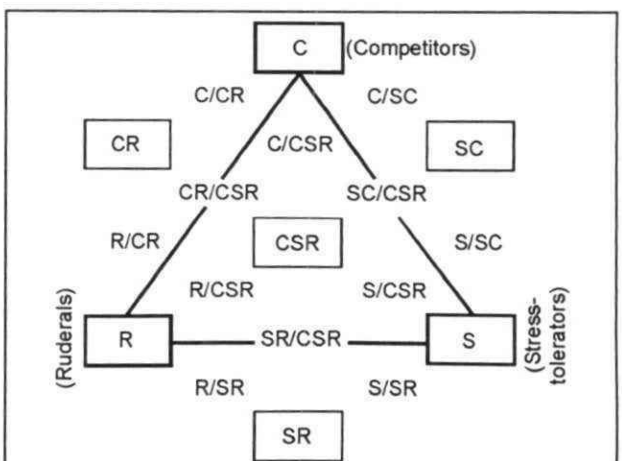


Figure 7.1 The C-S-R triangle ordination, showing the three principal functional types and intermediate positions

7.2.4 TRISTAR2 conflated the weighted abundance of up to a maximum of 19 individual functional types which may be present within each sample. This process created weighted abundance for each of seven broader groups of functional types. These seven groups represent the three extreme corners of the C–S–R triangle ordination (see Figure 7.1), its centre, and its principal intermediate positions. These seven groups were each converted into a two-part numerical code which provided a computational mechanism for representing both 'pure' and intermediate functional types.

7.2.5 Once converted, the classifications according to functional type provided the basis for all further work on the vegetation sample by TRISTAR2. Appendix 4 provides details of the TRISTAR model and how it has been used. The presentation for each scenario consists of a divided percentage bar diagram illustrating the functional composition of all the plot classes present in the initial vegetation, with an ecological interpretation.

Results

7.2.6 As stated in Chapter 2, calcareous grasslands are restricted to nutrient-poor basic soils. The vegetation is kept in a relatively open state by grazing. Typical functional types are stress-tolerator and competitor/stress-tolerator/ruderal. Thus, plot classes PCL (basiphilous/calcareous grassland, tussocky with herbs), PCO (calcareous grassland, short-turf, grazed, with small herbs) and PCT (northern calcareous grassland) (Table 4.4) are among the most 'typical' of calcareous grassland in terms of functional type.

7.2.7 However, because the survey was of a broad calcareous grassland mask, several plot classes do not conform to 'calcareous grassland' even in strategic terms, and these have been assigned to a 'woodland' or a 'grassland' grouping, as described in Chapter 4. The woodland plot classes are dominated by stress-tolerator/competitor and, to a lesser extent, competitor types. PCC (calcareous woodland, eutrophic, often woodland edge) expectedly has the smallest representation of S, a type which, in the context of woodland, is often associated with shade tolerance. PCM (basiphilous woodland, more open, grassy) has most species of SR, and most vernal species.

7.2.8 In the grassland plot classes, the competitor/stress-tolerator/ruderal type is the most characteristic of grazed conditions and classes PCH (fertile grassland, short, often disturbed), PCJ (neutral/basiphilous grassland, tall with herbs), PCK (neutral/basiphilous grassland, short, mown or grazed), PCL (basiphilous/calcareous grassland, tussocky with herbs), PCN (neutral permanent pasture), and PCP (neutral grassland, semi-improved, grazed or mown) are most typical of relatively productive grassland. In semi-natural 'unimproved' calcareous grassland (PCL – basiphilous/calcareous grassland, tussocky with herbs, PCO – calcareous grassland, short-turf, grazed, with small herbs, and PCT – northern calcareous grassland), where stocking rates are lower, there is some replacement of type competitor/stress-tolerator/ruderal by the stress-tolerator type. Where the frequency of type competitor, competitor/ruderal and stress-tolerator/competitor is high, this indicates low or no management inputs, ie dereliction. PCB (fertile grassland, overgrown, often shaded) and PCG (eutrophic grassland, overgrown, tall herbs, often shaded/wet) are extreme examples of abandoned grassland. A high incidence of type ruderal is associated with disturbed conditions and the presence of this type in PCA (fertile grassland, with annual weeds) and PCF (intensive grassland, rye-grass-dominated, often disturbed) may relate to disturbance, while it may concern management (mowing) in PCP (neutral grassland, semi-improved, grazed or mown), and abandonment in PCB (fertile grassland, overgrown, often shaded), PCD (tall, coarse grassland, open), and PCE (eutrophic grassland, often neglected).

7.2.9 Those classes grouped under 'acidic vegetation' (PCV – acid grassland, often rushy, PCW – dry grassland/heath, PCX – bracken/dry heath, often shaded, PCY – moorland grassland, PCZ – mossy heath, often planted with Sitka spruce (*Picea sitchensis*), PCAA – mire, and PCBB – wet heath/bog) are almost by definition 'unimproved'. An early stage in reclaiming the land for intensive agriculture would have been the application of lime. All have low representation of types associated with productive conditions (competitor, competitor/ruderal, ruderal). PCW (dry grassland/heath) and PCY (moorland grass, moist) have the highest proportion of type stress-tolerator, indicative of unproductive conditions, and PCAA (mire) and PCBB (wet heath/bog) most stress-tolerator/competitor type, indicating low intensities of grazing (perhaps often because of the presence of unpalatable rushes). PCZ is planted with Sitka spruce, and is also type stress-tolerator/competitor.

7.2.10 Maritime habitats (PCCC – mostly saltmarsh) are predominantly eutrophic and disturbed, with no representation of type stress-tolerator.

7.2.11 Key species include sheep's fescue (*Festuca ovina*) and heather (*Calluna vulgaris*), important constituents of unimproved pasture and heathland respectively, and important invaders are:

i. in derelict conditions, birch (*Betula pendula, B. pubescens*) and other trees and shrubs; bracken, mat-grass (*Nardus stricta*), tor-grass and other coarse grasses;
ii. in derelict eutrophicated conditions, gorse (*Ulex europaeus*), bramble (*Rubus fruticosus*), stinging nettle (*Urtica dioica*), rosebay willowherb (*Chamanerion angustifolium*) and other tall herbs, false oat (*Arrhenatherum elatius*) and other coarse grasses;
iii. in wet areas, soft rush (*Juncus effusus*), tufted hair-grass (*Deschampsia cespitosa*);
iv. in salt marshes, cord-grass (*Spartina anglica*).

7.2.12 In summary, most of the 'core' calcareous grassland vegetation was composed of stress-tolerator and competitor/stress-tolerator/ruderal types. The remaining vegetation plot types were representative of all other combinations of functional types

7.3 Phase II – effects of change scenarios on the abundance of functional types

Brief description of methods

7.3.1 The TRISTAR2 model was populated with six scenarios comprising selected combinations of two environmental factors – disturbance and eutrophication. Each scenario can have more than one possible management or climate change interpretation, and examples of the possible causes of each scenario are given in the results. The scenarios were:

i. decreased disturbance and no change in eutrophication
ii. decreased disturbance and increased eutrophication
iii. no change in disturbance and decreased eutrophication
iv. no change in disturbance and increased eutrophication
v. increased disturbance and decreased eutrophication
vi. increased disturbance and increased eutrophication

7.3.2 For each factor and functional type within the six specimen scenarios, TRISTAR2 applied an appropriate numerical multiplier according to our understanding of the effects of the factor. The essence of the approach is that seven functional types are each driven by this weighting in different directions and with different gradients, according to information from UCPE's extensive survey and screening databases.

Example results

7.3.3 Full outputs from the model are given in Appendix 4. Within this Chapter, summary results for only the core calcareous grassland plot classes are described.

Scenario 1. Decreased disturbance and no change in eutrophication

7.3.4 Possible causes of this scenario, as it affects the core calcareous grassland vegetation, include cessation/reduction of grazing or cutting, less recreational pressure, and reduced incidence of fires. Decreased disturbance is the scenario associated with abandonment or dereliction.

7.3.5 In less productive grassland, particularly 'unimproved' calcareous grassland and acidic vegetation, growth rates are slow and small changes are expected. Because of the lower productivity, type stress-tolerator/competitor rather than competitor is a major beneficiary of dereliction. Paradoxically, reduced disturbance from land use activities could, in unproductive situations, eventually result in episodes of increased disturbance. An increase in above-ground biomass is predicted and, in the event of fire, a greater quantity of combustible material would be present. The heat of any ensuing fire may cause greater mortality, opening up areas for recolonisation.

Scenario 2. Decreased disturbance and increased eutrophication

7.3.6 Possible causes of this scenario, as it affects the core calcareous grassland vegetation, include cessation/reduction of grazing, less recreational pressure, and reduced incidence of fires, together with increased fertilizer runoff or atmospheric deposition.

7.3.7 Increased eutrophication in combination with decreased disturbance will have a greater and more rapid impact on the distribution of functional types in core calcareous grassland than in Scenario 1. In less productive grassland, particularly 'unimproved' calcareous grassland and acidic vegetation, growth rates will be slow, and shifts to the competitor/stress-tolerator/ruderal type are expected.

Scenario 3. No change in disturbance and decreased eutrophication

7.3.8 Possible causes of this scenario, as it affects the core calcareous grassland vegetation, include decreased usage of or pollution from fertilizers.

7.3.9 As with scenario 2, large changes are forecast with increases in types stress-tolerator and stress-tolerator/competitor and decreasing competitor, competitor/ruderal and ruderal. However, an increase in the main beneficiary, type stress-tolerator, which grows very slowly, will take considerably longer and results may be less marked than predicted. Many species of the stress-tolerator type do not form a persistent bank of seeds in the soil or exhibit long-distance dispersal. In less productive grassland, particularly 'unimproved' calcareous grassland and acidic vegetation, growth rates will already be slow and a major shift to stress-tolerator type is expected.

Scenario 4. No change in disturbance and increased eutrophication

7.3.10 Possible causes of this scenario, as it affects the core calcareous grassland vegetation, include fertilizer runoff or atmospheric deposition.

7.3.11 Increased eutrophication is one of the most important scenarios to consider with respect to changing land use. In less productive grassland, particularly 'unimproved' calcareous grassland and acidic vegetation, growth rates are slow and the predicted shift is more from type stress-tolerator and stress-tolerator/competitor to competitor/stress-tolerator/ruderal.

Scenario 5. Increased disturbance and decreased eutrophication

7.3.12 Possible causes of this scenario, as it affects the core calcareous grassland vegetation, include higher incidence of fire, increased grazing, and more recreational pressure, together with less fertilizer runoff or atmospheric deposition.

7.3.13 Increased disturbance coupled with decreased eutrophication will have a major impact on the composition with respect to functional types. In less productive grassland, particularly 'unimproved' calcareous grassland and acidic vegetation, type stress-tolerator/ruderal, the main beneficiary of disturbance is likely to consist of low-growing and generally unpalatable bryophytes. The main impact of decreased eutrophication should be an increase in type stress-tolerator. However, this type grows very slowly and changes will also be correspondingly slow. The vegetation will become less fire-prone because of reduced above-ground biomass. There could also be a reduction in transpirational water loss leading to a slightly increased water table.

Scenario 6. Increased disturbance and increased eutrophication

7.3.15 Possible causes of this scenario, as it affects the core calcareous grassland vegetation, include increased incidence of fires, more grazing, and more recreational pressure, together with increasing fertilizer runoff or atmospheric deposition.

7.3.16 The combination of increased eutrophication and increased disturbance, which is a very common impact upon the British landscape, will have major impacts on the composition with respect to functional types. For less productive grassland, particularly 'unimproved' calcareous grassland and acidic vegetation, greatest losses of type stress-tolerator are predicted. There will be fewer fires because of the reduced biomass and less persistent litter associated with this scenario. Under these circumstances, fast-growing species of type competitor, competitor/ruderal and ruderal might be encouraged, particularly if these species had good dispersal in space (numerous wind-dispersed seeds or spores) and/or in time (a persistent seed bank in the soil).

Table 7.1 Mean 'indices of vulnerability' for six change scenarios

Scenario	Characteristics	Mean index of vulnerability	Impact
1	Decrease disturbance; no change in eutrophication	<0.01	Low
2	Decreased disturbance and increased eutrophication (eg decline in grazing pressure with an increase in fertilizers)	0.01	Low
3	No change in disturbance and decreased eutrophication (eg no change in grazing pressure but a decrease in fertilizers)	0.07	Low
4	No change in disturbance and increased eutrophication (eg no change in grazing pressure but an increase in fertilizers)	0.05	Low
5	Increased disturbance and decreased eutrophication (eg increase in grazing pressure with fewer fertilizers)	0.22	Medium
6	Increased disturbance and increased eutrophication (eg increase in grazing pressure and an increase in fertilizers)	0.28	Medium

7.4 Phase III – computation of an 'index of vulnerability'

7.4.1 For each of six scenarios, predictions for each functional type in each plot class present in the habitat (PCA, PCB, etc) are computed. An index of vulnerability is computed for each plot class. The index of vulnerability is displayed as a bar diagram for each plot class in Appendix 4 and is derived in three substages:

i. examine the original data to find the number of quadrats deviating appreciably from the typical;
ii. examine the TRISTAR2 predictions to find the new number of quadrats deviating appreciably from the original composition;
iii. find the 'index of vulnerability' for each plot class.

Summary of results

7.4.2 Full outputs from the model are given in Appendix 4 and a summary is given in Table 7.1.

7.4.3 Scenarios 1–4 all have low indices of vulnerability, even where eutrophication increases.

7.4.4 For scenario 5 (increased disturbance; decreased eutrophication) the values for index of vulnerability show a wide range of susceptibilities. Greatest vulnerability is shown by some of the more eutrophic plot classes but, of the calcareous grassland classes, PCL (basiphilous/calcareous grassland, tussocky with herbs) also shows moderate vulnerability.

7.4.5 For scenario 6 (increased disturbance; increased eutrophication), over half of the classes have at least moderate values for index of vulnerability. PCA (fertile grassland, with annual weeds), which is already eutrophic and disturbed, shows least vulnerability and those plot classes associated with tall little-managed vegetation (PCD – tall, coarse grassland, open, and PCJ – neutral basiphilous grassland, tall with herbs) and with unproductive conditions (PCO – calcareous grassland, short-turf, grazed, with small herbs, PCT – northern calcareous grassland, and PCV – acid grassland, often rushy) exhibit the greatest vulnerability. Long-term impacts on the composition of the vegetation with respect to both functional types and individual species will be large and difficult to reverse. The worst 'losers', type S, occupy a shrinking proportion of the British countryside and many are not very mobile.

7.5 Summary of modelling results

7.5.1 The calcareous grassland mask includes a heterogeneous grouping of calcareous grassland, other grassland types and woodland. However, most of the individual vegetation types are relatively unproductive and ecological theory would suggest that these classes would be relatively unresponsive, at least in the shorter term, to minor changes in land management. This hypothesis is borne out by the modelling results, only a handful of classes reaching 'moderate' vulnerability to change. However, the index of vulnerability differs markedly between scenarios. The most extreme scenario appears to be 'increased disturbance and eutrophication', with three plot classes showing high vulnerability.

7.5.2 The impact to the various scenarios can be ranked as follows.

Low impacts

- Disturbance decreased; eutrophication same (lowest impact)

- Disturbance same; eutrophication decreased
- Disturbance decreased; eutrophication increased
- Disturbance same; eutrophication increased

Moderate impacts

- Disturbance increased; eutrophication decreased
- Disturbance increased; eutrophication increased (highest impact)

7.5.3 Although the differences between habitat groupings are relatively slight, some of the coarser and taller grassland classes appear to be among the most vulnerable (eg PCD – tall, coarse grassland, open, PCJ – neutral/ basiphilous grassland, tall with herbs, PCQ – neutral grassland, unimproved, light/no grazing, some shading, and PCV – acid grassland, often rushy). Other, wetter grassland classes such as PCR (marsh/ rushy pasture), PCU (northern, damp pasture, often with flushes) and PCY (moorland grass, often moist) are under very little threat. The core calcareous grassland and woodland classes occupy an intermediate position. However, vulnerability differs markedly according to scenario. For example, PCJ (neutral/ basiphilous grassland, tall with herbs) is under the greatest threat of all under scenario 6 (disturbance increased; eutrophication increased) but has a very low vulnerability score under scenario 4 (disturbance same; eutrophication increased). It is therefore important when interpreting predictions to consider each scenario separately for a given plot class.

7.5.4 Calcareous grassland consists of a heterogeneous grouping of managed grassland, unmanaged grassland and woodland vegetation, most of which are relatively unproductive. The ecological hypothesis that such vegetation is likely to be unresponsive to changing management, at least in the short term, is supported by the results, with only four classes (all damp grassland types) reaching even 'moderate' vulnerability. In general, grassland plot classes are among the more vulnerable, with woodland being the best protected and calcareous grassland vegetation occupying a middle position.

7.5.5 Overall, the modelling results show that the plot classes within the calcareous grassland landscape are most vulnerable to a combination of increased disturbance and increased eutrophication. This scenario is most likely to result from increased grazing plus increased fertilizer runoff or continued large atmospheric inputs of nitrogen. The combination of factors would lead to a loss of characteristic species of the core calcareous grassland plot classes. Increased eutrophication with no change in the level of disturbance would lead to similar changes in the 'unimproved' calcareous grassland.

Chapter 8 SUMMARY OF THREATS AND POLICY RESPONSES

8.1 Introduction

8.1.1 This Chapter summarises what is known about the existing extent and quality of calcareous grassland, reviews existing policy instruments, and assesses threats to this landscape/habitat type.

8.1.2 Calcareous grasslands are ancient landscapes created and shaped by human activity. They are recognised for their ecological value and for their scenic, recreational and historic importance. Ecologically they are particularly valued for their botanical diversity and in recreational terms because they often provide open accessible land near urban areas and with good viewpoints. Some of the large ancient hillforts and burial grounds also occur in these landscapes. Considerable areas of chalk grassland have been lost in recent years as a result of pasture improvement, conversion to arable or forestry, or under-grazing.

8.2 Key findings of the survey

Field survey

8.2.1 Table 8.1 summarises key findings from the field survey and provides a more detailed analysis of soft/chalk grasslands and hard/ northern limestones, based on the quality of habitat and the vegetation cover. The survey shows that, of the 26 343 km² comprising the calcareous grassland mask, only 1.5% of this (some 41 260 ha) can be classified as unimproved (species-rich), or 'core', calcareous grassland.

8.2.2 The survey data have been presented on the basis of two different types of chalk grassland habitat with different geographical spread, land use and other management characteristics as follows.

- Soft/southern chalk grasslands occur mainly in the south and east of the country (South Downs, South Wessex Downs, Cotswold Hills, etc). Sites are

Table 8.1 Estimates of the extent (ha) of the calcareous grassland landscape by category (source: field survey)

Type of habitat	Soft/southern chalk	Hard/northern limestone	Total
Core calcareous grassland	33 200[1]	8 060[2]	41 260
• Designated	30 240	6 890	37 130
• Undesignated	2 960	1 170	4 130
Neutral improved grass[3]	488 830	273 610	761 440
Woodland[4]	179 720	81 110	260 830
Arable	815 010	60 600	875 610
Other	403 240	281 620	684 860
Total	1 928 400	705 900	2 634 300
• Designated	1 075 100	463 000	1 538 100
• Undesignated	853 300	242 900	1 096 200

[1] Plot classes L and O
[2] Plot class T
[3] Plot classes A, B, D to H, J, K, P to R, U to BB
[4] Plot classes C, I, M, S

often within extensive arable or livestock farming systems, generally small and often adjacent to woodlands.

- Hard/northern limestone grasslands occur mainly in the north and west of the country (Yorkshire Dales, north-west, etc) and tend to be within extensive livestock farms and in relatively large units, offering considerable opportunities for natural regeneration and improvement. Hard limestone grasslands tend to contain more semi-natural vegetation than chalk grasslands, but little calcareous grassland *per se*.

8.2.3 Independent estimates are not strictly comparable due to differences in classification and definition, but English Nature estimates that there are some 45 000 ha of semi-natural lowland calcareous grasslands, all of which it would wish to see enhanced through appropriate management. Rough estimates by the countryside agencies during the 1995 review of Countryside Stewardship suggest that there is a further 30 000 ha of upland chalk and magnesium limestone grasslands (mainly in Northumberland and Durham) of similar conservation value. Furthermore, the Countryside Commission suggests that much of the surrounding landscape is former downland which has been degraded through intensification, neglect or scrubbing-up and that some 40 000 ha would benefit from restoration. Finally, there are arable areas on thin soils which are susceptible to erosion, and which would benefit from reversion to grassland sward to provide conservation, recreation, access and flood control benefits. This area is estimated to be 50 000 ha. The Countryside Commission thus estimates that, in addition to the 41 000 ha of core unimproved grasslands identified in the field survey, a further 125 000 ha offers potential for creation of high-quality calcareous grasslands in the longer term. The total target area for good management would thus be 166 000 ha or 6% of the total landscape mask identified by the field survey.

Threats

8.2.4 The remaining areas of calcareous grassland are under threat to their existence and to their quality. The key threats were identified by a meeting of experts (convened as part of this project) where exogeneous threats to calcareous grasslands were said to be limited (as borne out by the UCPE data shown in Table 8.2); in particular, air pollution is thought to have very little effect.

8.2.5 The future threats are largely management-related. Maintenance of species richness in unimproved calcareous grassland is dependent on the continuance of traditional grazing management. Therefore, the major threats to chalk grasslands include:

- **changes in grazing regimes**: under-grazing of soft chalks leads to invasion by shrubs, and over-grazing of limestone grasslands leads to a decline in species diversity and a decline in species typical of scrub/grassland margins;
- **invasion by tree seeds and woodland colonisation** from nearby woodlands: a threat on soft chalk grasslands but less likely on limestone grasslands due to more limited tree cover in the landscape mask;
- **intensification and fragmentation**: many areas of unimproved chalk and limestone grassland are now very small parts of a wider farming system (surrounded by intensive grazing or a sea of arable). For instance, in Dorset only 12.6% of the 174 chalk grassland sites surveyed were over 40 ha (Keymer & Leach 1990). In many areas this makes traditional management by grazing unviable unless new grassland is created to link and extend semi-natural areas and create more viable management units.
- **lack of management incentives**. Ownership data are limited; however, large blocks of soft chalk grasslands are owned by the Ministry of Defence (MOD), with Salisbury plain alone covering an estimated 20 000 ha which is the largest area of calcareous grassland in Europe. Furthermore, a large area is owned by bodies such as the National Trust (NT). Areas owned by central government are not eligible for good management incentive schemes, but areas owned by the NT may be leased to farmers, whose behaviour will be shaped by the Common Agricultural Policy, accompanying measures, and other environmental programmes.

Conservation objectives

8.2.6 The survey does not provide information on the ownership of calcareous grassland or about how past and current policies have affected its extent and quality. Information

Table 8.2 Summary of UCPE scenario findings

Potential threat	Possible causes	Interpretation of results
Scenarios which would threaten calcareous grassland quality		
Decreased disturbance and no change in eutrophication	Decreased agricultural management or abandonment	A general decrease in stress-tolerant strategies and ruderality and an increase in competitiveness. This implies a greater fall in nature conservation interest than if nutrients were increased (200% increase in competitors against 90%). In calcareous grassland plot classes the model shows a move to grass dominance. In other grasslands the move is from unmanaged grassland to species-poor tall grassland communities dominated by 'rank' grasses, eg tor-grass, upright brome, etc
Decreased disturbance and increased eutrophication	Reduced grazing and/ or recreational pressure but increased fertilizer runoff and/or atmospheric deposition (nitrogen or sulphur)	Increased nitrogen would reduce the nature conservation interest of all the plot classes, especially calcareous grasses (plot classes N, P and T) which are the most vulnerable of the vegetation type, showing the largest fall in stress-tolerant species (in turn those most likely to have conservation interest). In the best chalk grassland there is likely to be an increase in grasses at the expense of broadleaved herbs, and in marginally more degraded chalk grassland the situation would be worse, with coarse grasses and weeds increasing as well. In other grassland classes there is an increase in coarse grasses and weeds at the expense of fine grasses and grassland forbs, with consequent loss of species diversity and deterioration in nature conservation value among the neutral grasslands
No change in disturbance and increased eutrophication	Increased fertilizer runoff and/or atmospheric deposition (nitrogen or sulphur)	As above
Scenarios which would improve calcareous grassland quality		
No change in disturbance and decreased eutrophication	Decreased usage of/ pollution from fertilizers	This scenario implies a general increase in stress-tolerant strategies and a decrease in competitiveness and ruderality
Increased disturbance and decreased eutrophication	Increased grazing and cutting; reduced fertilizer runoff, ie increased agricultural management	This leads to a general increase in stress-tolerant strategies and ruderality and a decrease in competitive species. In the chalk and limestone grassland plot classes this implies a move towards a species-diverse sward dominated by broadleaved herbs. In other grassland plot classes where stress tolerators are scarce or lacking, then an increase in management simply leads to an increase in ruderals, meaning they become more weedy
Increased disturbance and increased eutrophication	Increased grazing and cutting with increased runoff and atmospheric deposition	May be slightly beneficial for chalk and limestone grasslands; on improved grassland plot classes, increased stocking and increased eutrophication are likely to lead to an increase in weeds

from other sources including non-departmental public bodies and non-governmental organisations has been collected to assist in the assessment of existing policies. As a starting point it was necessary to establish policy objectives for calcareous grassland against which policies could be assessed. Three objectives were defined.

- The first priority is to protect and enhance management of the relatively limited area of existing good-quality calcareous grassland.
- The second priority is to restore recently modified 'near' calcareous grassland (both in terms of succession and spatial distribution), particularly where this is close to well-managed core calcareous grassland.
- The final priority is to re-create or create calcareous grasslands in key areas linking

with and between existing areas of calcareous grassland, on land which is distant from calcareous grasslands or was never calcareous grasslands (established woodland, improved agricultural land). This will be more costly than the other options.

8.2.7 This hierarchy of objectives was derived by an expert group working from the UK *Biodiversity Action Plan* (DOE 1994) draft objectives as a starting point. Based on the results of the survey, these objectives may be expressed in terms of the following targets.

- To maintain and enhance all extant areas of unimproved calcareous grassland – an estimated total of 41 300 ha within a much larger farming landscape – using a whole unit management approach. This will focus on achieving stocking with appropriate species and rates.

- To restore and enhance poor semi-natural or improved grasslands – from the total area of 750 000 ha across the country – targeting thin soils with low nutrient levels adjacent to existing calcareous grasslands. Except in cases where phosphorus levels in soils are very high, improved grasslands offer the best opportunities for restoration of calcareous grasslands. The countryside agencies suggest that such measures should be targeted at 40 000 ha.

- To re-create calcareous grasslands by the reversion of small areas of arable or chalk in areas where there would be other benefits, such as reducing agricultural runoff in nitrate-sensitive areas, or where it would serve as a demonstration of what is technically possible. There are limited opportunities to enlarge species-rich areas through reversion of improved grassland, arable or woodland areas. The countryside agencies suggest that long-term reversion to grasslands would be beneficial for some 50 000 ha.

- To improve the management of chalk woodlands. In addition it should be noted that calcareous woodlands make up some 10% of the calcareous grassland landscape and are found on steep chalky inclines; in most cases it would be inappropriate to try and re-convert these areas to unimproved grassland, but a whole-farm management approach could enhance the conservation value of these woods.

8.2.8 In order to meet these policy objectives, a number of key issues have to be addressed.

- **The importance of grazing**. Appropriate grazing levels will differ for soft chalks and limestone grasslands. The agricultural support regime has the greatest impact on grazing levels.

- **Fragmentation**. Unimproved chalk and limestone grassland is mainly found in small, fragmented areas within wider farming landscapes, and may be below the critical threshold for economic management through grazing.

- **Ownership**. Large blocks of soft chalk grasslands are owned by the Ministry of Defence (MOD), with Salisbury plan alone covering an estimated 20 000 ha, but with no direct incentive for long-term management or conservation activities. The MOD is required to exercise environmental care over its holdings but does not have a direct budget to do so.

8.3 Impacts of current policies

8.3.1 Available policy instruments fall into a number of categories which may be summarised as follows:

- regulations to provide protection against deleterious activities, planning proposals or to encourage good management practices;
- economic instruments, such as the European Union's Common Agricultural Policy and packages of grants and subsidies aimed specifically at calcareous grassland management, covering grazing intensities/stocking rates and fertilizer inputs or which provide capital costs for re-creating unimproved grasslands);
- measures to provide information and advice and to demonstrate and disseminate lessons about the sustainable management of grasslands.

Policies to protect calcareous grassland

8.3.2 International and UK legislation provides a complex framework of designations for the protection of calcareous habitats and of important grassland species, such as rare flora and fauna. A hierarchy of designations exists as follows.

- NNR, SSSI and Scheduled Monument status are protective designations which also prevent deleterious actions.

- Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) are protective designations at the European level; a number of calcareous grassland types are listed on Annex I of the EC Habitats Directive including the priority semi-natural dry grassland (important orchid sites) type. Proposals for areas which qualify as SACs have been submitted to the EC.

- National Park, AONB and Green Belt designations provide protection against planning permission for the change of use of the site.

- ESA designation is not protective but delineates an area where incentives for positive management practices are available.

8.3.3 From the field survey results, it appears that 90% of all unimproved calcareous grasslands are already designated, and that 66% of the whole landscape mask had one or more designations, including SSSI, NNR, AONB and Green Belt. However, much of it is designated for reasons other than its calcareous character.

8.3.4 AONBs cover the largest area overall, while National Parks are most common in hard northern limestone areas and ESAs are most common on farming lands in soft southern chalk regions, where Green Belts also provide some protection against urban expansion. SSSIs are significant in both areas.

8.3.5 A higher proportion of northern limestones is designated, largely because the habitat is less extensive, and because individual areas are larger and in better condition than southern chalk grasslands. In the south some 90% of calcareous grasslands are designated, but only 55% of the calcareous grassland landscape mask as a whole. Limestone pavements are provided with special protection under Section 34 Part II of the Wildlife and Countryside Act 1981 (the Limestone Pavement Order), which gives additional powers of protection to local agencies.

8.3.6 Current designations provide some protection for a large percentage of the unimproved calcareous grasslands, and particularly limestone pavements, from exogeneous development threats. These designations may be further strengthened by European designations, such as the SAC and SPA. However, the main threats to existing unimproved calcareous grasslands are from the management regimes for individual sites. In the past, agreements in Section 15 of the Countryside Act 1968 could only compensate for income lost through avoiding damaging activities. However, new positive Section 15 agreements offer incentives as well as compensation, and this is the basis for English Nature's Wildlife Enhancement Scheme which is described in the following section.

Incentives for positive management and restoration

8.3.7 There are currently three main environmental land management schemes providing incentives for positive management of calcareous grasslands and restoration or enhancement of neutral grasslands, arable land or chalk woodlands.

- The English Nature Wildlife Enhancement Scheme (WES) is focused on trying to reduce grazing rates and encouraging diversification of calcareous habitats through two very localised schemes covering a total of 6200 ha of northern limestone SSSI (see Box 8.1).

- The MAFF Countryside Stewardship Scheme (CSS) is focused on areas not covered by either WES or other schemes such as Environmentally Sensitive Areas. It may complement WES by targeting both SSSI and non-SSSI land because it has a larger budget and may be more appropriate for land holdings which include large areas of non-SSSI. CSS applies to both core calcareous grassland and restoration of other grassland (see Box 8.2).

- The MAFF Environmentally Sensitive Areas (ESA) scheme is providing support to the maintenance and improvement of calcareous grassland in the South Downs, South Wessex Downs, Cotswold Hills and Pennine Dales ESAs (see Box 8.3).

8.3.8 While different plant communities will require different management techniques and policies, in general the focus is on increasing grazing ratios in the south and

Box 8.1 Wildlife Enhancement Scheme

The Wildlife Enhancement Scheme (WES) provides grants for positive management to landowners and tenants of valued habitats of different types. In the past, the scheme has only been applied in one calcareous area – Craven limestone in the Yorkshire Dales – but since September 1994 a new WES has been introduced for improved management of magnesium limestones over a 200 ha strip stretching from Tyne and Wear through County Durham, Yorkshire and Nottinghamshire to Derbyshire.

The Craven limestone WES was targeted at 6000 ha composed of large-scale farms where chalk grasslands have suffered from past over-grazing. Payments are made at two different rates:

- £60 ha yr^{-1} for reduction in stocking rates to appropriate levels;
- £90 ha^{-1} for excluding stock from woodlands to allow natural regeneration.

The scheme has been successful in bringing 3000 ha (50% of the total) under management agreements, but is unlikely to be extended any further because most of the remaining area is within the Yorkshire Dales National Park or within an ESA.

The magnesium limestone WES has been developed to meet the very different management needs of some 50 very small and fragmented SSSIs (typically 0.5–1 ha) which are generally on urban fringes and surrounded by other land uses,including arable, horticulture and grazing areas for horses and ponies.

The objective of the scheme is to re-introduce permanent chalk grasslands by payments of:

- £180 ha^{-1} yr^{-1} for re-introduction of appropriate grazing (cattle or sheep) either by the landowner or through joint grazing arrangements with County Trusts or private landowners;
- £130 ha^{-1} yr^{-1} for cutting in areas (particularly steep hillsides) where grazing is inappropriate.

In addition, the scheme provides annual payments of £45 ha^{-1} yr^{-1} for management of calcareous woodland, equivalent to the special management payments of the Forestry Commission's Woodland Grant Scheme. The magnesium limestone area is not covered by any other incentive scheme.

Box 8.2 Countryside Stewardship Scheme

The Countryside Stewardship Scheme was introduced in 1991 with the following objectives for calcareous grasslands:

- to support and re-introduce traditional management to sustain and extend the grasslands and the wildlife they support;
- to restore and protect characteristic landscape features;
- to create and improve opportunities for people to enjoy the landscape and its wildlife.

The scheme focuses on the following types of land:

- existing permanent calcareous grasslands, including sheep walks, chalk downland and upland pastures;
- grasslands where the re-introduction of grazing would be beneficial or where invasive scrub threatens wildlife and the open character of the landscape;
- reversion of arable land and grass leys, to permanent grassland, in areas of high scenic value;
- reversion of arable land and grass leys, to permanent grassland, that link or extend fragmented remnants of existing grassland;
- historical landscapes, particularly those rich in archaeological and historical remains;
- land that offers opportunities for people to enjoy the landscape through new access, existing public rights of way, or by visibly enhancing the landscape.

Landowners enter into a ten-year agreement selecting a combination of measures from a menu of management options and capital works. Payments, which cover works such as scrub clearance, hedge restoration and the provision of access facilities, are made annually in arrears, and reviewed on a three-year cycle.

- £50 ha^{-1} yr^{-1} for management of existing grasslands plus supplementary payments of £40 ha^{-1} for the first year for initial work to establish or re-introduce grazing. Between 1991 and 1995 some 21 855 ha were entered into the scheme.

- £250 ha^{-1} yr^{-1} for re-creation of permanent calcareous grassland on arable land or ley grasslands plus supplementary payments of £40 ha^{-1} in the first year for additional work to help re-create calcareous grassland. Between 1991 and 1995 some 2882 ha have been entered in the scheme for regeneration of chalk/limestone grassland.

Box 8.3 Environmentally Sensitive Areas scheme

The Environmentally Sensitive Area (ESA) scheme was introduced by the Ministry of Agriculture, Fisheries and Food (MAFF) in 1987, to encourage farmers to safeguard areas of the countryside where the wildlife, landscape and historical interest is of national importance and is dependent on the use of beneficial farming practices. The scheme is voluntary and farmers receive annual payments for entering into ten-year management agreements (five-year before 1992) which require them to follow a set of management prescriptions, tailored to the characteristics and environmental objectives of the ESA. An ESA has one or more tiers of entry and individual tiers can have a number of different options.

The scheme covers three calcareous grassland areas in the south as follows:

- South Downs ESA – an eligible area of some 51 700 ha, of which 11 600 ha are covered by three different tiers, tier three having three options, of management agreement and payment rate;
- South Wessex Downs ESA – an eligible area of 38 300 ha, of which 20 500 ha are already covered by one of two tiers with seven options, three in tier one and four in tier two;
- Cotswold Hills ESA – an eligible area of 66 100 ha, of which 37 500 ha are already covered by one of two tiers, with three options under tier 1, and rates of payment.

The above ESA schemes provide grants to farmers who enter into management agreements based on conservation plans. Grants are currently being paid for a total of 61 930 ha of land at a total annual cost of £3.38M. There are three main tiers of management, with annual payment rates varying from £8 ha^{-1} yr^{-1} for management of grazing and ley land to improve its quality, up to £260 ha^{-1} yr^{-1} or reversion of arable land to chalk grassland or extensive permanent grassland. The average payment is currently £55 ha^{-1} yr^{-1}; 85% of land so far entered into the scheme is eligible for tier 1 payments for extensive management of existing grasslands.

The scheme has been successful in bringing between 35–42% of the target area under tier 1 management for which the rates of grant vary from £8 ha^{-1} yr^{-1} in South Wessex to £12 ha^{-1} yr^{-1} in the Cotswold Hills to £40 ha^{-1} yr^{-1} in the South Downs. The scheme appears to have been less successful in bringing land under tier 3 management. For example, of a total 36 835 ha of arable land in the South Downs ESA targeted for reversion to chalk grassland, permanent grassland or conservation headlands, the take-up has only been 922 ha, 5192 ha and 51 ha respectively. Similarly, in South Wessex the take-up of management agreements to create downland turf or revert arable land to permanent grassland has been only 949 ha and 110 ha respectively out of an eligible area of 27 230 ha.

Take-up of grants for ecological improvement of existing permanent grassland has been high in South Wessex (214 out of 500 ha) and the Cotswold Hills (6898 ha out of an eligible area of 10 000 ha).

relaxing grazing ratios on northern limestone.

8.3.9 Based on the field survey results, the two WES cover some 77% of the total northern hard limestones, and over 90% of the total designated area of northern limestone. It is expected that the ultimate take-up of the scheme will be 3200 ha, as much of the target area adjoins non-SSSI designated areas. The WES is complemented by the Reserves Enhancement Scheme which applies to County Wildlife Trust Reserves, with rates of grant available at slightly lower rates than the WES.

8.3.10 The Countryside Stewardship Scheme includes no overall target for the area of calcareous grassland to be covered by the scheme. So far nearly 25 000 ha of chalk grassland have been entered into approved management agreements (13 145 ha in the first two years and 5335 ha and 3375 ha in the subsequent two years). No figures are currently available on the proportion of land within the scheme which is designated, or the quality of the land, but at a very general level it appears that some 88% of land in the scheme is existing grassland (both unimproved and improved), while 12% is arable land being restored to calcareous grassland. The average size of management agreement varies widely from less than 10 ha on soft chalks to up to 70 ha in some limestone areas such as the Yorkshire Dales.

8.3.11 The ESA scheme (see Box 8.3) covers three southern calcareous grassland areas – South Downs, South Wessex Downs, Cotswold Hills – covering a total area of 200 000 ha, of which 18 750 ha are mainly calcareous grasslands, some 115 100 ha arable lands, and the rest improved grassland or woodland. An estimated 62 000 ha are already included. Based on the survey figures, these three areas would account for 10% of the total calcareous grassland landscape in the south and over 56% of the total soft chalk grasslands identified in the field survey. However, it should be emphasised that the field survey grasslands may not be co-located with these ESA chalk grasslands.

Other incentives to management of calcareous grasslands

8.3.12 In addition to direct incentives for environmental land management, there has been a growing emphasis on cross-compliance (environmental management conditions) attached to agricultural support schemes. For instance, in areas which are susceptible to over-grazing, such as the Yorkshire Dales, MAFF has reportedly withdrawn or threatened to withdraw agricultural payments until stocking rates are reduced to sustainable levels.

8.3.13 Each of the schemes described above offers advice to farmers on the best opportunities and methods for restoration of chalk grasslands. In the case of the ESA scheme, this is offered through locally based project officers. All of the schemes provide guidance on appropriate stocking levels for sites in different conditions. In addition, experts advise on the best opportunities for restoration of chalk grasslands from neutral improved grasslands. Existing work suggests that this should be targeted at thin top soils with low nutrient levels, on south- or west-facing slopes and on sites adjacent to existing chalk grassland to provide a seed source for natural and artificial re-seeding. Techniques include use of slot seeding, plugging or scrub and thistle removal. Soil stripping may be required if nutrient levels are too high.

8.3.14 There is currently less information on the restoration of chalk grasslands from arable lands. Although high-quality calcareous grassland may take hundreds of years to re-create, it may be possible to re-create a more limited calcareous grassland resources in 10–20 years (see Chapter 2). This is likely to involve intensive techniques (such as ploughing and re-planting with plantlets) and the success will depend on the proximity of surviving calcareous grassland, the former use of the land and survival of a seedbed, climate, and ongoing management, eg through livestock grazing. Research work is currently being undertaken on the most effective techniques, which will also require evaluation of their cost-effectiveness.

Effectiveness of current policies

8.3.15 Previously, no full assessment of the effectiveness of the schemes has been carried out. However, a review of ways of better integrating and focusing all environmental land management schemes was undertaken in 1995 by the DOE, MAFF, Countryside Commission, English Nature and English Heritage. The schemes cover an estimated 83 000 ha, or 55% of the calcareous grassland landscape which offers long-term potential as a high-quality landscape. However, it is not possible to determine what proportion of this area is unimproved, improved grassland or arable land.

8.3.16 The success of schemes is related to the following factors.

- ESA and WES are targeted at designated areas and already provide positive incentives for management of nearly 60% of the designated areas identified in the field survey.

- Each is targeted at different areas with specific management problems, for instance:
  - ESA and Countryside Stewardship Schemes are intended to re-introduce appropriate stocking on under-grazed lowland chalk grasslands or to reduce intensity of management where over-grazed;
  - the ESA scheme and CSS are intended to encourage conversion of improved grassland and arable land to calcareous grassland by re-seeding or natural regeneration where this would lead to environmental benefits;
  - the WES scheme is intended to reduce over-grazing in the Yorkshire Dales and re-introduce grazing through collaborative efforts on the very fragmented patches of magnesium limestone.

- The Countryside Stewardship Scheme in particular provides the advantage of a flexible menu of management options to the landowner and is not confined to designated areas.

- All of the schemes minimise administrative costs and increase cost-effectiveness by offering standard rates which are periodically reviewed to ensure that they cover the additional costs or profits foregone by landowners.

8.3.17 While the take-up of schemes for the management of existing calcareous and permanent grasslands is impressive, there has been less success in encouraging landowners to convert arable or woodlands to grasslands.

8.3.18 For instance, the three southern chalk/limestone ESA schemes include an area of 115 000 ha of arable land which would be eligible for payments of £200–260 ha^{-1} yr^{-1} if restored to either calcareous or extensive permanent grassland. This incentive has so far been taken up on 7410 ha (6.5% of the target area) at a total cost of £1.72M yr^{-1}, an average cost of £232 ha^{-1} yr^{-1}.

8.3.19 The greatest success has been in encouraging farmers to convert arable land to permanent grassland in the South Downs, while the rate of conversion of arable to chalk grassland (980 ha out of a possible 36 900 in the South Downs) has been disappointing.

8.3.20 The main reason appears to be that incentive payments do not compare favourably with returns from arable land in the current agricultural grants context. To a lesser extent, limited technical experience in re-creating chalk grassland presents a barrier.

8.3.21 The scope for conversion of forest or wooded land to chalk grasslands appears low. The Forestry Commission reports that there are few opportunities for large-scale re-creation of chalk grasslands within existing plantations. However, opportunities do exist for restoration of small areas of grassland within forests where open space is being provided as part of forest restructuring. The greatest opportunities are in areas adjacent to existing good-quality chalk grasslands, but these areas will be susceptible to invasion by tree species without careful management.

8.4 Policy development

8.4.1 Future policies to meet the Government's objectives for calcareous grassland need to focus on four main areas.

i. A more detailed inventory of the distribution, size, management and quality of existing graslands within the calcareous grassland landscape.

ii. An assessment of the type and quality of the grasslands included in current MAFF or English Nature schemes, to determine what proportion of the 41 300 ha of high-quality 'core' calcareous grassland habitat identified in this study is covered by the schemes. English Nature's inventory should provide this type of information for chalk grasslands in lowland areas, but will not cover hard limestones.

iii. The establishment of a comprehensive set of targets for management, restoration and re-creation of calcareous grasslands. This will require co-ordination of all the agencies currently targeting chalk grasslands.

iv. Schemes targeted on restoration and enhancement, which can bring immediate benefits in terms of biodiversity, landscape, amenity and history. These efforts should concentrate on the 750 000 ha within the landscape which are in other grassland categories that might have been modified from calcareous grassland (modified calcareous grassland).

8.4.2 In addition it would be necessary to have a comprehensive set of targets for the management, restoration and re-creation of grasslands, and this will require co-ordination of all the existing agencies currently targeting chalk grasslands. However, in strategic terms, the emphasis of the countryside agencies should be on restoration and enhancement which can bring immediate benefits in terms of biodiversity, landscape, amenity and history.

8.5 Increasing the body of knowledge and potential for further work

8.5.1 In the longer term there are no guarantees that resources will be available for covering ongoing management costs. Thus it is imperative that new approaches to sustainable (economically viable) long-term management of calcareous grasslands are developed and publicised. More work is needed to evaluate and extend existing experience and to develop guidelines for landowners and managers (particularly of MOD and common land) on the most suitable and economically viable regime for their circumstances, and to assist in the establishment of arrangements/partnerships which will encourage managers to implement these practices. Guidelines need to reflect the type of grassland, the level of invasive species, the climatic conditions, and size and location in relation to other calcareous grassland.

8.6 Conclusions

8.6.1 Calcareous grassland is a valuable habitat, dominated by a non-climax vegetation type. Because the vegetation is non-climax, intervention is required to prevent calcareous grassland turning into scrub/woodland; calcareous grassland therefore requires management to maintain its condition. The survey results indicate that, of the area within the calcareous grassland mask (26 343 km^2):

- about 41 300 ha is good-quality 'core' calcareous grassland habitat;
- about 750 000 ha is in other grassland categories that might be modified from calcareous grassland (modified calcareous grassland);
- about 1 140 000 ha may at one time have been calcareous grassland, is still in a land use which could revert (eg forestry or agriculture), but has been long modified; and
- the remainder has no potential (eg built-up areas).

8.6.2 Working from the *Biodiversity Action Plan* draft objectives as a starting point, it would appear feasible to establish the following objectives:

- to maintain and enhance all extant areas of unimproved calcareous grassland – an estimated total of 41 300 ha;
- to restore and enhance poor semi-natural or improved grasslands – from the total area of 750 000 ha across the country – targeting thin soils with low nutrient levels adjacent to existing calcareous grasslands;
- to re-create calcareous grasslands by reversion of small areas of arable or chalk in areas where it would have other benefits;
- to improve the management of chalk woodlands.

8.6.3 The present study helps to define the calcareous grassland landscape type, in its broadest sense, and to describe its characteristics. To capitalise on the baseline study that has been completed, monitoring needs to be carried out at agreed intervals (eg at the time of the next Countryside Survey). Results from this baseline study and subsequent monitoring need to be analysed in the context of the success of the Countryside Stewardship Scheme and related work (eg Environmentally Sensitive Area monitoring).

8.6.4 If further work indicates that these targets are justifiable, it is recommended that they are achieved by extending existing schemes offering incentives for restoration and management on private land.

8.6.5 To ensure that the benefits of these measures are retained in the long term, and transferred to other areas, it is also essential that effective management approaches are identified and publicised and awareness of the value of calcareous grassland habitats is raised.

Chapter 9 SUMMARY AND CONCLUSIONS

9.1 Introduction

9.1.1 This Chapter summarises the Report in terms of the project objectives (as described in Chapter 1), briefly summarises the advantages and disadvantages of the approach, and discusses future research needs.

9.2 Summary in relation to the project objectives

Objective 1: To determine the distribution of the landscape type in England

9.2.1 The objective was to identify and map 1 km squares in England which support, or have some potential to support, calcareous grassland vegetation types. This objective was achieved by reference to geological map types suitable for calcareous grassland. To improve the coverage of sites found on escarpments, squares which were adjacent to 'calcareous' squares on steep slopes were also added to the mask. The mask was constrained by excluding all squares which contained more than 75% urban land.

9.2.2 Given the need to include a representative sample of existing and potential calcareous grassland areas and the use of whole 1 km squares (which may include fragments of other landscape types), comparisons with external data suggested that the fit of the mask was acceptable for the purposes of this project. The area identified for the field sampling programme does not exactly match the whole calcareous grassland resource in England, but does provide an adequate sampling framework for assessing the current status of the habitat in the core calcareous grassland areas.

Objective 2: To survey the habitats (including major land cover types and ecological features such as hedgerows) and historic features within each landscape type

9.2.3 For the field survey of habitats, the sampling unit was a 1 km square; 43 squares were surveyed in 1993 and data from 49 squares surveyed in Countryside Survey 1990 have been used, to give a total sample of 92. In addition, quadrat data from 48 squares in surveys of other threatened habitats fell within the calcareous grassland mask and have been used in producing vegetation classifications (although they have not been included in the quantitative analysis of quality measures). Results from the sample squares were extrapolated to the calcareous grassland landscape as a whole.

9.2.4 Land cover was recorded at points on a 16-position grid within each field survey square, and the nearest field boundary (within 100 m) was described. To provide 'quality' information, 2 m x 2 m quadrats were recorded at up to five random grid points where the vegetation was not intensively managed for agriculture (main plots). In addition, 2 m x 2 m quadrats were placed in semi-natural vegetation not represented by the main plots (habitat plots) and 10 m x 1 m plots were recorded adjacent to roads and tracks (verge plots).

9.2.5 For each of the field sample 1 km squares, data on historic features collected in the field (by ITE surveyors) were supplemented by selective analysis of aerial photographs and map interpretation of recent edition Ordnance Survey map extracts, and examination of County Sites and Monuments Records (SMRs) and the National Monuments Record (NMR).

9.2.6 Archaeological data were compiled for 398 archaeological sites in 42 sample squares. A breakdown by county shows considerable variation in the mean density of identified monuments.

Objective 3: To determine, on a regional basis and in relation to current designations, the composition of the landscape type in terms of the quantity and quality of the surveyed features

9.2.7 Quantitative estimates of land cover and boundaries have been made for the calcareous grassland mask and for strata within it. Just 1.6% (41 260 ha) was estimated to be calcareous grassland habitat, 90% of which occurred in designated km squares. Calcareous grassland vegetation was more frequent in soft limestone strata (1.7%) than in hard limestone areas (1.1%). The calcareous grassland habitat included a range of vegetation types, from maritime and bogs, through various grassland types, to vegetation becoming dominated by woody species.

9.2.8 In addition to the core calcareous grassland, neutral and modified grassland vegetation types comprised 25% of the soft limestone strata and 39% of the hard limestone areas. These modified calcareous grassland areas occurred throughout the calcareous grassland landscape and may provide the best opportunity for calcareous grassland restoration. Calcareous woodland types, which may also provide opportunities for habitat re-creation, were more common in designated strata (14% by area) than in non-designated strata (7%).

9.2.9 Objective measures of vegetation have been related to quality criteria, to provide an empirical evaluation of the quality of calcareous grassland vegetation in different parts of the calcareous grassland landscape: size, diversity, naturalness, representativeness, rarity, fragility, potential value.

9.2.10 Using at least two separate measures of each of the quality criteria, the four strata were ranked. Based on quadrat information, calcareous grassland in the designated soft limestone stratum ranked highest for 13 of the 17 measures and the designated hard limestone stratum was the highest in the other four (including three measures of diversity). This result confirms the relationship between designated land and 'good-quality' calcareous grassland, with a larger amount of high-quality calcareous grassland occurring in the designated strata.

Historical aspects

9.2.11 The current project has shown that the calcareous grassland mask contains features from all historic periods, although representation of the Early Medieval period is sparse. Prehistoric periods are mainly represented by 'find' sites (ie where objects have been found), together with hut circles and Bronze Age barrows. The Roman period is also dominated by find sites, although with a scattering of other site types, particularly roads. The Early Medieval period has only a few barrows. The Medieval period has more settlement sites, together with farms and field systems. The Post Medieval period has settlements including many villages and some small towns and industrial and transport sites. Many of the unspecified sites almost certainly belong to the Post Medieval period, and this group follows the same pattern as the Post Medieval distribution.

Designation

9.2.12 The results from the field survey show that 90% of the remaining unimproved calcareous grassland is covered by one of the designations considered in the study. However, a monitoring programme would be required to determine whether existing high-quality calcareous grassland was designed or the designation is leading to enhancement of the grassland.

9.2.13 Results related to designation are included in Section 8.3, but clearly different types of designation may have different purposes. Within the calcareous grassland landscape, AONBs cover the largest area in the soft limestone strata, while National Parks are more extensive in the hard limestone strata. SSSIs, ESAs and Green Belts are significant in both limestone strata.

Objective 4: To develop models to predict the effect of environmental and management changes on the distribution and quality of the landscape types and their constituent habitats

9.2.14 Areas of calcareous grassland likely to be affected by excessive atmospheric acid deposition have been mapped using the 'critical loads' approach. The map of 'current' deposition is based on data collected from 1989 to 1991, which when overlaid on the critical loads map gives an exceedance map. The effects of various change scenarios, compared to the 1989–91 baseline, have been evaluated in terms of the proportion of calcareous grassland in areas where the soils' critical loads are exceeded. During the period 1989–91, 18% of all areas within the calcareous grassland mask was in exceeded areas (ie where the pollutant deposition exceeds the weathering rate of the soil), with a higher rate in the hard limestone areas (32%) than in the soft limestone strata (7%). Designated areas were also more at risk (18%) than non-designated strata (8%).

9.2.15 Under the 70% UNECE emissions reduction scenario, the forecast is that no areas in the calcareous grassland mask would receive excessive acid deposition.

9.2.16 Average atmospheric deposition of nitrogen (NO_x and NH_x) in calcareous grassland areas is 21 kg nitrogen ha^{-1} yr^{-1}, which is similar to that received by other parts of lowland England (19 kg nitrogen ha^{-1} yr^{-1}). Over 93% of calcareous grassland areas receive more than 14 kg N ha^{-1} yr^{-1}, and 50% receive over 20 kg N ha^{-1} yr^{-1}. High N deposition (>20 kg) occurs mainly in the northern hard limestone areas, where 42% of the area receives more than 25 kg nitrogen ha^{-1} yr^{-1}.

9.2.17 These rates of atmospheric N deposition are low compared to average agricultural inputs, and there is no experimental information describing the long-term effects of these rates on calcareous grasslands in Britain. However, it is likely that the low rates of atmospheric N will have a significant effect on community composition in calcareous grasslands, with gradual nutrient enrichment leading to a loss of plant species diversity.

9.2.18 The study has made use of the C-S-R classification of functional types and the TRISTAR2 model which takes a given specification of an initial steady-state vegetation, adopts some altered environmental and/or management scenario, and predicts the composition of the new steady-state vegetation in terms of its component functional types. Most of the 'core' calcareous grassland vegetation is composed of stress-tolerator and competitor/stress-tolerator/ruderal species. The remaining vegetation plot types are representative of all other combinations of functional types.

9.2.19 The TRISTAR2 model calculated the predicted change in abundance of the functional types, under each of six specimen change scenarios, and an index of vulnerability was produced. The calcareous grassland mask consists of a heterogeneous grouping of calcareous grassland, grassland and woodland vegetation, all of which are relatively unproductive. In general, differences in vulnerability are small but some of the coarser and taller grassland classes appear to be among the most vulnerable Other, wetter grassland classes are under very little threat. The core calcareous grassland and woodland classes occupy an intermediate position and are vulnerable to scenarios which include increased eutrophication.

Objective 5: To make recommendations on ways in which policy instruments may be refined to further protect, enhance or re-establish habitats which characterise the landscape type

9.2.20 The results from the field survey and the outputs from the vegetation change and atmospheric impact models have been considered in the light of current policy measures.

9.2.21 Calcareous grassland is a valuable habitat, dominated by a non-climax vegetation type. Because the vegetation is non-climax, intervention is required to prevent calcareous grassland turning into scrub/ woodland; calcareous grassland therefore requires management to maintain its condition. The survey results indicate that, of the area within the calcareous grassland mask (26 343 km^2):

- about 41 300 ha is good-quality 'core' calcareous grassland habitat,
- about 750 000 ha is in other grassland categories that might be modified from calcareous grassland (modified calcareous grassland),
- about 1 140 000 ha may at one time have been calcareous grassland, is still in a land use which could revert (eg forestry or agriculture), but has been long modified, and
- the remainder has no potential (eg built-up areas).

9.2.22 Working from the *Biodiversity Action Plan* draft objectives as a starting point, it would appear feasible to establish the following objectives:

- to maintain and enhance all extant areas of unimproved calcareous grassland – an estimated total of 41 300 ha;
- to restore and enhance poor semi-natural or improved grasslands – from the total area of 750 000 ha across the country – targeting thin soils with low nutrient levels adjacent to existing calcareous grasslands;
- to re-create calcareous grasslands by

reversion of small areas of arable or chalk in areas where it would have other benefits.

- to improve the management of chalk woodlands.

9.2.23 If further work indicates that these targets are justifiable, it is recommended that they are achieved by extending existing schemes offering incentives for restoration and management on private land.

9.2.24 To ensure that the benefits of these measures are retained in the long term, and transferred to other areas, it is also essential that effective management approaches are identified and publicised and that awareness of the value of calcareous grassland habitats is raised.

Objective 6: To develop a methodology for measuring change in these habitats which is sufficiently robust and precise to assess the effectiveness of policies at a national (England) scale

9.2.25 In designing the field survey, measurement of future change was a major consideration. Methods were developed from the Countryside Survey 1990 approach (which has as a major objective the establishment of a high-quality baseline against which future change can be measured). The potential and chosen approaches to measuring change are reported separately from these landscape reports (Bunce in prep.).

9.3 Advantages and disadvantages of the research approach

9.3.1 The basic approach used to address the objectives given above is shown in para 1.4.2 The advantages and disadvantages of the approach are considered under a range of headings.

Use of available, spatial data to define the calcareous grassland mask

9.3.2 At the start of the study there was no national map of calcareous grassland. Because change was a major consideration, the potential areas of calcareous grassland were important as a basis for monitoring the extent of the calcareous grassland resource. However, the use of objective criteria to define the calcareous grassland mask (basically geological types) did not take into account the idiosyncrasies of vegetation: there was no perfect correlation between certain geological types and present or potential areas of calcareous grassland. The quality of the source data is unknown and it may be that some of the mismatch may be due to spatial differences in geological mapping.

Use of a 1 km square as a sampling unit

9.3.3 To be compatible with Countryside Survey 1990, the sampling unit was a 1 km square. This is said to represent a good balance between an area which contains enough information for it to be classified as a particular land type and one which is not too large to be field-surveyed. Much existing calcareous grassland, as well as areas of relevant soil types which might support calcareous grassland, are fragmented and spatially dispersed. Thus, by sampling a whole 1 km square, instead of smaller units within it, there was some inefficiency and wasted effort. In particular, there was poor representation of 'higher-quality' sites, meaning that less could be deduced about potential change in 'core' calcareous grassland than in the areas of potential calcareous grassland. The approach did allow the calculation of national estimates but, for reasons of scale, these estimates are not highly accurate (see calculation of statistical errors in Chapter 4).

The choice of strata

9.3.4 Part of the sampling strategy was to stratify the field sample so that differences in vegetation change between different limestone types, and between designated and non-designated areas, could be identified. The relatively small number of samples meant that only four strata were appropriate and, further, all designation types had to be aggregated to allow any comparisons to be made at all: no results are available in relation to any one designation type. The choice of 'soft' and 'hard' limestone strata was a natural one and proved revealing, but more samples in a wider range of land types would have given clear indications as to where threats were greatest and most change was likely to occur.

Modelling vegetation change

9.3.5 The modelling of atmospheric inputs achieved its aims in that it identified the broad geographical areas where calcareous grassland was under threat. However, the spatial overlaying approach did not lend itself to forming inputs to the vegetation change modelling as readily as might have been expected.

9.3.6 Although not as conceptual in approach as had originally been specified, the UCPE modelling was shown to be valuable in terms of identifying vulnerability to likely threats under a range of scenarios. However, the links between suggested scenarios and policy implementation were not spelled out and might form the focus of further work.

9.4 Future research needs

9.4.1 Research of the type undertaken in this ambitious project cannot answer every question and inevitably leads to more questions. Some of the areas for future research are listed below.

Monitoring

9.4.2 As stated above, the present project has laid a baseline against which further survey results may be measured and compared. It will be important to monitor the land cover changes and the quadrats which have already been recorded and to link these monitoring results with information on take-up from Countryside Stewardship Scheme monitoring. Links should be made explicitly with other environmental monitoring schemes, including any future Countryside Surveys and the Environmentally Sensitive Area monitoring. Only in this way can change be objectively determined and links with policy instruments properly understood.

Interpretation of modelling results

9.4.3 There is scope for further analysis of the modelling results, especially in identifying both the spatial and vegetational characteristics of areas likely to undergo change.

Integration of data

9.4.4 As stated above, opportunities to link the results of this study with work elsewhere should be sought so that links between change, habitat management/creation and policy may be better understood.

Experimental work

9.4.5 Some of the assumptions made in the interpretation of the change analyses are less well researched than others. For example, the effects of atmospheric nitrogen on calcareous grasslands have not been well studied in Britain. Experimental work of the type undertaken in continental Europe and elsewhere, is timely.

Landscape ecology

9.4.6 The spatial characteristics of calcareous grassland are interesting in terms of fragmentation and connectedness. If habitat creation (and management) is to lead to maximum calcareous grassland quality, then the spatial characteristics of potential areas of calcareous grassland need to be known. Will increasing the areas of existing calcareous grassland be adequate or are there crucial links or 'stepping stones' that need to be made? The landscape ecology of calcareous grasslands needs further investigation, especially in relation to areas of potential calcareous grassland as defined within this project.

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- Purely scientific literature on ecological processes in calcareous grasslands.
- Phytosociological literature on calcareous grasslands.
- Literature dealing with the practical detail of calcareous grassland management (for conservation).
- Amenity management and amenity issues in calcareous grassland.
- Agricultural use of calcareous grassland (ie the agri-science side of the literature).

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Appendix 1 Technical appendix to Chapter 3 – Defining the calcareous grassland mask

This Appendix includes details of how the calcareous grassland mask was validated using two independent data sources.

A1.1 Validation procedures

A1.1.1 Figure 3.1 in Chapter 3 shows the 'the calcareous grassland mask' identified by the above procedure. The map covers 26 555 km squares in lowland England which, according to geological type, contain, or have potential to contain, calcareous grassland. The extent to which this map captures the current distribution of calcareous grassland would provide some validation, but this procedure is not possible because of the absence of definitive information on the current distribution of calcareous grassland in England. Instead, the calcareous grassland mask has been compared against two national datasets, neither of which provide definitive or directly comparable data for validation purposes, but which together provide some indication of the overall accuracy and usefulness of the calcareous grassland mask.

A1.2 Checks against soils data

A1.2.1 Table A1.1 shows a comparison between the main areas of calcareous soils (Soil Survey of England and Wales 1993) found inside and outside the area covered by the calcareous grasland mask. The analysis is based on an SSLRC database which gives the dominant and subdominant soil type in each 1 km square of England. The mask covers 7131 (76%) of the 9425 1 km squares in England in which calcareous soils are the dominant soil type. The remaining 19 424 1 km squares in the mask did not have a dominant or subdominant cover of calcareous soil types. Although these squares are unlikely to support calcareous grassland as a dominant landscape type, the nature of the underlying geology indicates that they may contain small areas of these grasslands. In view of the current patchy and dispersed nature of this habitat, these squares are likely to make an important contribution to the total resource and, for this reason, they have been included in the calcareous mask.

A1.2.2 Because the calcareous mask covers areas in which calcareous soils may not be dominant, there is some overlap between it and the mask used in the key habitats project on lowland heath. This overlap is particularly apparent in the Brecklands of East Anglia, where 538 1 km squares have been classified as being in areas which are both potentially lowland heath (on the basis of acidic soils) and potentially chalk grasslands (on the basis of underlying geology). In the Brecklands area the calcareous mask covers an area in which chalk grasslands only occur as scattered patches in an area which is dominated by other landscape types.

A1.3 Comparison with English Nature's database on calcareous sites

A1.3.1 The calcareous mask was compared with the locations of known calcareous sites in England. The site data are based on results from NCC's

Table A1.1 Soil types indicating potential calcareous grassland and their occurrence in the areas covered by the calcareous mask (based on SSLRC 1 km data)

Dominant soil		Limestone Massive	Limestone Oolitic	Limestone All	Chalk	Chalk + limestone	Buffer	All mask	All England
3.41	Humic rendzinas	0	1	1	327	328	33	361	380
3.42	Grey rendzinas	0	0	0	743	743	129	872	973
3.43	Brown rendzinas	5	1442	1447	3228	4675	317	4992	5715
3.45	Gleyic rendzinas	0	0	0	3	3	0	3	4
3.46	Humic gleyic rendzinas	0	0	0	13	13	0	13	19
3.61	Typical sand para-rendzinas	1	0	1	3	4	1	5	130
3.72	Gleyic rendzina-like alluvial soils	0	0	0	0	0	0	0	49
3.73	Humic gleyic rendzina-like alluvial soils	0	0	0	0	0	0	0	0
3.11	(or subdominant) Humic rankers	307	13	320	11	331	128	459	1102
3.13	(or subdominant) Brown rankers	308	6	314	0	314	112	426	1053
Total squares with calcareous soils		*621*	*1462*	*2083*	*4328*	*6411*	*720*	*7131*	*9425*

Table A1.2 Correspondence between English Nature (EN) records of calcareous grassland sites and the coverage of the calcareous mask

	In calcareous mask			
	Soft limestone	Hard limestone	Total	Not in mask
Number of EN chalk sites	1747	0	1747	227
Number of EN limestone sites	389	239	628	113
All EN sites	2136	239	2375	340

England Field Unit Survey from 1983 to 1989 which give the location of sites containing an element of calcareous grassland. A complete census database of chalk grasslands is now available at English Nature, but there are some gaps in the database on limestone grassland. In addition, many of the sites may contain only small pockets of calcareous grassland on locally untypical soils and, because the data were collected between 1983 and 1989, they may not accurately reflect the current status of the grassland. The dataset has not been validated and there may be some inaccuracy in the grid references of some sites.

A1.3.2 The recorded point locations of known calcareous grasslands were transformed to digital format and overlaid on the calcareous mask for comparison (Table A1.2). The calcareous grassland mask covered 89% of the English Nature chalk sites and 87% of the limestone sites. Given the coarse resolution of the geological data on which the mask was based and the possibility that there are errors in the English Nature database, we regard this as good agreement.

A1.4 Conclusion

A1.4.1 The map of calcareous grassland areas derived using only geological data has missed many small pockets of calcareous grasslands. However, most areas of existing calcareous grasslands have been covered. The lack of resolution provided by using geological data at a 1 km scale was one of the main causes of the discrepancies between the calcareous grassland mask and known areas of calcareous grassland. Within the resources available to this project, there were no alternative datasets which could have improved the accuracy of the map in these problem areas.

A1.4.2 Given the need to include a representative sample of existing and potential calcareous grassland areas and the constraint on the overall size of the calcareous grassland mask, the fit of the mask was judged acceptable for the purposes of this project. The area we have identified for our sampling programme does not cover the whole calcareous grassland resource in England, but does provide an adequate sampling framework for assessing the current status of the calcareous grassland resource in the core calcareous grassland areas.

Appendix 2 Tables to accompany Chapter 4 – Ecological characteristics of the calcareous grassland mask

This Appendix includes Tables that add detail to Chapter 4 and information on the use of quality criteria for site evaluation (Box A2.1).

Box A2.1 The use of quality criteria for site evaluation

The development of the concept of evaluation for sites originated in the post-war years when the Nature Conservancy was set up with the objective of identifying a series of National Nature Reserves. The impetus originally came from the work of Tansley (1939) on British vegetation and was encapsulated in Cmnd 7122. Whilst it was implicit that the sites should form a representative series of the 'best' examples of habitats in Britain, explicit criteria were not defined and other factors such as diversity and variety of species often determined the status of individual sites. In some regions, series were set up explicitly, eg the woodland series of sites set up by R E Hughes (unpublished) on the basis of a combination of geological and climate criteria in north Wales. The necessity to rationalise the number of sites throughout Britain led to the *Nature conservation review*, carried out in the early 1970s but eventually described by Ratcliffe (1977). That document set out the quality criteria that had been used in the selection process but these were largely *post hoc* as the large number of contributors largely worked independently.

In the early 1980s there was much discussion of the necessity for objective criteria, eg the conference at University College London (Rose 1981). Bunce (1981) laid out the necessity of prerequisites of classification to ensure that differences of quality were not inherently due to basic differences between the ecological character of sites. For example, limestone vegetation is usually species-rich whereas acid vegetation is species-poor. More recently, Usher (1991) has also pointed out that the diversification of inherently simple ecological systems represents degradation.

Usher (1986) summarised the work up to that date on evaluation and drew heavily on the work by Margules and Usher (1981). He discussed in detail the criteria laid down by Ratcliffe and showed how they had been used by various studies in different ways. He also showed how the relative weighting attached to the importance of the criteria varied widely between individuals. In this respect, conservation evaluation had paralleled that in the analogous field of landscape evaluation. Liddle (1977) laid out comparable principles and Robinson *et al.* (1976) demonstrated how objective criteria could be used for landscape assessment. The next stage for both topics was that objective criteria were virtually ignored because of the over-riding necessity for speed in the evaluation process. In landscape evaluation a decision on objective criteria could take one or even two orders of magnitude longer than on-the-spot examination, yet the outcome would, to a policy advisor, be identical.

In the case of nature conservation evaluation, the criteria had been laid down but the pressure for site safeguard meant that the majority of sites were evaluated intuitively. Within the voluntary movement this is epitomised by the recent requirement to justify the status of many sites long after they had been identified as of conservation significance.

Although there is negligible recent literature on evaluation techniques in Britain, there has been a continuing programme abroad, especially in Australia. A major meeting on systematic and conservation evaluation was held in South Africa in 1992, where most of the British speakers emphasised the need for speed in the evaluation process because of threats rather than the development of objective criteria. Crowe (1993) summarised these criteria and identified particularly the work by Margules (1989), Pressey and Nicholls (1989), Rebolo and Siegfried (1990) and Williams, Vane-Wright and Humphries (1993) in that 'together their papers embodied principles, criteria and analytical methods necessary for scientific evaluation'. They agreed that the limit of analysis should be the site and that accurate species and abundance data for the sites under consideration should be obtained. Whilst this is never completely possible, surrogate measures could be used which allow the prediction of presence or absence of individual species.

This strategy had been followed in the threatened habitats project, with measures of vegetation being used as the taxon for evaluation, partly because of the ease of consistent recording and partly because of its ready correlation with other groups. Crowe (1993) concluded that ecologists did not appreciate the severity of the conservation crisis and that short cuts were essential to identify species in crisis. Whilst this conclusion may be true on a world scale, the necessity in the present project is to develop objective measures which can determine explicitly the effects of designation in statistical terms. In this respect the methodology employed in the current project represents a combination of the criteria laid down by Margules (1989) and Pressey and Nicholls (1989), together with the vegetation survey principles of Austin and Heyligers (1989). It has also been decided as a matter of principle to rank the various scores separately and not to add them together to achieve a final 'score' – statistical considerations preclude such additions as the scale of the various measures is not known. Further, as Pielou (1991) has emphasised, and Crowe (1993) has subsequently reinforced, simple measures are more readily understood.

Table A2.1 Land cover estimates for calcareous landscapes, based on descriptions of land cover at 16 grid points in each survey square

Land cover	Designated Hard limestone Area (km²)	SE	%	Designated Soft limestone Area (km²)	SE	%	Non-designated Hard limestone Area (km²)	SE	%	Non-designated Soft limestone Area (km²)	SE	%
Semi-natural calcareous grass	69	34	1.5	302	113	2.8	12	12	0.5	30	30	0.3
Neutral/improved grass	1709	340	36.9	2755	417	25.6	1027	188	42.3	2133	484	25.0
Recreational grass	0	0	0.0	151	112	1.4	70	70	2.9	148	72	1.7
Crops	69	56	1.5	4032	529	37.5	537	190	22.1	4118	668	48.3
Unmanaged grass/tall herbs	14	14	0.3	252	79	2.3	0	0	0.0	178	61	2.1
Acid grass/bracken	661	196	14.3	67	53	0.6	105	72	4.3	30	30	0.3
Moorland grass	813	241	17.6	0	0	0.0	82	56	3.4	0	0	0.0
Heathland	55	43	1.2	302	227	2.8	140	117	5.8	0	0	0.0
Bog	262	109	5.7	0	0	0.0	47	27	1.9	0	0	0.0
Waterside	41	23	0.9	50	37	0.5	47	47	1.9	30	30	0.3
Woodland/trees	648	249	14.0	1294	278	12.0	163	44	6.7	504	195	5.9
Scrub	28	19	0.6	235	82	2.2	12	12	0.5	30	30	0.3
Rail/road/track	83	35	1.8	353	108	3.3	58	27	2.4	444	124	5.2
Urban	14	14	0.3	470	128	4.4	70	37	2.9	830	354	9.7
Other	165	51	3.6	487	142	4.5	58	27	2.4	59	30	0.7
All	*4630*		*100.0*	*10751*		*100.0*	*2429*		*100.0*	*8533*		*100.0*

Land cover	Designated Area (km²)	SE	%	Non-designated Area (km²)	SE	%	Hard limestone Area (km²)	SE	%	Soft limestone Area (km²)	SE	%	All Area (km²)	SE	%
Semi-natural calcareous grass	371	118	2.4	41	32	0.4	81	21	1.1	332	117	1.7	413	122	1.6
Neutral/improved grass	4464	538	29.0	3161	519	28.8	2736	338	38.8	4888	639	25.3	7624	747	28.9
Recreational grass	151	112	1.0	218	101	2.0	70	126	1.0	299	133	1.6	369	150	1.4
Crops	4101	532	26.7	4656	694	42.5	606	343	8.6	8150	852	42.3	8756	875	33.2
Unmanaged grass/tall herbs	266	80	1.7	178	61	1.6	14	0	0.2	430	100	2.2	444	100	1.7
Acid grass/bracken	729	203	4.7	135	78	1.2	767	129	10.9	97	60	0.5	863	217	3.3
Moorland grass	813	241	5.3	82	56	0.7	895	101	12.7	0	0	0.0	895	247	3.4
Heathland	358	231	2.3	140	117	1.3	195	211	2.8	302	227	1.6	498	259	1.9
Bog	262	109	1.7	47	27	0.4	309	48	4.4	0	0	0.0	309	112	1.2
Waterside	92	44	0.6	76	55	0.7	88	84	1.2	80	48	0.4	168	70	0.6
Woodland/trees	1941	373	12.6	667	200	6.1	811	79	11.5	1797	340	9.3	2608	424	9.9
Scrub	263	84	1.7	41	32	0.4	39	21	0.6	265	87	1.4	304	90	1.2
Rail/road/track	435	113	2.8	503	127	4.6	141	49	2.0	797	164	4.1	938	170	3.6
Urban	484	129	3.1	900	356	8.2	84	67	1.2	1300	376	6.7	1384	378	5.3
Other	653	151	4.2	118	40	1.1	224	49	3.2	546	145	2.8	770	156	2.9
All	*15381*		*100.0*	*10962*		*100.0*	*7059*		*100.0*	*19284*		*100.0*	*26343*		*100.0*

Table A2.2 Proportion of boundary types by strata, in calcareous landscapes, based on nearest non-curtilage boundary (within 100 m) to each grid point

Boundaries	Designated Hard %	Designated Soft %	Non-designated Hard %	Non-designated Soft %	Total Desig-nated %	Total Non-designated %	Total Hard %	Total Soft %	Total %
% of points without boundary	29	44	14	23	39	21	24	35	32
% of points with boundary	71	56	86	77	61	79	76	65	68
% of points with a boundary:									
Bank	1	1		+	1	+	1	1	1
Fence	30	53	44	40	45	41	36	46	43
Fence/bank	1	2	1	0	2	1	1	1	1
Hedge	3	18	11	24	13	21	6	21	17
Hedge/bank	1	1	3	2	1	2	2	2	2
Hedge/fence	5	20	21	26	14	25	11	23	19
Hedge/fence/bank	4	2	4	1	3	2	4	1	2
Hedge/wall	1				+		1		+
Hedge/wall/fence	+			0	+	+	+	+	+
Wall	23	3	11	1	10	3	18	2	7
Wall/bank			1			+	+		+
Wall/fence	32	1	4	5	12	4	21	3	8
Wall/fence/bank				0		+		+	+
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*

Table A2.3 Classification of quadrats from the calcareous landscape (using TWINSPAN). Numbers in plain type give the numbers of quadrats at each division. Bold letters in square brackets correspond to the plot class

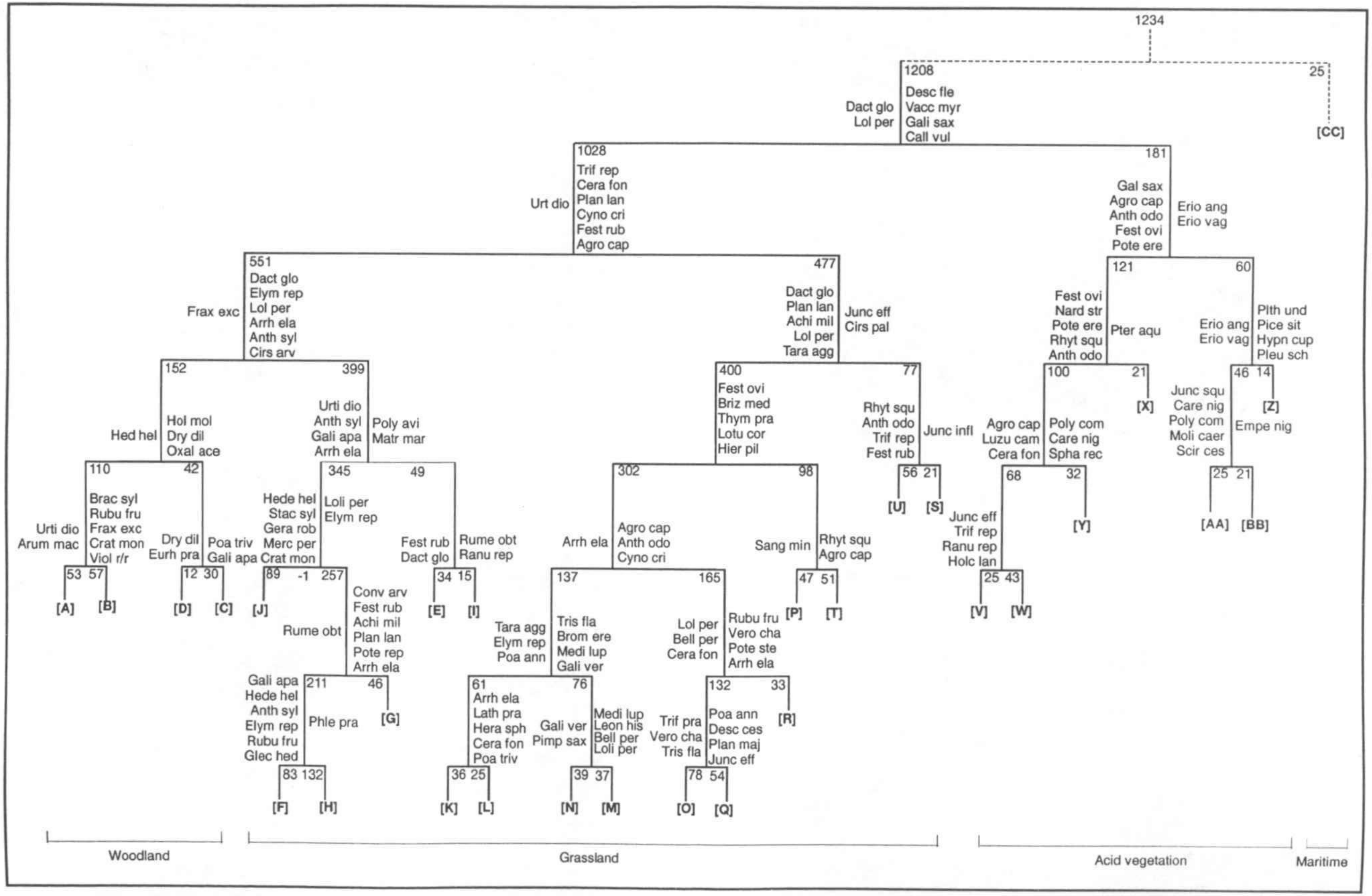


Table A2.4 Calcareous landscapes – description of TWINSPAN plot classes

Plot class	Total no. of plots	Habitat	Description	Limestone Hard/Soft	Predominant land uses	Preferential species	Constant species	Dominant species
PCA	53	Woodland	Calcareous, eutrophic, often woodland edge	S	Woodland	*Urti dio Hede hel Samb nig*	*Urti dio Gali apa Hede hel*	*Hede hel Merc per Urti dio*
PCB	57	Woodland	Calcareous, mainly ash	S	Woodland	*Frax exc Rubu fru Hede hel*	*Frax exc Rubu fru Hede hel*	*Hede hel Merc per Rubu fru*
PCC	30	Woodland	Basiphilous, more open, grassy	S/H	Woodland	*Holc mol Eurh sp. Hyac non*	*Eury sp. Poa triv Agro stol*	*Holc mol Poa triv Urti dio*
PCD	12	Woodland	Neutral/acid, bramble-dominated	H	Woodland	*Dryo dil Eurh prae Rubu fru*	*Dryo dil Rubu fru Eury pra*	*Rubu fru Holc mol Eury prae*
PCE	34	Grassland	Fertile, with annual weeds	S	Neut/impr'd grass Unmg'ed grass	*Poly avi Matr mat Loli per*	*Loli per Poly avic Elym rep*	*Loli per Fest rub Poly avi*
PCF	83	Grassland	Fertile, overgrown, often shaded	S/H	Unmg'ed grass Tall herbs	*Elym rep Anth syl Urti dio*	*Elym rep Urti dio Dact glo*	*Elym rep Arrh ela Urti dio*
PCG	46	Grassland	Tall, coarse, open	S	Unmg'ed grass	*Arrh ela Conv arv Elym rep*	*Arrh ela Dact glo Fest rub*	*Arrh ela Fest rub Elym rep*
PCH	132	Grassland	Eutrophic, often neglected	S/H	Neut/impr'd grass Unmg'ed grass Tall herb	*Urti dio Loli per Elym rep*	*Dact glo Loli per Agro sto*	*Loli per Agro sto Dact glo*
PCI	15	Grassland	Intensive, rye-grass-dominated, often disturbed	S/H	Neut/impr'd grass	*Poly avic Rume obt Poa ann*	*Loli per Cirs arv Poa ann*	*Loli per Poa ann Poa triv*
PCJ	89	Grassland	Eutrophic, overgrown, with tall herbs, often shaded, often associated with water	S/H	Tall herbs Woodland	*Urti dio Gali apa Arrh ela*	*Urti dio Dact glo Arrh ela*	*Arrh ela Hede hel Agro stol*
PCK	36	Grassland	Fertile, short, often disturbed	S	Neut/impr'd grass	*Tara agg Plan maj Plan lan*	*Dact glo Tara agg Loli per*	*Loli per Fest rub Agro sto*
PCL	25	Grassland	Neutral/basiphilous, tall with herbs	H/S	Verge	*Arrh ela Plan lan Hera sph*	*Dact glo Arrh ela Loli per*	*Fest rub Arrh ela Agro sto*
PCM	37	Grassland	Neutral/basiphilous, short, mown/grazed	S/H	Neut/impr'd grass Calcareous grass	*Medi lup Plan lan Fest rub*	*Dact glo Fest rub Plan lan*	*Fest rub Loli per Agro sto*
PCN	39	Grassland	Basiphilous/calcareous, tussocky with herbs	S	Neut/impr'd grass Calcareous grass	*Gali ver Fest rub Plan lan*	*Fest rub Dact glo Plan lan*	*Fest rub Brom ere Arrh ela*
PCO	78	Grassland	Neutral permanent pasture	H/S	Neut/impr'd grass	*Cyno cri Cera fon Trif rep*	*Holc lan Loli per Trif rep*	*Loli per Fest rub Holc lan*
PCP	47	Grassland	Calcareous, short turf, grazed, with small herbs	S/H	Calcareous grass	*Sang min Care fla Lotu com*	*Plan lan Lotu com Sang min*	*Fest rub Fest ovi Care fla*
PCQ	54	Grassland	Neutral, semi-improved, grazed/mown	H/S	Neut/impr'd grass	*Trif rep Poa ann Cera fon*	*Trif rep Loli per Holc lan*	*Loli per Agro sto Trif rep*
PCR	33	Grassland	Neutral unimproved, light/no grazing, some shading	H/S	Neut/impr'd grass	*Vero cham Anth odo Agro cap*	*Dact glo Plan lan Agro cap*	*Fest rub Agro cap Rubu fru*
PCS	21	Grassland	Marsh / rushy pasture	H/S	Marsh	*Junc inf Junc eff Fili ulm*	*Holc lan Junc eff Junc inf*	*Junc inf Holc lan Junc eff*
PCT	51	Grassland	Northern, calcareous	H/S	Neut/impr'd grass Calcareous grass	*Fest ovi Briz med Lotu cor*	*Agro cap Fest ovi Trif rep*	*Fest ovi Fest rub Agro cap*

Table A2.4 continued

Plot class	Total no. of plots	Habitat	Description	Limestone Hard/Soft	Predominant land uses	Preferential species	Constant species	Dominant species
PCU	56	Grassland	Northern, damp pasture, often associated with flushing or streamsides	H/S	Neut/impr'd grass Streamside Flush	*Cirs pal* *Junc eff* *Anth odo*	*Holc lan* *Anth odo* *Trif rep*	*Agro cap* *Holc lan* *Agro sto*
PCV	25	Acid veg'n	Acid grassland, often rushy	H	Acid grass Moorland grass	*Gali sax* *Desc cesp* *Nard str*	*Agro cap* *Anth odo* *Gali sax*	*Fest ovi* *Agro cap* *Nard str*
PCW	43	Acid veg'n	Dry grassland / heath	H	Acid grass Moorland grass Dry heath	*Fest ovi* *Gali sax* *Rhyt squ*	*Fest ovi* *Gali sax* *Agro cap*	*Fest ovi* *Desc fle* *Nard str*
PCX	21	Acid veg'n	Bracken / dry heath, often shaded	S/H	Woodland Dry heath	*Pter aqu* *Vacc myr* *Dryo dil*	*Pter aqu* *Vacc myr* *Call vul*	*Pter aqu* *Vacc myr* *Agro cap*
PCY	32	Acid veg'n	Moorland grass, moist	H	Moorland grass Flush	*Poly com* *Desc fle* *Fest ovi*	*Poly com* *Fest ovi* *Desc fle*	*Nard str* *Poly com* *Moli cae*
PCZ	14	Acid veg'n	Mossy heath, often planted with Sitka	H	Woodland	*Plag und* *Hypn cup* *Pleu sch*	*Hypn cup* *Plag und* *Pleu sch*	*Pice sit* *Pleu sch* *Hypn cup*
PCAA	25	Acid veg'n	Mire	H/S	Bog	*Erio ang* *Erio vag* *Junc squ*	*Erio ang* *Erio vag* *Call vul*	*Call vul* *Erio vag* *Poly com*
PCBB	21	Acid veg'n	Wet heath/bog	H/S	Bog Heath	*Call vul* *Empe nig* *Vacc myr*	*Call vul* *Empe nig* *Vacc myr*	*Call vul* *Erio vag* *Vacc myr*
PCCC	25	Maritime	Mostly saltmarsh	S	Saltmarsh	*Elym pyc* *Halm por* *Pucc mar*	*Elym pyc* *Halm por* *Fest rub*	*Halm por* *Fest rub* *Limn bin*

Table A2.5 Mean number of plots per square, in each plot class, by strata
i. Main plots

Plot			Designated				Non-designated				Total		Total		Total		Total			
			Hard		Soft		Hard		Soft		Designated		Non-des		Hard		Soft		Total	
class	Description		Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
PCA	Woodland	Calcareous, eutrophic, often woodland edge	0.05	*1*	0.13	*7*	0.08	*3*	0.11	*8*	0.10	*4*	0.10	*6*	0.06	*2*	0.12	*7*	0.10	*5*
PCB		Calcareous, mainly ash	0.14	*3*	0.30	*17*	0.23	*8*	0.11	*8*	0.25	*10*	0.14	*8*	0.17	*4*	0.22	*14*	0.20	*9*
PCC		Basiphilous, more open, grassy			0.08	*4*	0.15	*5*	0.11	*8*	0.05	*2*	0.12	*7*	0.05	*1*	0.09	*6*	0.08	*4*
PCD		Neutral/acid, bramble-dominated	0.14	*3*	0.03	*1*	0.15	*5*			0.06	*2*	0.03	*2*	0.15	*4*	0.01	*1*	0.05	*2*
PCE	Grassland	Fertile, with annual weeds							0.06	*4*			0.04	*2*			0.02	*1*	0.02	*1*
PCF		Fertile, overgrown, often shaded																		
PCG		Tall, coarse, open			0.03	*1*			0.11	*8*	0.02	*1*	0.09	*5*			0.06	*4*	0.05	*2*
PCH		Eutrophic, often neglected	0.05	*1*	0.20	*11*	0.15	*5*			0.15	*6*	0.03	*2*	0.08	*2*	0.11	*7*	0.10	*5*
PCI		Intensive, rye-grass-dominated, often disturbed			0.08	*4*			0.11	*8*	0.05	*2*	0.09	*5*			0.09	*6*	0.07	*3*
PCJ		Eutrophic, overgrown, tall herbs, often shaded/wet			0.08	*4*			0.06	*4*	0.05	*2*	0.04	*2*			0.07	*4*	0.05	*2*
PCK		Fertile, short, often disturbed			0.08	*4*	0.08	*3*			0.05	*2*	0.02	*1*	0.03	*1*	0.04	*2*	0.04	*2*
PCL		Neutral/basiphilous, tall with herbs																		
PCM		Neutral/basiphilous, short, mown or grazed			0.08	*4*			0.06	*4*	0.05	*2*	0.04	*2*			0.07	*4*	0.05	*2*
PCN		Basiphilous/calcareous, tussocky with herbs			0.10	*6*			0.11	*8*	0.07	*3*	0.09	*5*			0.10	*6*	0.08	*4*
PCO		Neutral permanent pasture	0.71	*16*	0.20	*11*	0.62	*21*	0.33	*24*	0.35	*14*	0.40	*23*	0.68	*18*	0.26	*16*	0.37	*17*
PCP		Calcareous, short-turf, grazed, with small herbs	0.05	*1*	0.13	*7*					0.10	*4*			0.03	*1*	0.07	*4*	0.06	*3*
PCQ		Neutral, semi-improved, grazed or mown	0.48	*11*	0.05	*3*	0.38	*13*	0.11	*8*	0.18	*7*	0.17	*10*	0.44	*11*	0.08	*5*	0.18	*8*
PCR		Neutral, unimproved, light/no grazing, some shading	0.10	*2*					0.11	*8*	0.03	*1*	0.09	*5*	0.06	*2*	0.05	*3*	0.05	*2*
PCS		Marsh/rushy pasture																		
PCT		Northern calcareous	0.29	*7*			0.08	*3*			0.09	*3*	0.02	*1*	0.21	*5*			0.06	*3*
PCU		Northern, damp pasture, often with flushing/streamsides	0.24	*5*			0.15	*5*			0.07	*3*	0.03	*2*	0.21	*5*			0.06	*3*
PCV	Acid veg'n	Acid grassland, often rushy	0.29	*7*			0.23	*8*			0.09	*3*	0.05	*3*	0.27	*7*			0.07	*3*
PCW		Dry grassland/heath	0.57	*13*	0.03	*1*	0.23	*8*			0.19	*7*	0.05	*3*	0.45	*12*	0.01	*1*	0.13	*6*
PCX		Bracken/dry heath, often shaded			0.15	*8*					0.10	*4*					0.08	*5*	0.06	*3*
PCY		Moorland grass, moist	0.81	*18*			0.08	*3*			0.24	*9*	0.02	*1*	0.56	*14*			0.15	*7*
PCZ		Mossy heath, often planted with Sitka	0.24	*5*			0.08	*3*			0.07	*3*	0.02	*1*	0.18	*5*			0.05	*2*
PCAA		Mire	0.10	*2*	0.03	*1*	0.15	*5*			0.05	*2*	0.03	*2*	0.12	*3*	0.01	*1*	0.04	*2*
PCBB		Wet heath/bog	0.05	*1*	0.08	*4*	0.08	*3*			0.07	*3*	0.02	*1*	0.06	*2*	0.04	*2*	0.05	*2*
PCCC	Maritime	Mostly saltmarsh	0.10	*2*							0.03	*1*			0.06	*2*			0.02	*1*
All			*4.38*	*100*	*1.80*	*100*	*2.92*	*100*	*1.39*	*100*	*2.58*	*100*	*1.73*	*100*	*3.88*	*100*	*1.62*	*100*	*2.22*	*100*

Table A2.5 Mean number of plots per square, in each plot class, by strata
ii. Habitat plots

Plot			Designated				Non-designated				Total		Total		Total		Total			
			Hard		Soft		Hard		Soft		Designated		Non-des		Hard		Soft		Total	
class		Description	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
PCA	Woodland	Calcareous, eutrophic, often woodland edge	0.05	*1*	0.73	*15*	0.15	*3*	0.39	*8*	0.52	*10*	0.34	*7*	0.08	*2*	0.58	*12*	0.44	*9*
PCB		Calcareous, mainly ash	0.29	*6*	0.43	*9*	0.23	*5*	0.28	*6*	0.38	*8*	0.27	*5*	0.27	*5*	0.36	*7*	0.33	*7*
PCC		Basiphilous, more open, grassy	0.19	*4*	0.18	*4*	0.31	*6*	0.06	*1*	0.18	*4*	0.11	*2*	0.23	*5*	0.12	*2*	0.15	*3*
PCD		Neutral/acid, bramble-dominated	0.10	*2*	0.03	*1*	0.15	*3*			0.05	*1*	0.03	*1*	0.12	*2*	0.01	*0*	0.04	*1*
PCE	Grassland	Fertile, with annual weeds			0.20	*4*			0.17	*3*	0.14	*3*	0.13	*3*			0.19	*4*	0.14	*3*
PCF		Fertile, overgrown, often shaded			0.20	*4*	0.08	*2*	0.33	*7*	0.14	*3*	0.28	*6*	0.03	*1*	0.26	*5*	0.20	*4*
PCG		Tall, coarse, open			0.23	*5*			0.11	*2*	0.16	*3*	0.09	*2*			0.17	*3*	0.13	*3*
PCH		Eutrophic, often neglected			0.43	*9*	0.23	*5*	0.89	*18*	0.30	*6*	0.74	*15*	0.08	*2*	0.63	*13*	0.48	*10*
PCI		Intensive, rye-grass-dominated, often disturbed			0.03	*1*	0.15	*3*	0.11	*2*	0.02	*0*	0.12	*2*	0.05	*1*	0.06	*1*	0.06	*1*
PCJ		Eutrophic, overgrown, tall herbs, often shaded/wet	0.10	*2*	0.45	*9*	0.38	*8*	0.83	*17*	0.34	*7*	0.73	*15*	0.19	*4*	0.62	*13*	0.51	*10*
PCK		Fertile, short, often disturbed			0.10	*2*	0.08	*2*	0.06	*1*	0.07	*1*	0.06	*1*	0.03	*1*	0.08	*2*	0.07	*1*
PCL		Neutral/basiphilous, tall with herbs	0.05	*1*			0.15	*3*	0.06	*1*	0.01	*0*	0.08	*2*	0.08	*2*	0.02	*0*	0.04	*1*
PCM		Neutral/basiphilous, short, mown or grazed			0.08	*2*	0.08	*2*	0.33	*7*	0.05	*1*	0.28	*6*	0.03	*1*	0.19	*4*	0.15	*3*
PCN		Basiphilous/calcareous, tussocky with herbs	0.05	*1*	0.28	*6*	0.08	*2*	0.39	*8*	0.21	*4*	0.32	*6*	0.06	*1*	0.33	*7*	0.25	*5*
PCO		Neutral permanent pasture	0.29	*6*	0.25	*5*	0.62	*12*	0.17	*3*	0.26	*5*	0.27	*5*	0.40	*8*	0.21	*4*	0.26	*5*
PCP		Calcareous, short-turf, grazed, with small herbs	0.14	*3*	0.63	*13*	0.15	*3*	0.06	*1*	0.48	*10*	0.08	*2*	0.15	*3*	0.37	*7*	0.31	*6*
PCQ		Neutral, semi-improved, grazed or mown					0.08	*2*	0.11	*2*			0.10	*2*	0.03	*1*	0.05	*1*	0.04	*1*
PCR		Neutral, unimproved, light/no grazing, some shading	0.29	*6*	0.05	*1*	0.15	*3*	0.17	*3*	0.12	*2*	0.16	*3*	0.24	*5*	0.10	*2*	0.14	*3*
PCS		Marsh/rushy pasture	0.24	*5*	0.15	*3*	0.54	*11*	0.17	*3*	0.18	*4*	0.25	*5*	0.34	*7*	0.16	*3*	0.21	*4*
PCT		Northern calcareous	0.57	*11*	0.05	*1*	0.54	*11*	0.11	*2*	0.21	*4*	0.21	*4*	0.56	*11*	0.08	*2*	0.21	*4*
PCU		Northern, damp pasture, often with flushing/streamsides	1.10	*22*	0.08	*2*	0.23	*5*	0.06	*1*	0.38	*8*	0.09	*2*	0.80	*16*	0.07	*1*	0.26	*5*
PCV	Acid veg'n	Acid grassland, often rushy	0.24	*5*	0.03	*1*					0.09	*2*			0.16	*3*	0.01	*0*	0.05	*1*
PCW		Dry grassland/heath	0.29	*6*	0.10	*2*	0.15	*3*			0.16	*3*	0.03	*1*	0.24	*5*	0.06	*1*	0.11	*2*
PCX		Bracken/dry heath, often shaded	0.14	*3*	0.08	*2*	0.08	*2*	0.06	*1*	0.10	*2*	0.06	*1*	0.12	*2*	0.07	*1*	0.08	*2*
PCY		Moorland grass, moist	0.19	*4*	0.03	*1*	0.15	*3*	0.06	*1*	0.07	*1*	0.08	*2*	0.18	*4*	0.04	*1*	0.08	*2*
PCZ		Mossy heath, often planted with Sitka	0.14	*3*							0.04	*1*			0.09	*2*			0.03	*1*
PCAA		Mire	0.24	*5*	0.05	*1*	0.15	*3*			0.11	*2*	0.03	*1*	0.21	*4*	0.03	*1*	0.08	*2*
PCBB		Wet heath/bog	0.33	*7*	0.05	*1*	0.08	*2*			0.14	*3*	0.02	*0*	0.25	*5*	0.03	*1*	0.09	*2*
PCCC	Maritime	Mostly saltmarsh			0.13	*3*					0.09	*2*					0.07	*1*	0.05	*1*
All			*5.00*	*100*	*4.98*	*100*	*5.00*	*100*	*4.94*	*100*	*4.98*	*100*	*4.96*	*100*	*5.00*	*100*	*4.96*	*100*	*4.97*	*100*

Table A2.5 Mean number of plots per square, in each plot class, by strata
iii. Verge plots

Plot class	Description	Designated Hard Mean	%	Designated Soft Mean	%	Non-designated Hard Mean	%	Non-designated Soft Mean	%	Total Designated Mean	%	Total Non-designated Mean	%	Total Hard Mean	%	Total Soft Mean	%	Total Mean	%
PCA Woodland	Calcareous, eutrophic, often woodland edge			0.05	*1*	0.08	*2*	0.06	*1*	0.03	*1*	0.06	*1*	0.03	*1*	0.05	*1*	0.05	*1*
PCB	Calcareous, mainly ash			0.10	*2*	0.15	*3*			0.07	*2*	0.03	*1*	0.05	*1*	0.06	*1*	0.05	*1*
PCC	Basiphilous, more open, grassy			0.05	*1*	0.15	*3*	0.06	*1*	0.03	*1*	0.08	*2*	0.05	*1*	0.05	*1*	0.05	*1*
PCD	Neutral/acid, bramble-dominated																		
PCE Grassland	Fertile, with annual weeds			0.35	*7*	0.15	*3*	0.33	*7*	0.24	*5*	0.29	*6*	0.05	*1*	0.34	*7*	0.27	*6*
PCF	Fertile, overgrown, often shaded	0.10	*3*	0.90	*18*	0.38	*8*	1.33	*27*	0.66	*15*	1.12	*22*	0.19	*5*	1.09	*22*	0.85	*18*
PCG	Tall, coarse, open			0.65	*13*			0.33	*7*	0.45	*10*	0.26	*5*			0.51	*10*	0.37	*8*
PCH	Eutrophic, often neglected	0.52	*17*	0.93	*19*	0.77	*15*	1.44	*29*	0.80	*18*	1.29	*26*	0.61	*16*	1.15	*23*	1.01	*22*
PCI	Intensive, rye-grass-dominated, often disturbed			0.08	*2*	0.08	*2*	0.06	*1*	0.05	*1*	0.06	*1*	0.03	*1*	0.07	*1*	0.06	*1*
PCJ	Eutrophic, overgrown, tall herbs, often shaded/wet	0.62	*20*	0.43	*9*	0.69	*14*	0.28	*6*	0.48	*11*	0.37	*7*	0.64	*17*	0.36	*7*	0.44	*10*
PCK	Fertile, short, often disturbed			0.40	*8*	0.08	*2*	0.50	*10*	0.28	*6*	0.41	*8*	0.03	*1*	0.44	*9*	0.33	*7*
PCL	Neutral/basiphilous, tall with herbs	0.33	*11*	0.13	*3*	0.54	*11*	0.11	*2*	0.19	*4*	0.21	*4*	0.40	*11*	0.12	*2*	0.20	*4*
PCM	Neutral/basiphilous, short, mown or grazed	0.19	*6*	0.35	*7*			0.22	*4*	0.30	*7*	0.17	*3*	0.12	*3*	0.29	*6*	0.25	*5*
PCN	Basiphilous/calcareous, tussocky with herbs			0.15	*3*	0.08	*2*	0.11	*2*	0.10	*2*	0.10	*2*	0.03	*1*	0.13	*3*	0.10	*2*
PCO	Neutral permanent pasture	0.29	*9*	0.03	*1*	0.15	*3*			0.10	*2*	0.03	*1*	0.24	*6*	0.01	*0*	0.07	*2*
PCP	Calcareous, short-turf, grazed, with small herbs			0.08	*2*	0.62	*12*			0.05	*1*	0.14	*3*	0.21	*6*	0.04	*1*	0.09	*2*
PCQ	Neutral, semi-improved, grazed or mown	0.38	*12*	0.23	*5*	0.23	*5*	0.06	*1*	0.27	*6*	0.09	*2*	0.33	*9*	0.15	*3*	0.20	*4*
PCR	Neutral, unimproved, light/no grazing, some shading	0.33	*11*	0.05	*1*			0.11	*2*	0.14	*3*	0.09	*2*	0.22	*6*	0.08	*2*	0.11	*2*
PCS	Marsh/rushy pasture					0.23	*5*					0.05	*1*	0.08	*2*			0.02	*0*
PCT	Northern calcareous	0.24	*8*			0.15	*3*			0.07	*2*	0.03	*1*	0.21	*6*			0.06	*1*
PCU	Northern, damp pasture, often with flushing/streamsides	0.05	*2*			0.15	*3*			0.01	*0*	0.03	*1*	0.08	*2*			0.02	*0*
PCV Acid veg'n	Acid grassland, often rushy					0.08	*2*					0.02	*0*	0.03	*1*			0.01	*0*
PCW	Dry grassland/heath	0.10	*3*			0.23	*5*			0.03	*1*	0.05	*1*	0.14	*4*			0.04	*1*
PCX	Bracken/dry heath, often shaded																		
PCY	Moorland grass, moist																		
PCZ	Mossy heath, often planted with Sitka																		
PCAA	Mire																		
PCBB	Wet heath/bog																		
PCCC Maritime	Mostly saltmarsh																		
All		*3.14*	*100*	*4.93*	*100*	*5.00*	*100*	*5.00*	*100*	*4.39*	*100*	*5.00*	*100*	*3.78*	*100*	*4.96*	*100*	*4.64*	*100*

Appendix 3 Technical appendix to Chapter 5 – Historical characteristics of the calcareous grassland mask

This Appendix includes:
- details of the work programme associated with characterising the calcareous grassland mask (A3.1)
- commentary on available data (A3.2)
- Tables which provide further, detailed results from work on historical aspects of the calcareous grassland mask (A3.3), not given in Chapter 5.

A3.1 Detailed work programme

A3.1.1 At the outset, a work programme was set out in a project design but this was later modified to reflect the nature of the data gathered. The resulting methodology is summarised below.

1. Review of literature and consultations with ITE
2. Survey of historic features
   2.1 Collation of existing data from ITE
   List of 1 km squares for the calcareous grassland landscape in paper and digital form
   List of aerial photographs (APs) available at ITE
   Map overlay for each square
   2.2 Collation of data from County Sites and Monuments Records (SMRs) and National Archaeological Record (NAR)
   Mailing to SMRs and NAR, requesting map overlay and data printout for each square
   Data collation and map interpretation
   Computer entry of collated SMR, NAR and ITE data
   Collation of additional data on management regimes from English Heritage (EH) Register of Scheduled Monuments (RSM)
   Computer entry of EH RSM data
   2.3 AP work
   Examination of subsample of squares defined by AP availability at ITE
   Computer entry of AP data
   2.4 Data analysis
   Correlation of site type/period/form, the Royal Commission on the Historical Monuments of England (RCHME) classes and designations within the calcareous grassland landscape
   Quantification of management history data
3. Assessment of the effectiveness of current designations in protecting historic features within the calcareous grassland landscape type
4. Predictive models of the effect of environmental and policy changes – effect on historic features, including an assessment of the impact of archaeological management plans.
5. Recommendations for refinement to policy instruments – to enhance protection of historic features. Based on results of 3 and 4, formulation of proposals to minimise threats to archaeology.

A3.1.2 Physical examination of the sample squares was carried out by ITE field surveyors during the course of the ecological fieldwork between 1990 and 1993. The major part of the work was contained in stage 2, essentially a data-gathering process involving consultation with archaeological curators, together with limited AP analysis and map interpretation. This work was carried out between July 1993 and April 1994. As expected and as described below, the available data were found to be inadequate to carry out items 3–5.

A3.2 Assessment of archaeological data

Data sources

A3.2.1 The extended national archaeological database in England is composed of several distinct databases (see RCHME 1993). SMRs provide regionally co-ordinated summaries of recorded archaeological sites. The core of these records is a computerised index. The NMR is maintained by RCHME as a permanent, publicly accessible source of information in three main parts: the National Archaeological Record (NAR), the National Buildings Record (NBR), and the National Library of Air Photographs (NLAP). Together these three sections are responsible for creating a national database of information about sites and buildings of historic and architectural interest. Historically, the NAR developed in parallel with county SMRs, and it is this subset of the NMR which has been consulted.

A3.2.2 In theory, data exchange between SMRs and the NAR should enable consultation with this single central database to provide a full indication of the recorded archaeological content of each square. In practice, such exchange is in its early days and is far from standard such that, in general, the SMRs hold a great deal of information not yet indexed by the NAR. In addition, the NAR holds additional datasets not on the county SMRs. Hence, both databases were consulted. In addition, the RSM is maintained by English Heritage as a management tool for Scheduled Ancient Monuments and holds additional data on the condition of these monuments.

A3.2.3 Information on listed buildings is not yet in computerised form for the whole country. Some SMRs have computerised the lists at least in part. In 1994, the RCHME commenced central computerisation of these lists on to the NBR. Hence, for this project, the incidence of listed buildings on the project database will not reflect reality, rather the policy of individual SMRs over whether to include or exclude entries from the lists of historic buildings and, if included, to what extent this listing has been implemented.

Database structure

A3.2.4 Data compiled from the above sources were used to create a database of archaeological sites identified for the ITE sample squares. The structure of this database is outlined in Table A3.1. The information collated divides into three main groups:

- identifiers and location;
- archaeological classification; and
- management information.

A3.2.5 Identifiers and location information is routinely given in archaeological databases and was readily collated.

A3.2.6 Archaeological classification is represented by standard RCHME classes, together with archaeological 'site types'. The specification of 'site types' is supposedly standardised. In practice, there is considerable variation between SMRs. A rationalisation process was therefore undertaken to check site type against the RCHME thesaurus and modify it accordingly. However, as the data were compiled, it became apparent that the variety of site type entries was too great to be of use in the analysis process, and a further stage of simplification was carried out. For example, a wide variety of prehistoric flint implements have been found whose specific identification is of no relevance to this project. The variety of entries covering these artefacts is therefore replaced by the single entry 'flint'.

A3.2.7 The form entry is important as it provides the first indication of the condition of a monument. Very broadly, any archaeological site slowly decays from its original 'intact' state. Rates of decay vary considerably and some form of equilibrium may be achieved at any point. Once again, SMR entries are far from standard and it was necessary to impose an appropriate rationalisation as shown in Table A3.3 (based on Trueman & Williams 1993, 13). The interpretation of SMR/NMR entries which was necessary to enter this item during the course of the project made it apparent that some simplification of this system was required if any analysis of this entry were to be made. To this end the 'form group' field was added. This is structured to reflect decay from standing structures through to totally removed sites. (Note that 'features' are intended to be sites whose original form was an earthwork and which survives largely unaltered, a category which is very difficult to apply with many sites, and is probably best considered as part of 'earthworks'.)

A3.2.8 Management information was derived directly from SMR and NMR entries. A separate database of sample squares was supplied by ITE. This included designation data and in the analysis process was related to the archaeological database.

Nature and quality of archaeological data

A3.2.9 Archaeological data were compiled for 398 archaeological sites in 42 sample squares drawn from 21 counties. A breakdown by county (Tables A3.4 & A3.5) shows considerable variation in the mean density of identified monuments. This variation is as likely to reflect the difference in details in individual SMRs as much as any real variation in the archaeological resource.

A3.2.10 One factor which is clear in the biases of the compiled data is the effect of the extent and type of site identification work undertaken by individual SMRs. For example, the importance of sites from the period of England's industrial revolution has only recently been accepted by SMRs and the NMR (following the RCHME's decision in 1990 to move the NAR entry cut-off date from 1714 to 1945). In the process of SMR/NMR enhancement that is underway, some counties are well ahead (eg Cornwall), whilst others are not (eg Shropshire).

A3.2.11 A further clear factor is the presence of particularly well-known and thoroughly investigated sites. For example, the high Suffolk figure of 115 sites is boosted by 40 entries for the kilometre square containing Sutton Hoo. This variation in the data between counties precludes any attempt to examine genuine regional variations in the archaeological resource.

A3.2.12 New sites (120) identified through ITE fieldwork, AP work and map analysis constitute 30.2% of the total number, representing an increase of 43.3% on the SMR/NMR entries (278). Reflecting the dependence on recent edition OS maps, the majority of these new sites almost certainly originated in the Post Medieval and Modern periods (although technically in most cases they are, and have been entered on the database as, 'unknown'). Site types are dominated by farms (numbering 20) and field systems (25) as the largest group, with a range of industrial (42) and transport (28) sites also forming a major block. These site types were already represented on archaeological registers (although in notably smaller numbers). A third major group, wood banks (5), was identified by ITE field surveyors and is not represented on the registers for this dataset.

A3.2.13 By contrast, few sites were added by the identification process to the already well-represented site types of early periods. Examples include prehistoric barrows (15 on SMRs/NMR, no new sites) and find sites (eg 14 pottery sites, no new sites). This in part reflects the very limited fieldwork (carried out by non-archaeologists), together with the limited availability of appropriate AP cover. It probably also reflects the much greater attention previously given by archaeologists to Prehistoric, Roman and Medieval archaeology, over Post Medieval and Modern archaeology.

A3.2.14 It is also apparent from the compiled data that the mean density of monuments at 9.5 sites per km^2 is notably higher than the national figure of 1.2 per km^2 quoted for the Monuments at Risk Survey (MARS) project (Darvill, Fulton & Bell 1993, 11). However, this latter figure is based on NMR data and, as Table A3.7 makes clear, NMR figures for site numbers are consistently low in the calcareous grassland landscape when compared to SMR entries (by a factor of between 1.5 and 3).

A3.2.15 Although this project is only dealing with a specific landscape type, these data suggest that the national mean density of monuments on existing registers is considerably higher than previously supposed. However, the number and range of new sites identified strongly suggest that the data held by SMRs and the NMR fall well short of the total archaeological resource. Establishing a figure for this shortfall is not possible with the data presented here because of the severe limitations on the identification process used. Further work to establish the specific nature and size of SMR/NMR shortfalls for different periods would require an appropriate programme of combined mapwork, AP analysis and fieldwork.

A3.3 Tables which provide further, detailed results from work on historical aspects of the calcareous grassland mask, not given in Chapter 5

Table A3.1 Archaeological data structure

	Field	Type	Notes
Identifiers and location	ITE no	char	As ITE
	Km grid ref	char	In one field, eg SD7534
	Qtr sht	char	In one field, eg SD73SW
	County	char	Abbreviated name
	Source	char	SMR/NMR/RSM/ITE/AP
	SMR no	char	As SMR
	Map id	char	As SMR
	NMR no	char	As NMR
	NG code	char	Eg SD
	NG east	num	Eg 7521
	NG north	num	Eg 3412
Archaeological classification	Site type	char	As SMR if confirmed by RCHME thesaurus. Enter separate records for different periods on same site
	Period	char	General period only, codify as Box 2
	Form	char	Codify as Box 3
	Formgroup	char	Codify as Box 3
	RCHME class	char	As RCHME thesaurus
Management information	Status	char	As SMR/NMR
	SAM	char	As SMR/NMR
	Land status	char	As SMR/NMR
	Area status	char	As SMR/NMR
	Condition	memo	Free text

Table A3.2 RCHME codes for period

Code	Period	Dates
PR	Prehistoric	PA–IA
PA	Palaeolithic	To 8000 BC
ME	Mesolithic	8000–3800 BC
NE	Neolithic	3600–2500 BC
BA	Bronze Age	2500–700 BC
IA	Iron Age	700 BC–43 AD
RO	Roman	43–410 AD
EM	Early Medieval	410–1066 AD
MD	Medieval	1066–1540 AD
PM	Post Medieval	1540–1901 AD
MO	Modern	1901–present
UN	Unknown	

Table A3.3 Form entry

Type	Term	Form code	Form group
Intact	Roofed building	ROOF	STRUCTURE
	Structure	STRU	
	Machinery	MACH	
	Linear feature	LIN	FEATURE
	Other feature	FEA	
	Underground feature	UFEA	UNDERGROUND
Ruinous	Roofed ruin	RRUIN	RUIN
	Ruined building	RUIN	
	Ruined structure	RSTRU	
	Foundations	FOUN	
	Earthworks	EARTH	EARTHWORK
Buried remains	Crop mark	CROP	CROP/SOIL
	Soil mark	SOIL	
	Aerial photograph	AP	AP
	Geophysical survey	GEO	Not used
	Finds spot	FIND	FIND
Unlocated remains	Documentary	DOC	DOC/ORAL
	Oral	ORAL	
Non-extant	Excavated	EXC	EXC/REM
	Removed	REM	

Table A3.4 Data source totals for calcareous grassland

County	All sites SMR/ NMR	All sites New	Heath SMR/ NMR	Heath New
Beds	13	7		
Berks	16	22		
Bucks	14	17	14	17
Cambs	4	4	4	4
Cleveland	2	4		
Cornwall	213	36		
Cumbria	53	32	12	6
Derbyshire	5	8		
Devon	141	29	9	4
Dorset	44	46	8	15
Durham	6	7	1	
Essex	9	12		2
E Sussex	12	18		
Gloucester	50	15	14	2
Hants	51	46	2	3
Herts	'2		2	
Humberside	28	14		
Isle of Wight	58	27	4	4
Kent	36	16	32	10
Lancs	18	15		
Lincoln	3	2		
Norfolk	110	47		
Northants	14		14	
Northumberland	16	19	10	7
Nottingham	2	5	41	14
N Yorks	65	40	9	2
Oxford	9	2	10	3
Salop	3	16	4	4
Somerset	16	5		
Staffs	20	16		
Suffolk	135	21		
Surrey	14	32		
Tyne & Wear	8	1		
Warwick	4	5		
Wiltshire	29	6	29	6
W Midlands		4		
Worcester	1	1		
W Sussex	28	8		
York Dales	77	11	58	9
Totals	*1329*	*616*	*278*	*120*
	1945		*398*	

Table A3.5 Total number of sites and average per square km, by county for full dataset

County	No. of km squares	SMR/ NMR sites	Enhanced site totals	SMR/ NMR sites km^{-2}	Enhanced sites km^{-2}
Bedfordshire	2	13	20	6.5	10.0
Berkshire	5	16	38	3.2	7.6
Buckinghamshire	4	14	31	3.5	7.8
Cambridgeshire	1	4	8	4.0	8.0
Cleveland	2	2	6	1.0	3.0
Cornwall	13	213	249	16.4	19.2
Cumbria	23	53	85	2.3	3.7
Derbyshire	2	5	13	2.5	6.5
Devon	17	141	170	8.3	10.0
Dorset	12	44	90	3.7	7.5
Durham	4	6	13	1.5	3.3
Essex	7	9	21	1.3	3.0
East Sussex	3	12	30	4.0	10.0
Gloucestershire	6	50	65	8.3	10.8
Hampshire	17	51	97	3.0	5.7
Hertfordshire	1	2	2	2.0	2.0
Humberside	7	28	42	4.0	6.0
Isle of Wight	5	58	85	11.6	17.0
Kent	6	36	52	6.0	8.7
Lancashire	4	18	33	4.5	8.3
Lincolnshire	2	3	5	1.5	2.5
Norfolk	15	110	157	7.3	10.5
Northamptonshire	1	14	14	14	14.0
Northumberland	11	16	35	1.5	3.2
Nottinghamshire	4	2	7	0.5	1.8
North Yorkshire	10	65	105	6.5	10.5
Oxfordshire	2	9	11	4.5	5.5
Shropshire	4	3	19	0.8	4.8
Somerset	3	16	21	5.3	7.0
Staffordshire	6	20	36	3.3	6.0
Suffolk	8	135	156	16.9	19.5
Surrey	5	14	46	2.8	9.2
Tyne & Wear	1	8	9	8.0	9.0
Warwickshire	1	4	9	4.0	9.0
Wiltshire	2	29	35	14.5	17.5
West Midlands	1	0	4	0	4.0
Worcestershire	1	1	2	1.0	2.0
West Sussex	3	28	36	9.3	12.0
Yorkshire Dales	6	77	88	12.8	14.7
Totals	*224*	*1329*	*1945*	*5.9*	*8.7*

Table A3.6 Data source by period

Period	SMR/NMR sites	New sites
A-PR	111	
B-PA	10	
C-ME	32	7
D-NE	36	
E-BA	109	5
F-IA	63	
G-RO	107	3
H-EM	32	
I-MD	151	3
J-PM	384	94
K-MO	18	6
UN	276	498
Totals	*1329*	*616*

Table A3.7 Number of sites and number of sites per square

Data source	Calcareous grassland 89 squares Sites	km^{-2}
SMR only	259	6.2
NMR only	88	2.1
SMR/NMR	278	6.6
New survey	120	2.9
Combined sources	398	9.5

Table A3.8 Quantity of features – site types by period for calcareous grassland (showing site types occurring more than once in the dataset)

RCHME class	Site type	Period	No
Agriculture and subsistence	Agricultural building	J-PM	6
		UN	6
	Farm	UN	20
	Field system	A-PR	2
		C-ME	2
		I-MD	6
		J-PM	3
		UN	12
	Sheep fold	UN	2
	Stack stand	UN	3
	Wood bank	UN	5
Civil	Post Office	J-PM	2
	School	UN	4
Commercial	Inn	UN	3
Defence	Moat	I-MD	3
Domestic	Deserted village	I-MD	2
	Great house	J-PM	3
	House	J-PM	9
	Lodge	UN	2
	Settlement	F-IA	5
		G-RO	3
		I-MD	2
		UN	2
Industrial	Coal mine	J-PM	6
	Gravel pit	UN	2
	Irestone workings	I-MD	2
	Mill	UN	3
	Mine	J-PM	4
	Quarry	J-PM	7
		UN	18
Object	Arrowhead	UN	2
	Axe	E-BA	2
	Coin	F-IA	3
		G-RO	3
	Flint	A-PR	3
	Pottery	E-BA	2
		G-RO	9
Religious, ritual and funerary	Barrow	E-BA	5
		H-EM	3
		UN	5
	Burial	G-RO	3
		UN	3
	Burial cairn	E-BA	2
	Chapel	UN	2
	Church	I-MD	3
		UN	3

RCHME class	Site type	Period	No
Transport	Ford	UN	3
	Mile post	J-PM	3
	Railway	J-PM	6
	Railway bridge	J-PM	2
	Railway station	J-PM	2
	Road	A-PR	2
		G-RO	2
		J-PM	2
		UN	2
	Trackway	UN	4
Unassigned	Boundary	J-PM	3
	Circular feature	UN	2
	Ditch	F-IA	2
	Dyke	UN	2
	Enclosure	C-ME	2
		G-RO	2
		UN	5
	Linear feature	UN	12
	Mound	UN	5
	Ring ditch	UN	6
	Site	UN	4
	Wall	UN	4
Water and drainage	Leat	UN	2
	Pond	I-MD	2
	Reservoir	UN	3
	Weir	UN	3
	Well	UN	5
	Wind pump	UN	2

Appendix 4 Technical appendix to Chapter 7 – Predicting changes in calcareous grassland vegetation

This Appendix includes:
- details of the TRISTAR model
- figures showing the effects of different change scenarios on vegetation within the calcareous grassland mask.

A4.1 Introduction

A4.1.1 The UCPE contribution to the threatened habitats project involves taking vegetational survey data, provided for the selected habitats by ITE, and processing these data in three distinct phases by means of the TRISTAR2 model. After the final phase, the outputs of the modelling are examined and interpreted by UCPE. Each phase in this process will now be described separately, with illustrations given at intervals to provide a worked example.

A4.2 Phase I – allocation of functional types

A4.2.1 The initial steady-state vegetation is specified by ITE in the form of a list of abundances of species in each of many survey samples or records. An example of such data appears in Figure A. The record labelled A1-A is the first in the series and contains 12 species, *Agrostis curtisii* to *Ulex europaeus* inclusive. Each vegetation record arrives at UCPE bearing a classification according to both of two sets of criteria:
- the designated status, if any, of the site from which the record was taken, and
- the plant community type into which the vegetation of the quadrat falls.

The basis for these two classifications is the ITE TWINSPAN analysis which is described elsewhere in this Report.

A4.2.2 For each vegetation record, one of 19 functional types is then allocated to each of the component species using information from UCPE databases. The system used, the C-S-R classification of functional types (Grime 1974, 1979; Grime, Hodgson & Hunt 1988), has been explained in moderate detail by Hunt *et al.* (1991). Briefly, it recognises two external groups of factors, both of which are antagonistic to plant growth. The first group is called *stress* and consists of factors which place prior restrictions on plant production, such as shortages of light, water, carbon dioxide, mineral nutrients, or chronically non-optimal temperatures. The second group, called *disturbance*, causes the partial or total destruction of plant biomass after it has been formed, and includes management factors such as grazing, trampling, mowing and ploughing, and also phenomena such as wind damage, frosting, droughting, soil erosion, acutely non-optimal temperatures and fire.

A4.2.3 When the four permutations of high and low stress against high and low disturbance are examined (Figure B), a different primary strategy type emerges in association with each of the three viable contingencies: *competitors* in the case of minimum stress and minimum disturbance, *stress-tolerators* in the case of maximum stress and minimum disturbance, and *ruderals* in the case of minimum stress and maximum disturbance. The initials of these three 'primary' strategists give the C-S-R model its name. The fourth contingency, that of maximum stress and maximum disturbance, does not support plant life at all. The triangular diagram (Figure B) which emerges from this view of plant life gives the TRISTAR system its name.

A4.2.4 Intermediate types of C-S-R strategy can be identified, each exploiting a different combination of intensity of external stress and disturbance. The positions of any of a wide variety of species (or, by aggregating its component species, of any vegetation type) can thus be displayed on a hexagonal diagram (Figure C) which represents the central zone of the original triangle (Figure B) turned clockwise through 45°. The positions on this diagram can each be identified by means of a C, S, and R co-ordinate on a scale of 1–5 (Figure D), thus facilitating the quantitative treatment of any position within C-S-R space. This can be done for individual species, for individual samples, or for groups of samples. All play a part in the modelling conducted within the threatened habitats project. Plant strategy theory in this form is thus applicable to vegetation systems other than those from which it was derived, and does not rely upon the estimation of specific plant parameters.

A4.2.5 The TRISTAR2 conflates the weighted abundances of up to a maximum of 19 individual functional types which may be present within each sample. This process created weighted abundances for each of seven broader groups of functional types (those shown in bold type in Figure C). These seven groups represent the three extreme corners of the C-S-R triangle ordination, its centre, and its principal intermediate positions. The seven groups are each converted into a two-part numerical code (seen, for example, in the second and third columns of Figure E). The two-part code provides a computational mechanism for representing both 'pure' and intermediate functional types.

A4.2.6 Once converted, the classifications according to functional type provide the basis for all further work on the vegetation sample by TRISTAR2. The first page of the presentation for each habitat (or subhabitat, if appropriate) consists of a divided percentage bar diagram illustrating the functional composition of all the plot classes present in the initial vegetation. Ecological notes on the habitat as a whole appear at this point.

A4.3 Phase II – effects of change scenarios on the abundance of functional types

A4.3.1 The TRISTAR2 model is next provided with various climate change or management scenarios. These have various implications for vegetation because they represent possible changes in environmental stress and disturbance. Initially, eight specimen scenarios were suggested by the project team (Figure F). Although these were all of direct interest to the project, it was felt that sufficient information on habitat sensitivity and resilience could be obtained by applying a smaller number of scenarios (Figure G). These involve only certain of the possible combinations of the two variable factors, environmental disturbance and eutrophication (the latter being defined as a *relaxation* of stress).

A4.3.2 For each factor and functional type within the six specimen scenarios, TRISTAR2 applies an appropriate numerical multiplier according to our understanding of the effects of the factor. The essence of the approach is that seven functional types are each driven by this weighting in different directions and with different gradients, according to information from UCPE's extensive survey and screening databases.

A4.3.3 However, even the six simple scenarios adopted do not always have a simple environmental interpretation. Their value lies in there being a representative group of theoretical changes against which the robustness of different habitats, of different categories of designation, or of different functional types or plant community may be tested. The main difficulty here is that a single scenario condition, such as 'increased eutrophication', may have a multiplicity of meanings. For example, it may literally mean reduced stress, in the sense of a reduced presence of toxic compounds or of a movement away from chronically non-optimal temperatures, or it may mean an enrichment of the environment in the sense of an increased availability of mineral nutrients or an enhancement of CO_2 level. The term 'decreased eutrophication' may have the opposite meaning, and similar arguments apply to 'decreased' or 'increased' levels of disturbance factors such as grazing, trampling, mowing, ploughing, wind damage, frosting, droughting, soil erosion, acutely non-optimal temperatures and fire.

A4.3.4 For these reasons the scenarios listed in Figure G cannot be identified explicitly in terms of *all* the environmental or management changes which they may present. The total number of permutations of scenarios runs into tens of thousands, and even one of the scenario lines in the Table may have very many variants, according to which definitions of disturbance and eutrophication are adopted.

A4.3.5 Nonetheless, each scenario prompts TRISTAR2 to predict a new abundance for each functional type under the new stable state. New percentage abundances for each functional type and designation stratum are calculated for all scenarios.

A4.3.6 For each of six scenarios a Table is computed (but not presented) which groups the predictions for each functional type in each plot classes presenting the habitat (PCA, PCB, etc). TRISTAR2 calculates the predicted change in percentage abundance of each of the seven functional types C, C-R, CSR, R, S, SC and SR relative to the initial composition of each plot class in the habitat. When charted, this analysis form the top left-hand element in the display of predictions for each scenario (pages 105–113).

A4.4 Phase III – computation of an 'index of vulnerability'

A4.4.1 Next, an index of vulnerability is computed for each plot class. This is done in three substages.

i. Examine the original data to find the number of quadrats deviating appreciably from the typical

The mean and standard deviation (SD) of each functional type within each plot class is calculated (the type-mean and type-SD). The mean across all seven type-SDs within each plot class is also derived (the class-type-SD). Each individual quadrat is then examined and the percentage abundance of each of its functional types is compared with the type-mean from the appropriate plot class; the result is expressed as a deviation from the type-mean. The mean of all such deviations for the quadrat is then compared with the class-type-

SD to find which quadrats have mean deviations greater than one unit of SD. Such quadrats are classified as outliers and their number is noted; the remaining quadrats, those within one class-type-SD (the great majority), are classified as typical.

ii. Examine the TRISTAR2 predictions to find the new number of quadrats deviating appreciably from the original composition

In the model prediction the abundances of CSR types within each of the quadrats have often changed. The new abundances are compared with the original class- and type-means and SDs (as in substage (i)). The new counts of typical or outlying quadrats are obtained. Some plot classes may contain more outliers under the new scenario, but others may be more resistant to predicted change, or may even contain fewer outliers (ie be made more typical) in certain instances.

iii. Find the 'index of vulnerability' for each plot class

This is simply the proportional change (on a scale of −1.0 to +1.0) in the number of quadrats identified as 'outliers', in each plot class, found by comparing substages (i) and (ii).

A4.4.2 The index of vulnerability is displayed as a bar diagram for each plot class in the habitat (the top right-hand section of the presentation on pages 105–113). A value of 0.0 in this diagram indicates that no increase or decrease in number of outliers has taken place as a result of the imposition of the scenario in question. If some change has taken place, this is classified as 'decreased' (ie having fewer outlying quadrats, indicating a composition even more typically uniform than before), or 'increased' to a 'low', 'moderate' or 'high' degree (indicating an appropriate amount of departure from typicality) according to the thresholds shown on each diagram. These particular thresholds have no absolute validity in themselves and are provided only as comparative tools. The indices of vulnerability are summarised across all plot classes in a small Table below the diagram. Ecological notes on the effects of the particular scenario within the current habitat conclude the presentation of each scenario.

A4.4.3 Finally, page 114 summarises the mean index of vulnerability across all scenarios for each plot class within the current habitat. Further ecological notes are added at this point. Comparisons between different habitats (or subhabitats) will ultimately be made possible by means of such material.

Figure A. Sample of raw data as received from ITE

Quadrat identifier	Species	Cover (Inner nest)	Cover (Outer nest)
A1-A	*Agrostis curtisii*	5	0
A1-A	*Calluna vulgaris*	10	0
A1-A	*Campylopus* sp.	1	0
A1-A	*Carex pilulifera*	1	0
A1-A	*Erica cinerea*	15	0
A1-A	*Erica tetralix*	10	0
A1-A	*Hypogymnia physodes*	1	0
A1-A	*Leucobryum glaucum*	1	0
A1-A	*Molinia caerulea*	40	0
A1-A	*Potentilla erecta*	1	0
A1-A	*Pteridium aquilinum*	10	0
A1-A	*Ulex europaeus*	1	0
A1-B	*Calluna vulgaris*	95	0
A1-B	*Cladonia impexa*	1	0
A1-B	*Cladonia* sp.	1	0
A1-B	*Erica cinerea*	5	0
A1-B	*Molinia caerulea*	1	0
A1-C	*Agrostis canina canina*	1	0
A1-C	*Agrostis curtisii*	20	0
A1-C	*Molinia caerulea*	35	0
A1-C	*Polygala serpyllifolia*	1	0
A1-C	*Pteridium aquilinum*	90	0
A1-C	*Rubus fruticosus*	1	0
A1-C	*Teucrium scorodonia*	1	0
A1-C	*Ulex europaeus*	1	0
A1-D	*Calluna vulgaris*	95	0
A1-D	*Dicranum scoparium*	1	0
A1-D	*Erica cinerea*	1	0
A1-D	*Hypnum cupressiforme*	1	0
A1-E	*Agrostis curtisii*	1	0
A1-E	*Calluna vulgaris*	5	0
A1-E	*Cephalozia* sp.	1	0
A1-E	*Drosera intermedia*	1	0
A1-E	*Drosera rotundifolia*	5	0
A1-E	*Erica tetralix*	15	0
A1-E	*Eriophorum angustifolium*	1	0
A1-E	*Gymnocolea inflata*	1	0
A1-E	*Juncus bulbosus*	1	0

Figure B. The relationship between stress and disturbance factors and the C-S-R types

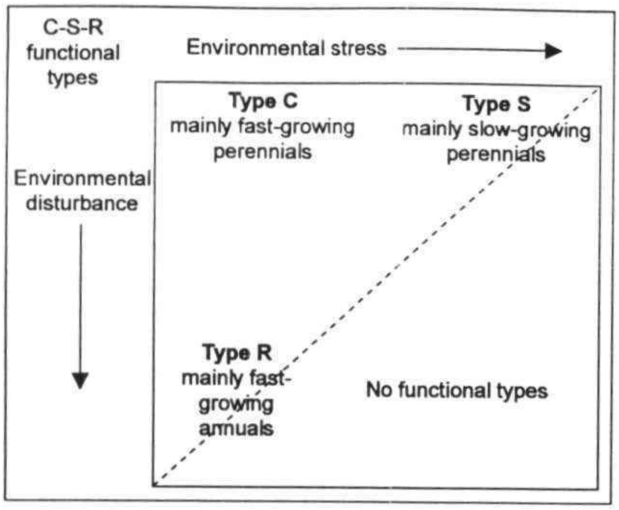


Figure C. The C-S-R triangle ordination showing the three principal functional types and intermediate positions

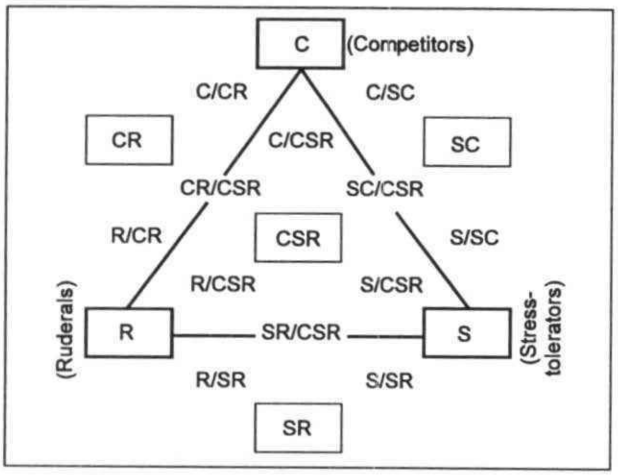


Figure D. C-S-R co-ordinates of functional types

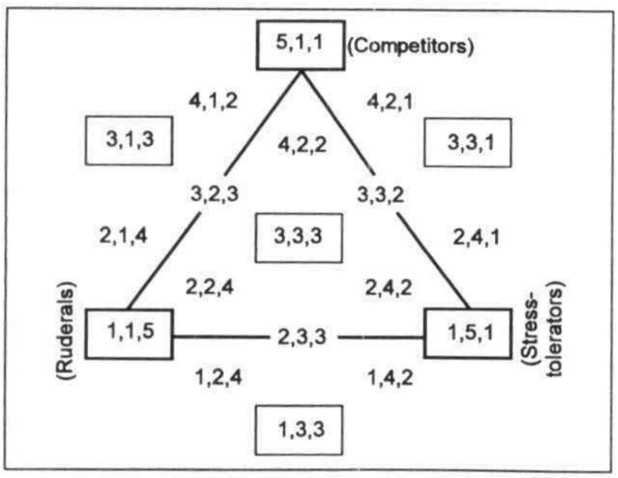


Figure E. Reclassification of species according to functional types

Quadrat identifier	Species	C-S-R classification Part 1	Part 2	Cover
A1-A	*Agrostis curtisii*	5	5	5
A1-A	*Calluna vulgaris*	6	6	10
A1-A	*Campylopus* sp.	7	7	1
A1-A	*Carex pilulifera*	5	5	1
A1-A	*Erica cinerea*	5	6	15
A1-A	*Erica tetralix*	5	6	10
A1-A	*Hypogymnia physodes*	0	0	1
A1-A	*Leucobryum glaucum*	5	5	1
A1-A	*Molinia caerulea*	6	6	40
A1-A	*Potentilla erecta*	3	5	1
A1-A	*Pteridium aquilinum*	1	1	10
A1-A	*Ulex europaeus*	6	6	1
A1-B	*Calluna vulgaris*	6	6	95
A1-B	*Cladonia impexa*	5	5	1
A1-B	*Cladonia* sp.	5	5	1
A1-B	*Erica cinerea*	5	6	5
A1-B	*Molinia caerulea*	6	6	1
A1-C	*Agrostis canina canina*	3	3	1
A1-C	*Agrostis curtisii*	5	5	20
A1-C	*Molinia caerulea*	6	6	35
A1-C	*Polygala serpyllifolia*	5	5	1
A1-C	*Pteridium aquilinum*	1	1	90
A1-C	*Rubus fruticosus*	6	6	1
A1-C	*Teucrium scorodonia*	3	4	1
A1-C	*Ulex europaeus*	6	6	1
A1-D	*Calluna vulgaris*	6	6	95
A1-D	*Dicranum scoparium*	5	5	1
A1-D	*Erica cinerea*	5	6	1
A1-D	*Hypnum cupressiforme*	5	7	1
A1-E	*Agrostis curtisii*	5	5	1
A1-E	*Calluna vulgaris*	6	6	5
A1-E	*Cephalozia* sp.	7	7	1
A1-E	*Drosera intermedia*	5	7	1
A1-E	*Drosera rotundifolia*	3	6	5
A1-E	*Erica tetralix*	5	6	15
A1-E	*Eriophorum angustifolium*	5	6	1
A1-E	*Gymnocolea inflata*	7	7	1
A1-E	*Juncus bulbosus*	3	7	1

Figure F. Eight specimen scenarios

1. An 80% reduction in sulphur emissions
2. A 40% reduction in nitrogen emissions
3. A 10% increase in nitrogen emissions
4. A 3°C increase in temperature, together with
   - 10% extra precipitation
   - 10% less precipitation
5. Reduction of grazing to 50% (where relevant)
6. Removal of land from arable (where relevant)
7. Removal of land from forest (where relevant)

Figure G. Six simplified scenarios used by UCPE

UCPE scenario	Disturbance factor	Eutrophication factor	Example
1	Decreased	The same	Less grazing, trampling, cutting or burning, etc, but resource levels unaltered
2	Decreased	Increased	Less grazing, trampling, cutting or burning, but more resources such as light, water or nutrients
3	The same	Decreased	No change in grazing, trampling, cutting or burning, etc, but fewer resources such as light, water or nutrients
4	The same	Increased	No change in grazing, trampling, cutting or burning, etc, but more resources such as light, water or nutrients
5	Increased	Decreased	More grazing, trampling, cutting or burning, etc, and fewer resources such as light, water or nutrients
6	Increased	Increased	More grazing, trampling, cutting or burning, etc, and more resources such as light, water or nutrients

Baseline [the intial state]

General notes on this habitat

The calcareous landscape plot classes are a large and ecologically heterogeneous grouping which have been subdivided into four groupings:

- **woodland** (plot classes A–D)
- **grassland** (plot classes E–U)
- **acidic vegetation** (plot classes V–BB)
- **maritime** (plot class CC)

The TWINSPAN analysis has not produced an ordered hierarchical classification with respect to habitat variables. One major subdivision, that between 'woodland' and the remainder, can be ascribed to management. However, the separation between 'grassland' and 'acidic vegetation' relates to soil type and within both there is also a wet/dry continuum. The 'maritime' class is too ecologically heterogeneous to provide easy interpretation of the scenarios that will subsequently be described. Saltmarshes may have little in common with other maritime habitats, other than proximity to the sea.

To enable like to be compared with like, the plot classes are placed into three groupings

1. **Woodland** (plot classes A–D) has its own range of management procedures with understorey shading by its woody dominants. Thus, it is a relatively natural grouping (but see plot classes X and Z). Analysis of data from the various scenarios is however difficult because separated analyses have not been carried out on the tree, shrub and herb layers. The three layers will not necessarily respond in the same way to the same scenario. For example, herbs will be considerably more susceptible to most forms of disturbance than mature trees of similar strategic type. A further problem relates to another characteristic group of woodland species not adequately separated by strategy alone, namely vernal herbs. These spring flowers are classified as type SR. They have more or less completed their annual growth cycle before the tree canopy is fully expanded, and are particularly important to the public perception of woodland. Some of Britain's best-loved flowers are woodland vernals (eg bluebell (*Hyacinthoides non-scripta*) and wild daffodil (*Narcissus pseudonarcissus*)). Plot class A (woodland calcareous, eutrophic, often woodland edge) expectedly has the smallest representation of S, a type which, in the context of woodland, is often associated with shade tolerance. Plot class C has most species of SR, and presumably most vernal species.

2. **Grassland (including acid vegetation)** (plot classes E–U) can be subdivided into groups relating to their management on the basis of plant types. Type CSR is the most characteristic of grazed conditions and, on this basis, plot classes K–O and Q are most typical of relatively productive grassland. In semi-natural 'unimproved' **calcareous grassland** (plot classes N, P and T), where stocking rates are lower, there is some replacement of type CSR by S (eg plot classes P and T). The presence of many species of type C, CR and SC indicates low or no management inputs, ie dereliction. Plot classes F and J are extreme examples of abandoned grassland. A high incidence of type R classically is associated with disturbed conditions and TRISTAR analyses assume this relationship. However, the presence of ruderal types is less easy to interpret for grassland habitats. Most ruderals are entirely dependent upon the production of seed for regeneration and flowering shoots tend to be removed by grazing animals. Thus, the presence of ruderals in grassland may paradoxically be most characteristic of derelict conditions. For example, there are more annuals in meadows, which have an unmanaged phase before the hay cut, than in pasture, which is grazed throughout the growing season. However, there are exceptions. A few species, particularly thistles (*Carduus* and *Cirsium*), are protected against most herbivores and the low-growing annual meadow-grass (*Poa annua*) is characteristic of over-grazed conditions. Also, ruderals may originate as a consequence of previous land use practices. If land was formerly under arable cultivation, weeds will appear in short-term leys for many years, even if they are unable to set seed. Their stock will be replenished from the soil seed bank. Thus, the presence of type R in plot classes E and I may relate to disturbance, while in plot class Q it may concern management (mowing), and in plot classes F–H abandonment.

Those classes grouped under **'acidic vegetation' (plot classes V–BB)** are almost by definition 'unimproved'. An early stage in reclaiming the land for intensive agriculture would have been the application of lime. All have low representation of types associated with productive conditions (C, CR, R). Plot classes W and X have the highest proportion of type S, indicative of unproductive conditions, and plot classes AA and BB most SC, indicating low intensities of grazing (perhaps often because of the presence of unpalatable rushes (particularly soft rush (*Juncus effusus*)). Plot class Z is planted with Sitka spruce (*Picea sitchensis*), also type SC.

3. **Maritime habitats** (plot class CC) appear predominantly eutrophic and disturbed, with no representation of type S.

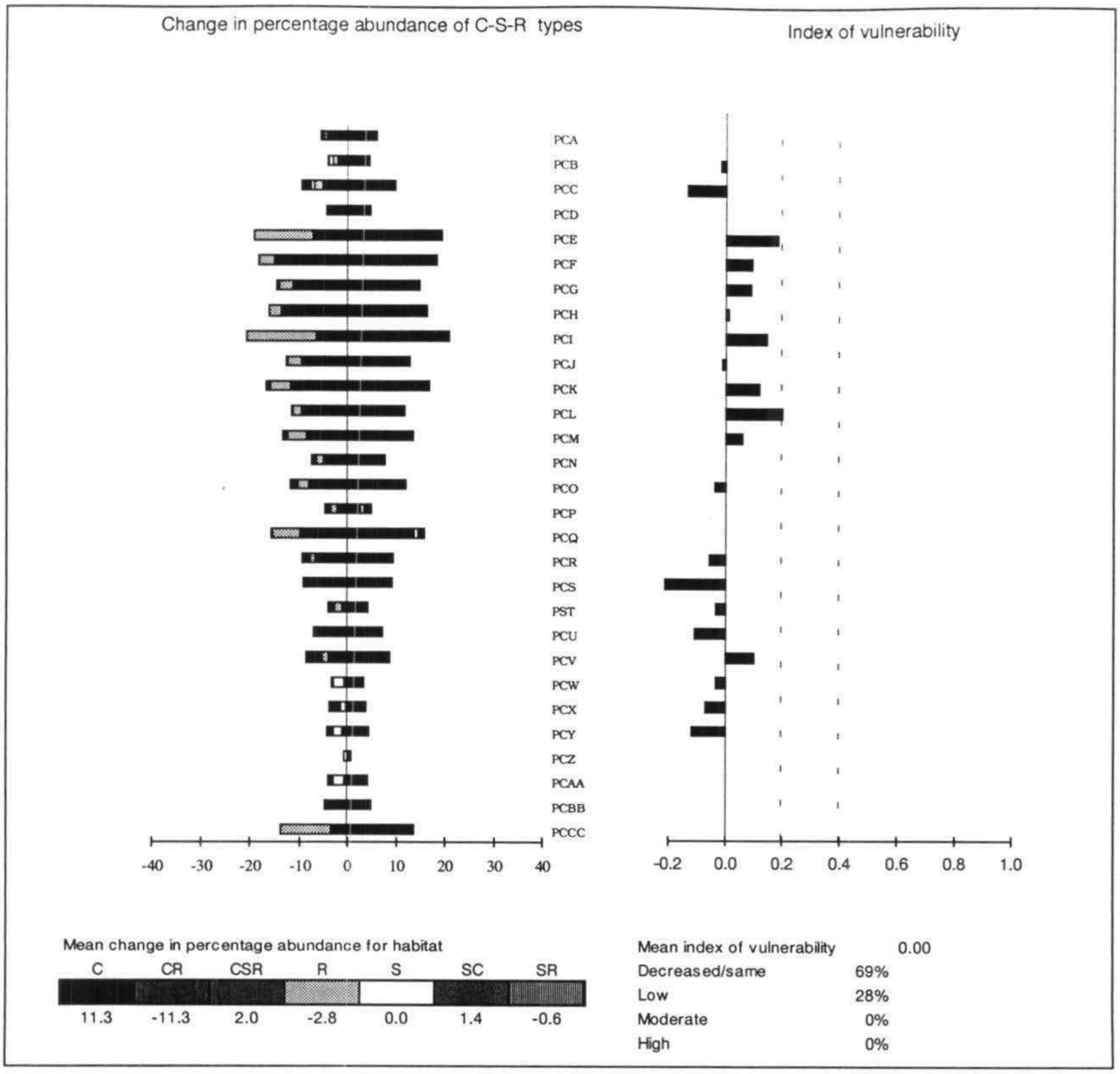
Key species

Sheep's fescue (*Festuca ovina*) and heather (*Calluna vulgaris*) are important constituents of unimproved pasture and heathland respectively

Important invaders

- **Derelict conditions**
  Birch (*Betula péndula, B. pubescens*) and other trees and shrubs
  Bracken (*Pteridium aquilinum*)
  Mat-grass (*Nardus stricta*), tor-grass (*Brachypodium pinnatum*) and other coarse grasses
- **Derelict eutrophicated conditions**
  Gorse (*Ulex europaeus*) – especially in areas which become burnt
  Bramble (*Rubus fruticosus*)
  Stinging nettle (*Urtica dioica*)
  Rosebay willowherb (*Chamaerion angustifolium*) and other tall herbs
  False oat (*Arrhenatherum elatius*) and other coarse grasses
  In wet areas
    soft rush (*Juncus effusus*)
    tufted hair-grass (*Deschampsia cespitosa*)
  In salt marshes
    cord-grass (*Spartina anglica*)

Scenario 1 – [Disturbance decreased; eutrophication the same]

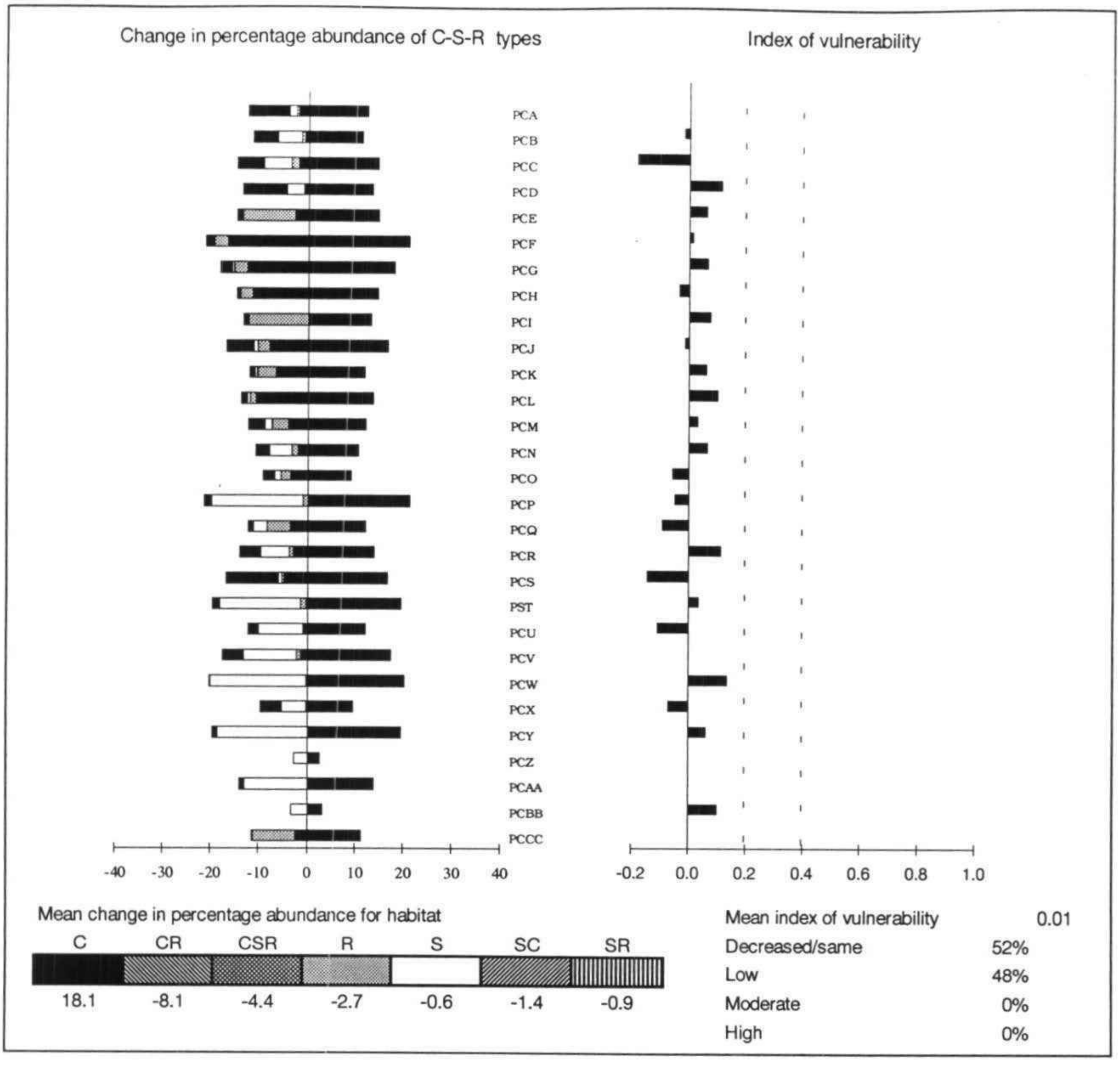


Possible causes of this scenario

- **Woodland** – *decreased disturbance* – no tree thinning [in heathy areas a reduced incidence of fires]
- **Grassland (including acid vegetation)** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires
- **Maritime** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, introduction of barrage schemes; deposition of mud and silt will ultimately reduce the disturbance effects of tidal movements

In **woodland** (plot classes A–D) only a small change is predicted by the model. This accords with expectations from ecological theory. Floristic and strategic composition is strongly influenced by the dominants of the system, ie trees. Most trees are of type SC and will change little. However, slightly increased shade and greater litter production are likely. This would tend to suppress further the herb layer and could even encourage species of type S. In **grassland** (plot classes E–CC) there are on average greater shifts in functional type. In the more eutrophic classes (eg plot classes E–L and S), a denser taller sward would be expected and, consistent with this, there are increases in types C and CSR at the expense of shorter-lived more ruderal types. However, in less productive grassland, particularly **'unimproved' calcareous grassland** and **acidic vegetation,** growth rates are slower and smaller changes are expected. Because of the lower productivity, type SC rather than C is a major beneficiary of dereliction. Paradoxically, reduced disturbance from land use activities could, in unproductive situations, eventually result in episodes of increased disturbance. An increase in above-ground biomass is predicted and, in the event of fire, a greater quantity of combustible material would be present. The greater heat of any ensuing fire may cause greater mortality, opening up larger areas for recolonisation than would otherwise be the case. Even **wet heaths** and **bogs** (plot classes AA and BB) may become more vulnerable to fire. Associated with the increased biomass will be increased water loss through transpiration. The colonisation of wetlands by trees can substantially reduce the water table. As biomass increases, more soil nutrients will be lost to the plant. For **maritime habitats,** which are eutrophic, a similar change to that for productive grassland is predicted, namely an increase in types C and CSR. However, it is important to take into account that reduced disturbance may result from either a relaxation in land management (eg grazing) or an abatement of natural processes (erosion and sedimentation), or a combination of the two. The values for index of vulnerability are low. This indicates that short-term impacts on the strategic composition of the vegetation will be slight.

Scenario 2 – [Disturbance decreased; eutrophication increased]

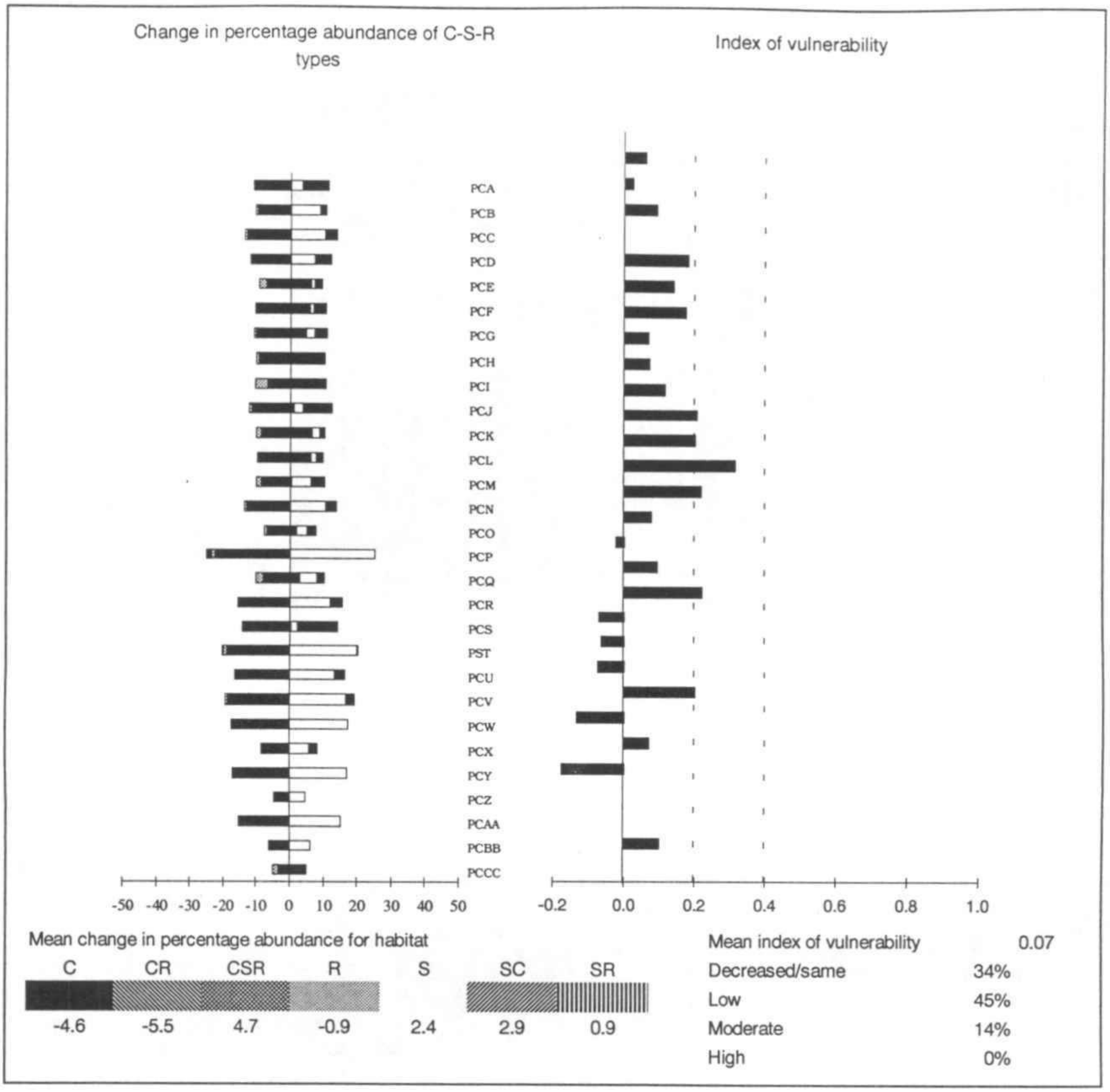


Possible causes of this scenario

- **Woodland** – *decreased disturbance* – no tree thinning [in heathy areas a reduced incidence of fires]; *increased eutrophication* – fertilizer runoff or atmospheric deposition
- **Grassland (including acid vegetation)** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires; *increased eutrophication* – fertilizer runoff or atmospheric deposition
- **Maritime** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, introduction of barrage schemes; deposition of mud and silt will ultimately reduce the disturbance effects of tidal movements; *increased eutrophication* – fertilizer runoff or atmospheric deposition, for strand line communities severe winter storms leading to increased deposition of seaweed, etc

Increased eutrophication in combination with decreased disturbance will have a greater and more rapid impact on the distribution of functional types than that exhibited in the previous scenario (disturbance decreased; eutrophication same). The vegetation should become taller and faster-growing and overall losses of types S and ruderals and an increased representation by type C are predicted. The reality for **woodland** (plot classes A–D) is likely to be somewhat different. Floristic and strategic composition is strongly influenced by the dominants of the system, ie trees. Most trees are of type SC and therefore the predicted losses within class SC are unlikely to happen. However, increased shade and litter production are likely. This would tend to suppress further the herb layer. **Grassland** (plot classes E–BB) conforms rather better than woodland to this general pattern. The more eutrophic classes (eg plot classes E–L and S) will produce the densest tallest sward and, consistent with this, there are increases in type C. However, in less productive grassland, particularly **'unimproved' calcareous grassland** and **acidic vegetation,** growth rates will be slower and shifts to class CSR are expected. For eutrophic **maritime habitats,** again an increase in type C is predicted. Even if natural processes (erosion and sedimentation) restrict the impact of this class, sites should be more strongly vegetated. Eutrophication should encourage rapid recovery following disturbance. The values for index of vulnerability are low. This indicates that short-term impacts on the strategic composition of the vegetation will be slight.

Scenario 3 – [Disturbance same; eutrophication decreased]

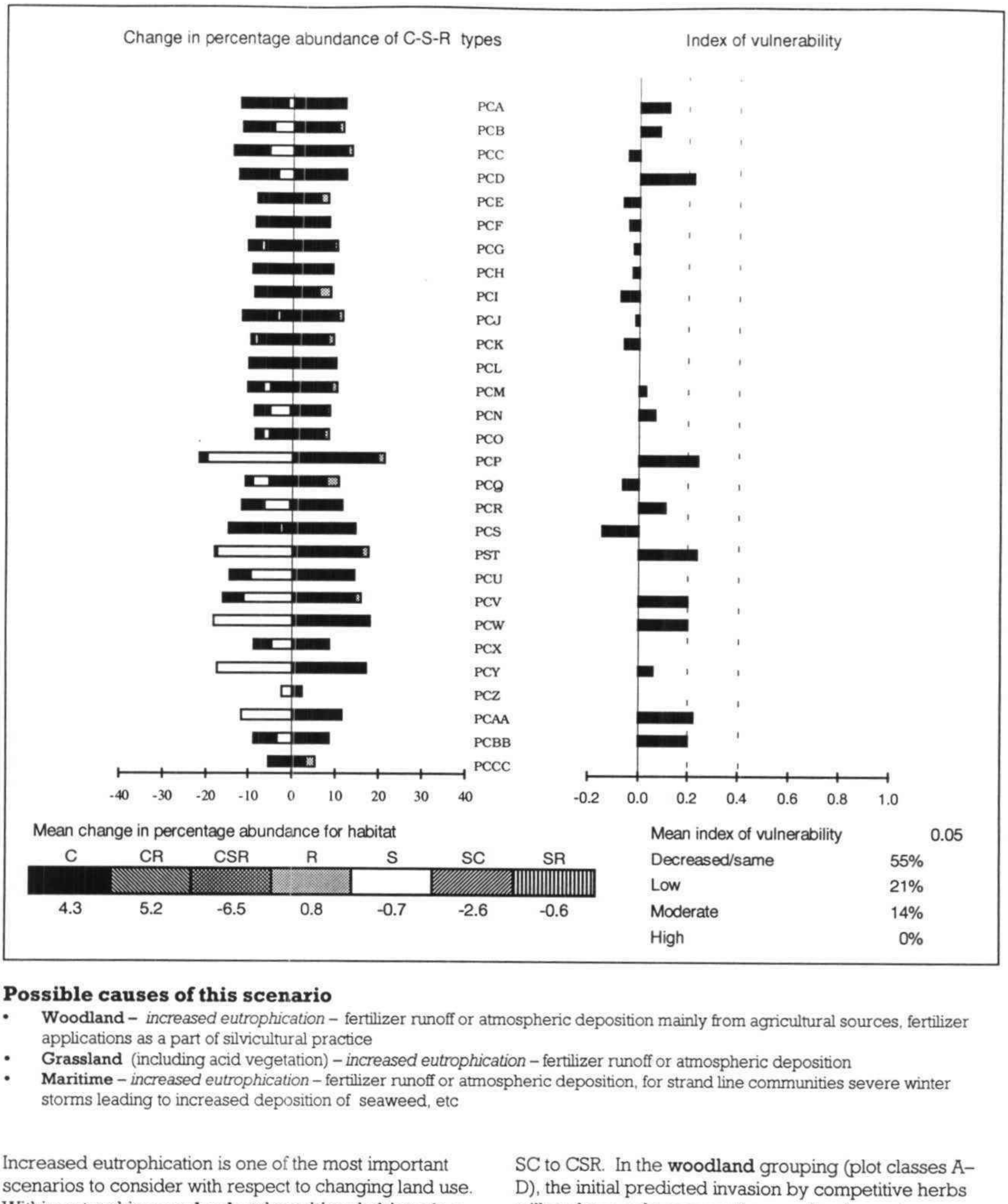


Possible causes of this scenario

- **Woodland** – *decreased eutrophication* – potentially a natural consequence of woodland ageing; the soil becomes progressively depleted of nutrients as the tree biomass increases
- **Grassland (including acid vegetation)** – *decreased eutrophication* – decreased usage of or pollution from fertilizers
- **Maritime** – *decreased eutrophication* – decreased usage of or pollution from fertilizers; decreased deposition of nutrient-laden mud and silt

Like the previous scenario (disturbance decreased; eutrophication increased) large changes are forecast, with increases in types S and SC and decreasing C, CR and R. However, an increase in the main beneficiary, type S, which grows very slowly, will take considerably longer and results may be less marked than predicted. Many species of type S do not form a persistent bank of seeds in the soil or exhibit long-distance dispersal. Thus, some sites in plot classes where type S is poorly represented (eg plot classes F and I) may fail to be colonised by type S. **Grassland** (plot classes E–BB) and **maritime** (plot classes CC) are expected to conform to this general pattern. In less productive grassland, particularly **'unimproved' calcareous grassland** and **acidic vegetation,** growth rates will already be slow and a major shift to class S is expected. However, the more eutrophic classes (eg plot classes E–L, S and CC) start with a high nutrient status and will therefore not reach such low levels of productivity. For this reason, greater increases in types SC and CSR than in type S are generally predicted. In practice, the decreased eutrophication in **maritime habitats** is rarely likely to occur. Impacts on the **woodland** grouping (plot classes A–D) are difficult to predict. The predictions given are probably incorrect because the canopy and herb layer were not separated prior to the analysis. If growth of the tree canopy is reduced, an increase in the biomass of the ground flora is possible. Because the nutrient demands of small fast-growing herbs may well be less than those of large slow-growing trees, increasing types could even include type C. Most values for index of vulnerability are low. This indicates that short-term impacts on the strategic composition of the vegetation will be slight.

Scenario 4 – [Disturbance the same; eutrophication increased]

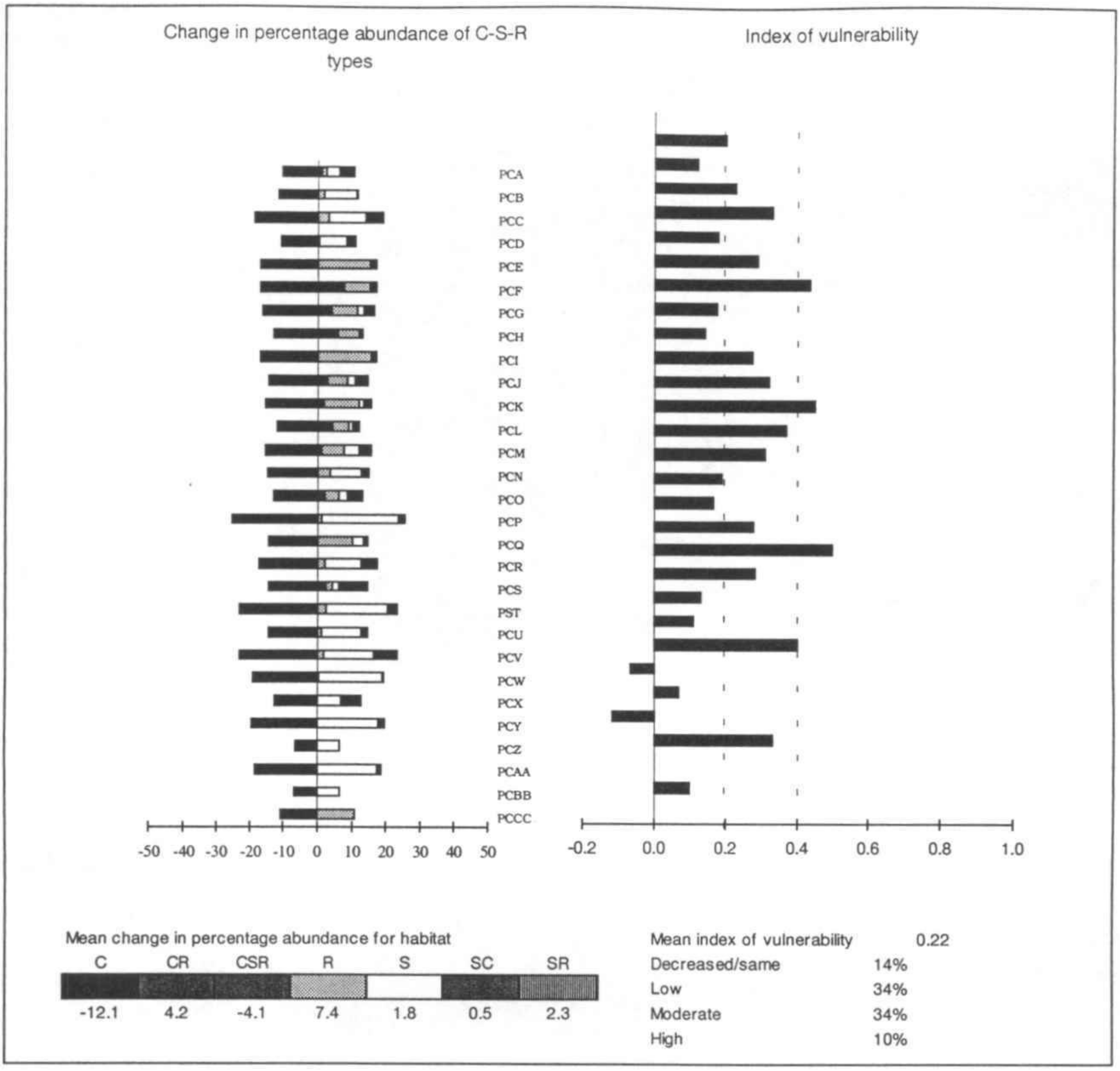


Possible causes of this scenario

- **Woodland** – *increased eutrophication* – fertilizer runoff or atmospheric deposition mainly from agricultural sources, fertilizer applications as a part of silvicultural practice
- **Grassland** (including acid vegetation) – *increased eutrophication* – fertilizer runoff or atmospheric deposition
- **Maritime** – *increased eutrophication* – fertilizer runoff or atmospheric deposition, for strand line communities severe winter storms leading to increased deposition of seaweed, etc

Increased eutrophication is one of the most important scenarios to consider with respect to changing land use. Within eutrophic **grassland** and **maritime** habitats (eg plot classes E–L, S and CC), where many species are fast-growing, rapid changes are predicted with a decrease in CSR and SC types and an increase in C and CR. However, the decreased eutrophication in **maritime habitats** is rarely likely to occur. In less productive grassland, particularly **'unimproved' calcareous grassland** and **acidic vegetation,** growth rates are slower and the predicted shift is more from class S and SC to CSR. In the **woodland** grouping (plot classes A–D), the initial predicted invasion by competitive herbs will perhaps only occur at the woodland margin. Increased eutrophication may increase tree growth and shade. This would reduce the cover of ground flora species of all functional types, except perhaps type S. The relatively low values for index of vulnerability indicate that short-term impacts on the strategic composition of the vegetation will be small in most plot classes. However, some less productive plot classes appear moderately vulnerable.

Scenario 5 – [Disturbance increased; eutrophication decreased]



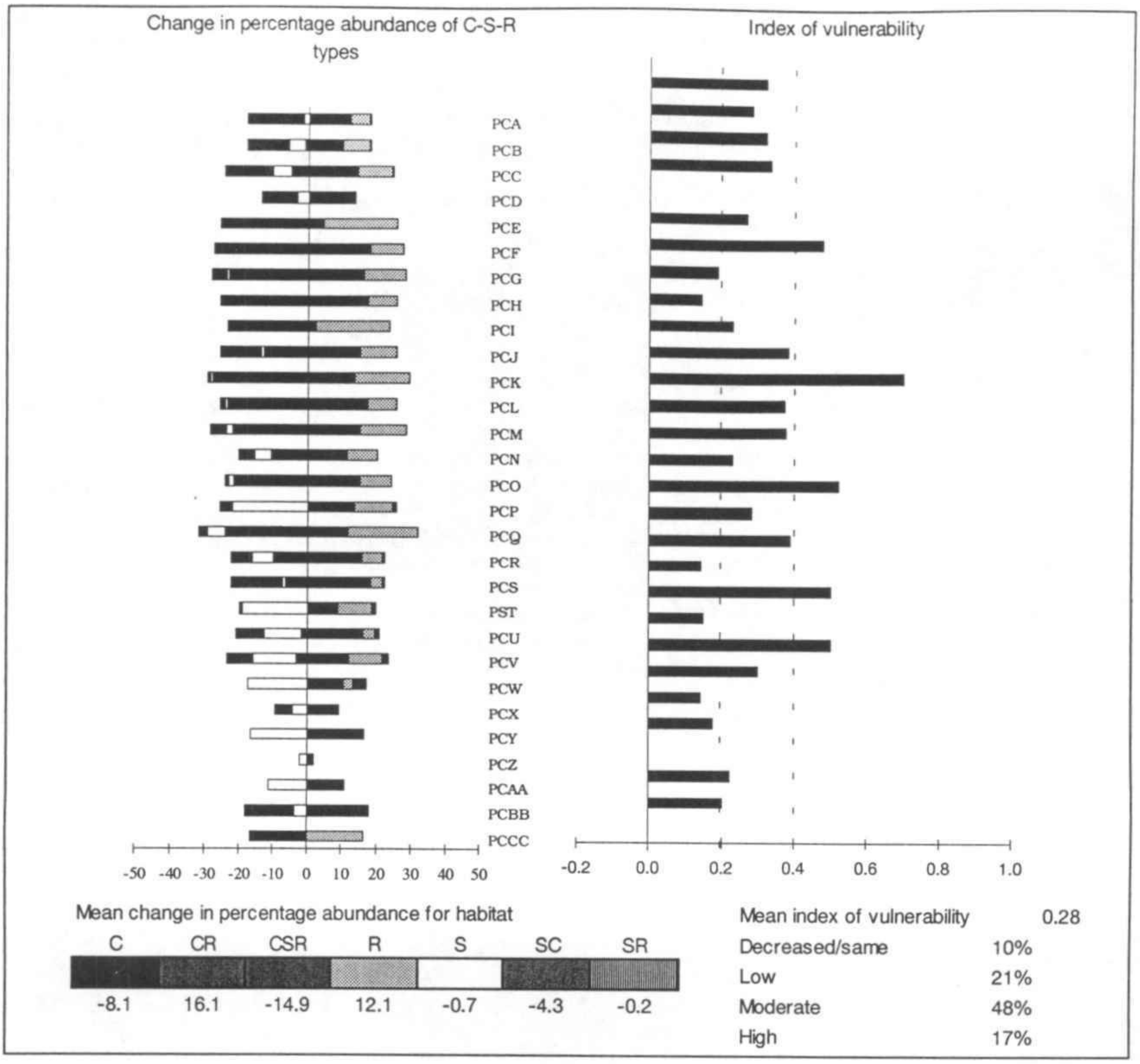
Possible causes of this scenario

- **Woodland** – *increased disturbance* – tree thinning, incidence of fire (discouraged during forestry practice); *decreased eutrophication* – less fertilizer runoff or atmospheric deposition mainly from agricultural sources, less fertilizer added as a part of silvicultural practice or more leaching
- **Grassland** – *increased disturbance* – increased grazing or cutting, reduced incidence of fires, increased recreational pressure; *decreased eutrophication* – less fertilizer runoff or atmospheric deposition
- **Maritime** – *increased disturbance* – increased grazing or cutting, increased recreational pressure, increased deposition of mud and silt or erosion; *decreased eutrophication* – less fertilizer runoff or atmospheric deposition, for strand line communities less severe winter storms leading to reduced deposition of seaweed, etc

Increased disturbance coupled with decreased eutrophication will have a major impact on the composition with respect to functional types. Impacts of increased disturbance will be rapid in eutrophic grassland and **maritime** habitats (eg plot classes E–L, S and CC). Damage to perennial species should allow the spread of types R and CR species. However, if disturbance is of regular occurrence (eg grazing) rather than intermittent (eg ploughing), these types will be less favoured because seed production will be impaired. Under these circumstances, perennial species of type CR and type CSR will be favoured. Unfortunately, TRISTAR does not distinguish these effects of low-level disturbance over long periods from more severe but punctuated episodes of disturbance. This difference is less important in less productive grassland, particularly **'unimproved' calcareous grassland** and **acidic vegetation** where opportunities for species with short life cycles are more restricted. Type SR, the main beneficiary of disturbance, is likely to consist of low-growing and generally unpalatable bryophytes. The main impact of decreased eutrophication should be an increase in type S. However, this type grows very slowly and changes will also be correspondingly slow. Indeed, in some of the more productive systems (eg plot classes E and BB), the initially more productive **grassland** grouping (eg plot classes E–L and CC) may eventually become more vulnerable to fires because more persistent litter will be formed. Other less productive classes (eg **'unimproved' calcareous grassland** and **acidic vegetation**) will become less fire-prone because of reduced above-ground biomass. There could also be a reduction in transpirational water loss leading to a slightly increased water table. The changes affecting the **woodland** grouping (plot classes A–D) are difficult to predict. Increased disturbance coupled with decreased eutrophication will reduce the density of the tree canopy. The extent to which the lower strata can respond to the decreased shading will depend on the severity of the nutrient stress imposed and on whether disturbance directly affects all strata. If it does, the predicted increase in type SR will probably be realised through an expansion in bryophytes. Less severe scenarios may encourage the expansion of all functional types in the ground layer. The values for index of vulnerability show a wide range of susceptibilities. Greatest vulnerability is shown by some of the more eutrophic plot classes.

NB This scenario assumes only modest changes in disturbance and eutrophication. Under conditions both of high stress (which permits only slow growth) and of high disturbance (where recovery necessitates rapid growth), no plant species can survive. This combination of high stress and high disturbance is characteristic of many areas of 'open country' suffering problems of recreational damage (eg the Pennine Way).

Scenario 6 – [Disturbance increased; eutrophication increased]



Possible causes of this scenario

- **Woodland** – *increased disturbance* – tree thinning, reduced incidence of fires (a normal component of forestry practice); *increased eutrophication* – fertilizer runoff or atmospheric deposition mainly from agricultural sources, fertilizer applications as a part of silvicultural practice
- **Grassland (including acid vegetation)** – *increased disturbance* – increased incidence of fires, more grazing, more recreational pressure; *increased eutrophication* – fertilizer runoff or atmospheric deposition
- **Maritime** – *increased disturbance* – increased grazing or cutting, increased recreational pressure, increased deposition of mud and silt or erosion; *increased eutrophication* – fertilizer runoff or atmospheric deposition, for strandline communities severe winter storms leading to increased deposition of seaweed, etc

The combination of increased eutrophication and increased disturbance, which is a very common impact upon the British landscape, will have major impacts on the composition with respect to functional types. For eutrophic **grassland** and **maritime** habitats (eg plot classes E–L, S and CC), these impacts will particularly involve losses of C, SC and CSR type species and an increase in types R and CR. However, in less productive grassland, particularly **'unimproved' calcareous grassland** and **acidic vegetation,** greatest losses of type S are predicted. There will be fewer fires because of the reduced biomass and less persistent litter associated with this scenario. In the **woodland** grouping (plot classes A–D), this combination of events may result in periods with a relatively open canopy immediately following disturbance but with rapid recovery because of eutrophication. Under these circumstances, fast–growing species of type C, CR and R might be encouraged, particularly if these species had good dispersal in space (numerous, wind-dispersed seeds or spores) and/or in time (a persistent seed bank in the soil). Over half of the classes have at least moderate values for index of vulnerability. Plot class E, which is already eutrophic and disturbed, shows least vulnerability, and those plot classes associated with tall little-managed vegetation (plot classes G and L) and with unproductive conditions (plot classes P, T and V) exhibit the greatest vulnerability. Long-term impacts on the composition of the vegetation with respect to both functional types and individual species will be large and difficult to reverse. The worst 'losers', type S, occupy a shrinking proportion of the British countryside and many are not very mobile.

Index of vulnerability

'Calcareous grassland' includes a heterogeneous grouping of calcareous grassland, other grassland types and woodland. However, most of the individual vegetation types are relatively unproductive, and ecological theory would suggest that these classes would be relatively unresponsive, at least in the shorter term, to minor changes in land management. This is borne out by the modelling results: only a handful of classes reach 'moderate' vulnerability to change. However, the index of vulnerability differs markedly between scenarios. The most extreme scenario appears to be 'increased disturbance and eutrophication', with three plot classes showing high vulnerability.

The impact to the various scenarios can be summarised as follows.

Low impacts

('Disturbance – decreased; Eutrophication – same'< 'Disturbance – decreased; Eutrophication – increased'<'Disturbance – same; Eutrophication – increased'<'Disturbance – same; Eutrophication – decreased')

Moderate impacts

('Disturbance – increased; Eutrophication – decreased'< 'Disturbance – increased; Eutrophication – increased')

Although the differences between habitat groupings are relatively slight, some of the coarser and taller grassland classes appear to be among the most vulnerable (eg PCD – tall, coarse grassland, open; PCJ – neutral/basiphilous grassland, tall with herbs; PCQ – neutral grassland, unimproved, light/no grazing, some shading; and PCV – acid grassland, often rushy). Other, wetter grassland classes such as PCR (marsh/rushy pasture), PCU (northern, damp pasture, often with flushes) and PCY (moorland grass, often moist) are under very little threat. The core calcareous grassland and woodland classes occupy an intermediate position. However, vulnerability differs markedly according to scenario. For example, PCJ (neutral/basiphilous grassland, tall with herbs) is under the greatest threat of all under scenario 6 (disturbance increased; eutrophication increased) but has a very low vulnerability score under scenario 4 (disturbance same; eutrophication increased). It is therefore important in all predictions to match exactly match the plot class with the scenario.