Department of the Environment

Current status and prospects for threatened habitats in England

Part 3

Upland landscapes

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

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Part 3

Upland landscapes

Edited by

C J Barr

Institute of Terrestrial Ecology
Merlewood Research Station
Grange over Sands
Cumbria LA11 6JU

This Report is one of a series describing work on threatened habitats commissioned by the Department of the Environment. Views expressed in it do not necessarily concide with those of the Department.

CONTRACT

No. CR0 102

1996

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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 the uplands 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 examination 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 upland landscape type. The broad geographical extent of the existing upland areas was determined by reference to the ITE Land Classification. The resulting database of 1 km squares was called the 'upland mask'.

3. The next step was to characterise the upland mask in terms of ecology, landscape features and archaeology. The 1 km squares were stratified according to land type (true or marginal upland) and designation status (designated or non-designated). Squares in these four strata were than 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. The upland mask comprised a range of vegetation types from wet heath and bogs, through heather moorland, to vegetation dominated by grass or scrub; 57% of the mask was covered by 'core' upland vegetation types and 81% of the upland mask contained one or more designation type. Nearly all core upland vegetation types were designated, and the undesignated areas were dominated by coniferous plantations.

5. In addition to the core upland vegetation, areas of modified neutral/improved grassland, agricultural crops and woodland/scrub were recorded; 80% of the woodland recorded throughout the upland landscape was conifers or mixed woodland.

	Area (ha)
Core upland vegetation types	890 100
Other vegetation types	671 500
Upland mask	1 561 600

6. Objective measures of vegetation (recorded in quadrats) have been related to quality criteria, to provide an empirical evaluation of the quality of upland vegetation in different parts of the upland landscape. Using at least two separate measures of each of the quality criteria, the four survey strata were ranked. Based on quadrat information, the designated true upland stratum ranked highest for most measures (12 out of 17) and the non-designated true upland stratum ranked higher than the marginal upland strata. This suggests that the quality of upland vegetation is higher in the true upland than in the marginal upland, irrespective of designation status.

7. From examination of historic records, the upland mask was shown to contain features from most periods of history, except the Early Medieval. There appeared to be no correlation between density of features and designation status.

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 upland habitat and some form of designation were because the designation had been effective, or whether the designation was made because of the quality of the upland vegetation. However, this study provides for the first time an essential baseline, necessary to conduct future monitoring of the effectiveness of designations.

Threats

9. Upland habitats are found on a range of soil types, typically being acid and wet with a low weathering rate in areas which are particularly vulnerable to the acidifying effects of acid deposition. During the period 1989–91, 95% of all areas within the upland mask was in exceeded areas (ie where the pollutant deposition exceeds the weathering rate of the soil). In contrast, in lowland England as a whole, the soil critical load of acidity was exceeded in 57% of the total area.

10. Current emission reduction scenarios appear to be relatively ineffective at protecting the upland habitat areas of England. There is insufficient quantitative information on the effects of sulphur deposition on upland fauna and flora to be certain of how damaging these exceedances will be to upland ecosystems as a whole.

11. Average atmospheric deposition of nitrogen (NO_x and NH_x) in upland areas is 26 kg nitrogen ha^{-1} yr^{-1}, which is greater than that received by other parts of England (19 kg nitrogen ha^{-1} yr^{-1}). Upland designated squares are more likely to be receiving over 20 kg nitrogen ha^{-1} yr^{-1} compared to upland non-designated squares.

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 uplands in Britain. However, experimental results from grasslands on peat soils elsewhere suggest that the rates of atmospheric N will have a significant effect on community composition in the uplands, with gradual nutrient enrichment leading to a loss of plant species diversity and a transition from heather moorland to grass.

13. Other threats to upland include:
    - over-grazing causing loss of dwarf shrubs in favour of species-poor grassland;
    - reduced burning regimes which lead to scrub encroachment;
    - drying out;
    - ploughing for agricultural improvement and afforestation;
    - eutrophication resulting from application of fertilizers on improved grasslands; and
    - recreational use.

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' upland vegetation is composed of stress-tolerator and stress-tolerator/competitor 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 a range of scenarios chosen to simulate the combined effects of grazing pressure, pollution, eutrophication and climatic warming, and an index of vulnerability was produced. The uplands consist of a heterogeneous grouping of heather moorland, bogs, upland grassland and woodland vegetation, all of which are relatively unproductive. The ecological hypothesis that such vegetation is likely to be resilient to changes in environmental conditions, at least in the short term, is supported by the results, with only a small number of classes of vegetation, in particular enriched flushes, wet heath and limestone grassland, reaching 'moderate' vulnerability.

17. The uplands comprise a valuable landscape, dominated by a non-climax vegetation type maintained by agricultural and sporting management practices. Because the vegetation is non-climax, intervention is required to prevent habitat such as moorland turning into scrub/woodland; these habitats therefore require management to maintain their condition. The survey results indicate that, of the area within the upland landscape (15 616 km^2), about 881 000 ha is upland heath and grassland and about 160 000 ha is woodland.

18 Working from the *Biodiversity Action Plan* draft objectives as a starting point, it would appear feasible to establish the following objectives:
    - to protect and maximise habitats which are rare within a European context; in

uplands rare habitats include flushes, montane features, cliffs and raised mires which should be protected through designation and specific conservation measures;

- to maintain and enhance existing upland habitats, by improving management of wider heather moorland and grassland by the promotion of sustainable agricultural management, and by active management for restoration of low-dominance heather moorland;
- to remedy existing damaging activities such as drainage;
- to restore or re-create former upland heath by removing improved grassland or Sitka spruce (*Picea sitchensis*) plantations.

19. 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 and implementing re-creation on Forestry Commission land.

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 the uplands 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 up-to-date information on general changes

Box 1.1

In the context of this project, the upland **landscape type** is a conceptual term for geographical area(s) in which upland habitats occur (which, in a GB-wide context, might include land at low altitudes in north-west Scotland). The **mask** is a cartographic term which, in this project, is a map of 1 km squares, some of which may include both upland and lowland areas. Individual **habitats**, such as moorland, woodland and other upland, occur within the landscape type.

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 upland 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 in Figure 1.1.

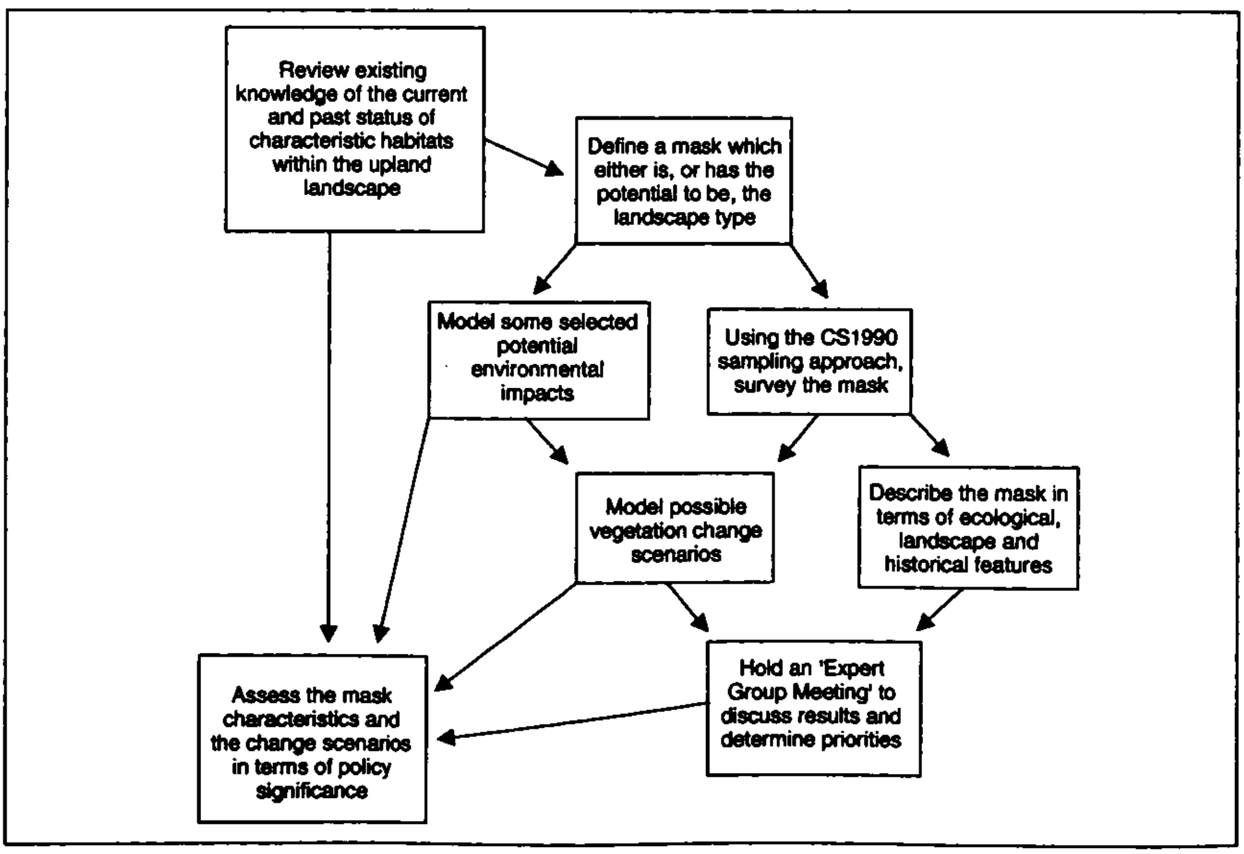


Figure 1.1 General approach used by the research team

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 THE UPLANDS

2.1 Introduction

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

2.2 The uplands – a general definition

2.2.1 The English uplands are areas of low-growing vegetation and peat found at higher altitudes. They comprise a diverse blend of fell, moor, meadow, pasture, river, wood and settlement. The uplands can be divided into marginal uplands – which are those found on the lower slopes and tend to be used more intensely for agriculture, forestry and housing development – and the true uplands, which are the higher, more barren wilderness areas. Within England, uplands are found mainly in the north of the country, running from Northumberland to the Midlands (Lake District, Pennines, Cheviots and North York Moors). They are also found in the south and west in smaller blocks, principally Dartmoor, Exmoor and the Shopshire hills. Although geographically dispersed, all upland areas have certain features in common. They receive high levels of rainfall, often leading to waterlogged soils, and the dominant vegetation is heather (*Calluna vulgaris*) and grass moor over peaty soils. Many of the uplands are included within National Parks; very little of the true uplands has not been designated, and much of the rest has been planted with conifers. The most common forms of designation in the true uplands are National Parks and Areas of Outstanding Natural Beauty. Chapter 4 looks at the occurrence of designations in greater detail.

2.3 The uplands as an ecological resource

2.3.1 The most widespread vegetation types in the English uplands are dominated by low-growing grasses, dwarf shrubs or mosses. Open scrub dominated by hawthorn (*Crataegus monogyna*) may occur, as may bracken (*Pteridium aquilinum*). On drier soils these open vegetation types can be grouped under the broad heading of moorlands, and they are gradually replaced by mire vegetation types, especially blanket bog, with increasing soil wetness.

2.3.2 Moorlands may be dominated by dwarf ericaceous shrubs, in which case they are classified as heaths, or by grasses (grasslands), and some are intermediate in character. Upland heaths have much in common with lowland heaths, and differ from them principally in having peaty rather than mineral soils. A wider range of ericaceous shrubs are present than on lowland heaths, although heather is the most important species in both. Other important species include bilberry

Table 2.1 Upland communities in the National Vegetation Classification

Wet	M7	*Carex curta–Spaghnum russowii* mire	Moor House: Cumbria
	M8	*Carex rostrata–Sphagnum warnstorfii* mire	Moor House: Cumbria
	M10	*Pingiuculo–Caricetum dioicae* mire	Lake District, Pennines
	M11	*Carici–Saxifragetum aizoides* mire	Lake District
	M15	*Scirpus cespitosus–Erica tetralix* wet heath	Dartmoor
	M17	*Scirpus cespitosus–Eriophorum vaginatum* blanket mire	Dartmoor, Bodmin
	M19	*Calluna vulgaris–Eriophorum vaginatum* blanket mire	Pennines
	M20	*Eriophorum vaginatum* blanket mire	Southern Pennines
	M26	*Molinea caerulea–Crepis paludosa* mire	Malham Tarn: Yorks
	M31	*Sphagno–Anthelietum julaceae* sping	Lake District
	M32	*Philonoto–Saxifragetum stellaris* spring	Lake Distict, Pennines
	M35	*Ranunculus omiophyllus–Montia fontana* rill	Dartmoor
	M37	*Cratoneuron commutatum–Festuca rubra* spring	Lake District, Teesdale
	M38	*Cratoneuron commutatum–Carex nigra* spring	Upper Teesdale
Wood	W9	*Fraxinux excelsior–Acer campestre–Mercurialis perennis* woodland	Yorks Dales, Pennines
	W11	*Quercus petraea–Betula pubescens–Oxalis acetosella* woodland	Lake District
	W17	*Quercus petraea–Betula pubescens–Dicranum majus* woodland	Dartmoor
	W19	*Juniperus communis* ssp. *communis–Oxalis acetosella* woodland	Teesdale
	W20	*Salix lapponum–Luzula sylvatica* scrub	Lake District
Rock	CG9	*Sesleria albicans–Galium sterneri* grassland	North Pennines
	CG14	*Dryas octopetala–Silene acaulis* ledge community	Lake District
	U7	*Nardus stricta–Carex bigelowii* grass-heath	Lake District
	U10	*Carex bigelowii–Rhacomitrium lanuginosum* moss-heath	L District, N Pennines
	U15	*Saxifraga aizoides–Alchemilla glabra* banks	Lake District
	U16	*Luzula sylvatica–Vaccinium myrtillus* tall-herb community	L District, Cheviots
	U17	*Luzula sylvatica–Geum rivale* tall-herb community	L District, N Wales
	U19	*Thelypteris limbosperma–Blechnum spicant* community	Upper Teesdale
	U21	*Cryptogramma crispa–Deschampsia flexuosa* community	Pennines, Lake District
Heath	H10	*Calluna vulgaris–Erica cinerea* heath	Lake District
	H12	*Calluna vulgaris–Vaccinium myrtillus* heath	North Yorkshire Moors
	H13	*Calluna vulgaris–Cladonia arbuscula* heath	Skiddaw: Lake District
	H18	*Vaccinium myrtillus–Deschampsia flexuosa* heath	Pennines, Lake District
	H19	*Vaccinium myrtillus–Cladonia arbuscula* heath	Skiddaw: Lake District
	H21	*Calluna vulgaris–Vaccinium myrtillus–Sphagnum capillifolium* heath	Lake District
Grass	CG10	*Festuca ovina–Agrostis capillaris–Thymus praecox* grassland	N Pennines, Cheviots
	CG11	*Festuca ovina–Agrostis capillaris–Alchemilla alpina* grass heath	Lake District
	U3	*Agrostis curtisii* grassland	Exmoor, Dartmoor
	U4	*Festuca ovina–Agrostis capillaris–Galium saxatile* grassland	Lake Distict, Pennines
	U5	*Nardus stricta–Galium saxatile* grassland	Pennines
	U6	*Juncus squarrosus–Festuca ovina* grassland	Pennines

(*Vaccinium myrtillus*), bell heather (*Erica cinerea*) – mainly on dry soils, and crowberry (*Empetrum nigrum*). Other species occur in bogs (especially cross-leaved heath (*Erica tetralix*)) and high mountains (especially bearberry (*Arctostaphylos* spp.). Grass moors are generally very poor in species, being dominated by a few grasses, mainly fescue (*Festuca*), bent (*Agrostis*), hair-grass (*Deschampsia*) and mat-grass (*Nardus*) species.

2.3.3 Omitting those restricted to the Scottish Highlands, the National Vegetation Classification (NVC) recognises about four types of heath (and a few other more montane NVC-heath classes), as well as a wide range of grasslands and related montane communities in the uplands (Table 2.1).

2.3.4 The ecological importance of the uplands is related to three features of the vegetation and to the bird communities it supports.

i. There are some uncommon species-rich plant communities which are only found in the uplands.

ii. Some of these plant communities are of international importance.

iii. The uplands are important ecologically because they are extensive and unfragmented.

Habitats of restricted occurrence

Wet habitats

2.3.5 There are various wet habitats in the uplands which are quite restricted. These are base-rich flushes, supporting diverse assemblages of plants, calcareous mires, raised bogs, fens, and springs and gills.

Woodlands

2.3.6 Of the remaining semi-natural woods in the uplands, the most restricted are ash (*Fraxinus excelsior*) woodland in limestone districts, oak (*Quercus*) woodland with atlantic bryophytes, alder (*Alnus glutinosa*) woods (on wet soils around mire edges) and juniper (*Juniperus communis*) scrub (at high altitudes).

Rock habitats

2.3.7 The three types of rock habitat which are especially important in the uplands are limestone pavements, which support plant communities of extreme species richness, ungrazed montane cliffs, supporting rare arctic/alpine plants, and high montane vegetation types, including *Rhacomitrium* moss-heaths and various sedge heaths.

Grasslands

2.3.8 Upland hay meadows and limestone grasslands are the two types of grassland which occur in the uplands, and these are restricted and becoming more scarce as a result of modern farming practices.

Habitats of international importance

2.3.9 The oceanic climate of Britain's uplands gives rise to plant communities of restricted distribution in Europe, the main counterparts being in Scandinavia and Iceland. Moreover, the British flora contains species that have very diverse geographical distribution patterns on the Continent (atlantic species, alpine species, etc), and the mixtures of species in British vegetation are therefore often unusual. In addition to various distinctive montane communities, the following general types are widely distributed:

- dwarf shrub heaths dominated by a range of different ericaceous shrubs, often in association with bryophytes;
- bryophyte and fern communities in areas of high humidity. In the west of Britain where rainfall and humidity are high, oak woods may support a wide range of atlantic species confined to the western seaboard of Europe.

Extensive habitats

2.3.10 Many upland areas support habitats that are species-poor at small patch sizes, but they are present in unfragmented blocks over large expanses of land, and they grade naturally into other types of habitat within the upland scene. The integrity of these habitats at the landscape level makes them of greater importance than would otherwise be the case, mainly for the following reasons.

- Unfragmented habitats are rare in the British Isles, except in the uplands. They are large enough to maintain viable populations of species (especially birds) that might not persist in small habitat patches. Among the birds found in the uplands are hen harriers (*Circus cyaneus*), peregrine (*Falco peregrinus*), merlin (*Falco columbarius*) and raven (*Corvus corax*), as well as breeding waders.
- The relationships between plant (and animal) communities and the physical environment can be studied in ways that would not be possible in fragmented landscapes.

2.4 Upland as a scenic resource

2.4.1 The popularity of the uplands has greatly increased since the Romantic period, before which time they were considered inhospitable places where ordinary people did not go, often for superstitious reasons. Since then, the uplands have become more popular as they symbolise, for many, the last wilderness.

2.4.2 The uplands are characterised by a feeling of rugged, desolate wilderness. They are areas with many scenic aspects including remote, wind-blown moors, with exposed stones, steep scree escarpments, and jagged hills with waterfalls, small valleys and gorges. Moorland landscapes are valued for their long views uninterrupted in extent, uniformity and simplicity of landform, creating a sense of space and freedom.

2.4.3 Valleys are valued for their more enclosed, sheltered and domestic landscapes. They are diverse and complex, with many patterns and textures in walled meadows and pastures. Other distinctive features in the landscape are the simple stone buildings, including farmsteads, barns and villages, and the upland fringes with their dramatic views.

2.4.4 It is said that moorland typifies the land cover of the British Isles and is what many foreign visitors come to see. These high treeless areas have long been considered as suitable areas for human relaxation and reflection, as can be seen by the number and diversity of ritual monuments found in these areas.

2.5 Upland as a recreational resource

2.5.1 Since early this century, Britain's uplands have been recognised as a prime recreational resource. Today, they are still the most valued areas for walking, climbing and other outdoor pursuits. There are certain areas that have always been popular with walkers, such as the Lake District, the Pennines and the Yorkshire Dales, but many of the more remote, rugged wilderness areas also attract significant numbers of visitors.

2.5.2 The vegetation of the uplands can be particularly sensitive to trampling, especially if it is already suffering from over-grazing.

2.6 Upland as an historical resource

2.6.1 Uplands are important as areas for archaeological remains as they have been subject to very low-intensity management for long periods. As a result, there are many upstanding remains which tend to be in better condition than examples in other land types. In addition, the uplands cover large areas so it is possible to find relatively complete patterns of ancient activity. The peat bogs found in many uplands often have preserved pollen, invertebrate and wood records, and provide useful information about historical land use. Furthermore, the ancient remains in the uplands are accessible which make them good recreational and educational areas.

2.6.2 There are limitations to the importance of historic remains in the uplands which can be attributed to the inhospitality of the climate such that only certain classes of site are represented, and settlement has only been possible, at certain times throughout history. In addition, relatively few artefacts are to be found in upland sites.

2.6.3 The most commonly occupied areas for settlement were the moorland fringes (marginal upland) where there are fewer time gaps in the remains found. The true uplands were used in a more spasmodic way, the periods of their use depending on the changing environment and socio-economic climate.

2.6.4 Archaeological sites in uplands have distinctive characteristics:

- monuments built of stone are still standing;
- they have thin soil cover and are thus easy to see;
- pits and ditches are rare because of the hard bedrock.

2.6.5 Settlements are the most numerous remains, and field systems are also fairly common. In some cases there appears to have been a move to demarcate areas used for farming from the higher unused areas (ie between marginal and true upland). Use for grazing has produced its own archaeology, including sheep folds, pens, shelters, sheep creeps and shielings (summer residences). Military use was also common, especially during Roman times, and there are many forts. Ritual and ceremonial monuments in the uplands are very diverse, as are quarries.

2.7 Evolution of upland habitats

2.7.1 The tops of some mountains in the Lake District are probably above the natural treeline, but the majority of the upland landscape was wooded at some point in the Post-Glacial period, and woodland has been replaced by moorland.

2.7.2 There is some dispute as to whether moorland is natural in England. While there is little doubt that human activity speeded up the process of deforestation, it is argued that many of the wildwoods which existed on the uplands would have disappeared naturally over time as a result of waterlogging and peat development. It cannot be doubted, however, that some of the drier upland areas would still be wooded but for human intervention.

2.7.3 Clearance probably began in the Mesolithic period, through recurrent burning by mesolithic hunters. Trees were probably lost first at the highest altitudes (where trees are under physiological stress and therefore less likely to regenerate), and a 100–200 m depression of the treeline may have occurred by about 7500 BP. From peat stratigraphy and pollen evidence it appears that extensive deforestation of the English uplands occurred in two phases, the first from about 2100–2600 BP in most areas except for the Lake District, and about 1400–1700 BP in the Lake District (Birks 1988). Semi-natural woodland has played a part in the economy of the marginal uplands, but has been largely absent in the true uplands in the last millennium.

2.7.4 All large moors currently in existence would have been created by the end of the Iron Age, although many of their boundaries would have been farmland with wildwood.

2.7.5 Sheep grazing probably became the predominant land use in the uplands at around 1750, though practised locally for much longer. Grouse moor management became locally important, especially in the southern Pennines and the North Yorks Moors from about 1840 onwards. Persecution of raptors was associated with both of these land uses (Ratcliffe & Thompson 1988).

2.8 Dynamics of uplands

2.8.1 The British uplands are characterised by unusually harsh climates (as compared with other upland regions in Europe), largely because of the oceanicity of the climate. The high humidity, low temperatures, high wind speeds and low levels of sunlight result in diminished rates of evapotranspiration. These various aspects of the climate have important consequence for the growth of the individual plant and for the development of vegetation.

- Plant growth rates are restricted by low temperatures, and photosynthetic activity is reduced by the low radiation, cloudy climate of the British uplands. Plant communities tend to be dominated by slow-growing, stress-tolerant species.
- Waterlogging of soils is common in the British uplands and, in many vegetation types, the dominant species have adapted accordingly.
- The prevailing coolness and wetness of both the climate and the soils have the further effect of slowing the decomposition of plant material, and halting it altogether under anaerobic conditions in wet acid soils. This leads to the formation of peaty soils, or to the formation of peat bogs in places where peat builds above the level of the mineral soil. Three types of bog are recognised: valley bogs, raised bogs and blanket bogs.

2.8.2 In addition to stresses imposed by the climate and soils, the following management factors also affect the uplands profoundly:

- grazing, mainly for agriculture (sheep in the true uplands, and sheep and cattle in the marginal uplands) and sport (deer), but also by rabbits (*Oryctolagus cuniculus*);
- burning, mainly for sport (eg on grouse moors where heather is burned to encourage new growth, an essential food source);
- recreation, mainly through trampling of (naturally) stressed vegetation which recovers less well than grassy swards in the lowlands (due to low growth rates).

2.9 Trends for change in the uplands

2.9.1 Intensive land use for development, urbanisation and recreation affects some parts of the uplands locally. So, too, do matters relating to agricultural management, and grazing is of paramount importance almost everywhere. Compared to many other habitats, however, global factors and extensive land use factors are of relatively high importance.

Climatic change

2.9.2 Altitudinal vegetation zones on British mountains appear to be related to changes in mean temperatures of as little as 1°C or 2°C. An upward shift of vegetation types might therefore be expected to result from global warming. Likely consequences would be a loss of the higher montane vegetation types from the less high mountains (especially in England where the mountain tops are of limited extent), and widespread reductions in the areas occupied by some of the more extensive types.

2.9.3 Changes in rainfall could also have marked effects. An increase in rainfall might lead particularly to a loss of some dwarf shrub heath types characteristic of well-drained soils in eastern Britain. However, increase in temperature might also affect evapotranspiration rates with severe effects on the species and vegetation types that are characteristic of cool, wet climates. Loss of atlantic bryophytes and ferns, and the drying out of several upland mire types might also be expected.

Acidification

2.9.4 Acidification in the uplands has two principal effects. First, it may affect catchments, leading to acidification of streams and lakes, and, second, it may affect vegetation directly. Acidification of surface waters has been a subject of prime concern in Britain, leading to extensive studies under the umbrella of the Surface Waters Acidification Programme. Direct damage to plants has received less attention in Britain, though it has been studied on the Continent in connection with damage to forest trees. There is concern that plants could be directly damaged by high acidity cloud water (Lee, Tallis & Woodin 1988).

2.9.5 Historically, in the period since the beginning of the Industrial Revolution, SO_2 deposition has been of considerable importance in the uplands. Various sources of evidence from lake sediments and peat stratigraphy show that species tolerant of acid conditions increased in abundance at the beginning of the 19th century (eg diatom assemblages in lake sediments). The most dramatic changes induced by SO_2 deposition occurred in ombrotrophic mires, where *Sphagnum* and other bryophytes (eg *Rhacomitrium lanuginosum*) disappeared in many places, especially close to sources of pollution (as in the southern Pennines). Recently, there have been cuts in sulphur emissions leading to reduced atmospheric levels of about 40 mg m^{-3}. At these levels re-introduction experiments with *Sphagnum* have shown some success (Lee *et al.* 1988), and there is at least anecdotal evidence of the natural return of *Sphagnum* species to sites from which they had altogether disappeared (eg Malham Tarn Moss). The importance of sulphur as an acidifying agent and general atmospheric pollutant has been overtaken by that of nitrogen which has increased in recent years.

Eutrophication

2.9.6 Whereas SO_2 emissions and resulting atmospheric levels of SO_2 have declined greatly in recent years (due to the reduction in coal burning in the UK), the levels for oxides of nitrogen have increased (due to increased use of motor vehicles). Lee *et al.* (1988) estimate that levels have increased by a factor of four since the 1860s. Thus, nitrogen deposition is now of greater concern than sulphur deposition in the British uplands.

2.9.7 Because nitrogen lowers pH, it may have the same effects as SO_2 deposition. However, nitrogen also acts as a fertilizer. Upland plant communities – bogs especially, but also high montane communities and dwarf-shrub moorlands – are for the most part very nutrient-poor, and adding additional nitrogen could cause eutrophication. One effect that might be anticipated is an increase of grass at the expense of ericaceous shrubs (as in Dutch lowland heaths), but there are no data to suggest that this might be happening in English uplands where grazing practice is probably of over-riding importance.

Radionuclides

2.9.8 Radionuclide deposition after events such as Chernobyl may be higher than in the lowlands because of the higher rainfall and occult deposition. Certain upland plants tend to take up high amounts of radionuclides such as ^{134}Cs, notably heather (Salt *et al.* 1994), and animals grazing on uplands, especially heather moors, might therefore accumulate high levels of radionuclides.

Afforestation

2.9.9 Since about 1920 the British uplands have been extensively planted with non-native conifers. This has been the main change in the uplands over this period.

2.9.10 There is a large scientific literature covering the ecological effects of upland afforestation. Wet soils and mires are usually lost altogether, and most upland species are lost although some may be retained in clearings. As a result of the vegetation change, a different and more diverse bird community may result, which may be a nature conservation benefit as the uplands are naturally species-poor. Outside plantations there are additional effects related to localised drying out of soils, acidification of catchments and severance of grazing access. In addition, there may be effects on the fauna of the uplands resulting from the use of agrochemicals (fertilizers, pesticides, herbicides) in forestry operations and from fragmentation of open vegetation. This leads to the loss of habitable territory for those animal species that require large unfragmented blocks of uniform habitat (mainly birds and especially raptors).

2.9.11 Insensitive afforestation in the uplands may also spoil the wilderness character and inhibit access. Uniform blocks of tree planting can be unappealing from a visual point of view, and thus reduce the scenic value. In addition, planting may damage (and sterilise) the archaeological resource.

2.9.12 A greater emphasis is now given to forest design which addresses many of the negative impacts of forestry practice in earlier decades.

Agriculture

2.9.13 Modern agriculture does not extend far into the true uplands, but various agricultural practices may affect moorlands and other habitats in the marginal uplands. Of these the most important are the following.

- The drainage of moorland with open ditches has adverse effects on the nature conservation interest of wet moorlands and mires. Though drainage has been practised historically, modern machinery and grants have made it possible to drain large areas. In the true uplands the effects of ditches are probably not great because rainfall is too high, but in the marginal uplands they may lead to loss of species diversity and the spread of grasses, with consequent reduction in ecological and scenic value; they appear to have little effect in improving conditions for grazing (Coulson, Butterfield & Henderson 1990).
- Agricultural improvement of grasslands in the marginal uplands by fertilizer use has led to the loss of upland hay meadows. Large areas of grass moor may also have been agriculturally improved, although this may be of lesser wildlife conservation concern.

2.9.14 The loss of heather to grass moorland has been very significant in the post-war period, leading to important ecological as well as landscape and amenity effects. Whether such a change is due to grazing practice, or to planned or environmental eutrophication, is not always clear.

Urbanisation/roads

2.9.15 Although not a major threat to the true uplands, development does take place in the marginal uplands, especially near existing centres of population. Such development causes fragmentation which is detrimental to both nature conservation and the scenic value of the uplands.

2.9.16 The biggest threat to the uplands from the archaeological point of view is the development of marginal uplands – these contain the most diverse remains but are also the most likely to be exploited. Mineral extraction, and natural and recreational erosion are also significant threats.

2.10 Conservation and restoration

2.10.1 Whereas many of the most important habitats for nature conservation in the lowlands are managed for nature conservation objectives, in the uplands this is exceptional, and most land is managed for low-intensity agriculture or game.

2.10.2 Sheep grazing is the major management factor over large parts of the open uplands. In general, over-grazing may lead to a loss of dwarf shrub species and their replacement by grasses. Severe over-grazing may lead to the establishment of species-poor swards dominated by the unpalatable mat-grass (*Nardus stricta*) which is not desirable from either a nature conservation or agricultural perspective. There are several existing management schemes aimed at redressing the balance of grass and heather moorland. Some are funded through the European Commission's Agri-Environment programme.

2.10.3 Conservation of upland vegetation which has not been improved is not as complicated a management issue as for some other habitat types. In many cases it is over-grazing which is causing problems and, if left alone, the moorland would manage itself (especially peat/bog). The management that is required in other areas is low-intensity grazing, with particular care not to over-graze in winter.

2.10.4 Countryside Stewardship guidelines state that regeneration of suppressed heather moorland is best achieved by excluding livestock in winter and light grazing (1 ewe per ha) in June/July, which can be increased slowly as the heather rejuvenates. In addition to the grazing regime, certain other conditions have to be fulfilled, eg no supplementary feeding (to reduce localised damage to vegetation), and no use of organic fertilizer, lime, slag, herbicides or other pesticides. In addition, no new drains or alterations to drains should be made.

2.10.5 Restoration of heather moorland on agriculturally improved land is best carried out on land converted in the last ten years which adjoins existing good-quality moorland. Land with a deep covering of bracken litter over more than 70% of the area will be difficult to regenerate. The best approach seems to be to cultivate the soil in the first year and cover with heather cuttings in October to December. Complete exclusion of livestock for the first few years allows heather to grow best, and this should then be followed with summer grazing only, until heather cover reaches 50%.

2.10.6 Restoration of areas that have been planted with conifers is more complicated as the soil conditions and drainage regime may have changed. It is not clear whether bogs and marshes which have been planted can be restored.

2.10.7 The uplands are more likely to be affected by global warming and patterns of global pollution than any other habitat in England, because of their altitude and high rainfall. This will present its own management requirements.

2.11 Summary

2.11.1 The upland landscape is one of the characteristic landscapes of the British Isles, valued for its large, open spaces, and its extensive unfragmented blocks of semi-natural vegetation. It contains many uncommon vegetation types and is internationally important for some types of Atlantic vegetation. It supports many 'Nationally scarce' and *Red Data Book* bird species, including several raptors. The uplands are an important scenic and amenity resource, as well as containing interesting archaeological remains.

2.11.2 The uplands are particularly sensitive to patterns of global pollution – such as acid rain and nitrogen deposition – and also to intensive farming and forestry. While these factors may particularly affect the ecology of the uplands, they also have the potential to change the scenic value (through changing the shapes and patterns of the landscape), and therefore amenity value, and also to affect archaeology. These problems may best be tackled through management initiatives which are focused on farming practices, sensitive forestry management, and global agreements on atmospheric discharge.

Chapter 3 DEFINING THE UPLAND MASK

3.1 Introduction

3.1.1 The upland landscape may be defined and described in a variety of ways (para 2.2) but, at the outset of this project, there was no obvious existing classification which met the needs of the project.

3.2 Defining the upland mask

3.2.1 While the use of contours might be expected to provide a simple method for mapping upland landscapes, land above certain altitude limits in northern England is very different, in overall character, to land above the same contour in the south.

3.2.2 To allow for the inherent variation in land above certain altitudes in different parts of England, the upland mask (see Box 1.1) was derived from the ITE Land Classification (Bunce & Heal 1984). This Classification uses a range of environmantal and physical parameters to assign all the 1 km squares in Great Britain into one of 32 land classes; these classes have then been aggregated into groups which are predominantly 'upland' (land classes 17–24 and 27–32) or predominantly 'lowland' (land classes 1–16, 25 and 26) in character.

3.2.3 The upland land classes are the same as those used in the definition of marginal upland and upland landscapes used to present results for Countryside Survey 1990, with the exception that land classes 29–32 were not included because they do not occur in England (cf para 4.2.2). Fifty-one 1 km squares which were predominantly urban (shown as >75% towns on Ordnance Survey 1:250 000 maps) were excluded, leaving a total of 15 616 squares in the final upland map (Figure 3.1).

3.2.4 The upland mask as defined includes some small areas which may not generally be thought of as upland in character, eg the higher parts of the Cotswolds. The 1 km squares comprising those areas will have been allocated objectively to one of the land classes more generally upland in character on the basis of the values of the combination of environmental parameters used to derive and define the land classes (Bunce *et al.* 1996). It should also be noted that a number of smaller upland areas, eg Bodmin Moor, are not visible on Figure 3.1 but were included in the upland mask.

Figure 3.1 The upland mask covering 1 km squares in England with predominantly upland characteristics
i. True uplands shown in black and marginal uplands in green
ii. Designated areas shown in green and non-designated areas in black

3.3 The upland mask – outputs

3.3.1 The upland mask shown in Figure 3.1 covers 15 616 km squares in England. The locational data of these squares are available as a dataset for use in the DOE's Countryside Information System.

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

Chapter 4 ECOLOGICAL CHARACTERISTICS OF THE UPLAND MASK

4.1 Introduction

4.1.1 The methods used to define the upland mask are described in Chapter 3. This Chapter goes on to describe 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 upland mask was stratified to ensure that the sample of surveyed squares was representative, and to allow comparison between upland landscapes in different parts of the country, and between upland types in designated and non-designated areas. The four strata are:

i. designated true uplands
ii. designated marginal upland
iii. non-designated true uplands
iv. non-designated marginal uplands

4.2.2 'Marginal upland' and 'true upland' refer to the land class groups derived from the ITE Land Classification, as used in Countryside Survey 1990 (Barr *et al.* 1993). The marginal upland land class group represents areas which are on the periphery of the uplands; they are dominated by mixtures of low-intensity agriculture, forestry and semi-natural vegetation (land classes 17, 18, 19, 20, 28 and 31). The true upland land class group represents areas which are largely above a height suitable for intensive farming; they are frequently dominated by sheep farming and semi-natural vegetation, and in England are largely restricted to the Pennines and Cumbrian mountains (land classes 21, 22, 23, 24, 29, 30 and 32).

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 databases assembled 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.

Table 4.1 The area of the upland mask and the number of squares in the field survey squares

Strata		Area of land		Number of sample 1 km squares		
Designation	True/marginal upland	km^2	%	1990	1993	Total
Designated	True upland	3826	24	10	13	23
Designated	Marginal upland	8832	57	15	9	24
Non-designated	True upland	550	4	1	3	46
Non-designated	Marginal upland	2408	15	6	7	13
Total		*15616*	*100*	*32*	*32*	*64*

4.2.4 The inclusion 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 point is mainly relevant to designations which affect small areas, eg SSSIs. Further, the designation may not be related to the 'upland' 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. As in CS1990, squares which were more than 75% built-up were excluded from the sample. A total of 32 squares were surveyed in 1993 (Table 4.1). In addition, 32 squares which were surveyed in Countryside Survey 1990 fell within the upland landscape; data from these squares have been extracted and added to the database.

4.2.6 The results from the sample squares have been used to calculate estimates for the upland landscape as a whole. The relationship between the survey squares and the size of each stratum is shown in Table 4.2. The decision to use CS1990 squares means that the final sample numbers are not directly proportional to the area of each stratum. However, because averaged and weighted stratum results are used in the overall calculation of ecological characteristics, this sampling strategy has no inherent bias.

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 32 squares which had already been recorded as part of the CS1990 survey, the same approach was used, ie 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 within the sample squares that support, or could support, upland habitats. In each quadrat, all species were recorded, and cover was estimated to the nearest 5%. All quadrats were permanently marked to allow future monitoring. Three different types of quadrats were recorded:

- **Main plots**: 200 m^2 nested 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 re-seeded or heavily fertilized), then no quadrat was recorded.

- **Habitat plots**: five 4 m^2 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 all upland vegetation types occurring in the survey square were recorded by quadrats.

- **Stream plots**: five 10 m x 1 m plots were recorded adjacent to rivers, streams or ditches (hereafter referred to as streamsides). The plots were placed parallel to the streamside to record the metre strip above the stream. Two of the stream plots were randomly located, the other three were placed so as to ensure that watercourses of different sizes, ie rivers, streams and ditches, were all sampled.

4.3.4 Main plots, habitat plots and stream plots were also recorded in Countryside Survey 1990. Information from these plots have been extracted to add to the 1993 plots.

4.3.5 Considerable care was given to maintaining quality in field recording and to minimising variation between surveyors. Quality measures included the use of a field handbook, a training course for surveyors, and constant supervision. During the field survey, independent ecological consultants revisited a sample of the survey squares, and repeated quadrats and land cover descriptions. Information from these repeat visits was given to surveyors so that consistency of recording was maintained.

4.3.6 A pilot study was carried out to assess this survey approach, which showed that the grid system was reasonably accurate at estimating the most extensive, or widely distributed, land cover types, but was poor for those with limited geographical extent.

4.4 Field survey results: land cover

4.4.1 The land cover recorded at the 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). Full details of the land cover estimates for each stratum, and for combined strata are given in Appendix 1.

4.4.2 These estimates show that 18% of the upland landscape was composed of dwarf shrub heath vegetation (dominated by heather, bell heather and/or bilberry) but that this was unevenly spread between strata. There was very little in non-designated squares, and a considerably higher proportion in the marginal upland strata than in the true upland strata. In contrast, bog vegetation was mostly found in the true upland strata, particularly in designated squares. Flushes were recorded only in designated strata, where they were more common in the marginal uplands. Moorland grass was more common in the true upland squares, though still had significant cover in the marginal uplands. It occurred in both designated and non-designated strata, but formed a greater proportion of the former. Acid grassland/ bracken occurred in both marginal and true uplands, and was more common in designated squares.

4.4.3 Neutral/improved grassland occurred in all strata, but formed a more important component of the landscape in the marginal uplands and in non-designated squares. Crops were recorded only in the marginal uplands, where they were more frequent in the non-designated stratum. Structures/ roads also occupied a larger area in the marginal uplands, where they were more significant in the non-designated stratum.

4.4.4 Woodland/scrub was most common in the true upland non-designated squares (mainly conifer plantation in Kielder Forest); 80% of the woodland recorded throughout the upland landscape was conifers or mixed. The deciduous woodland (including scrub) was most common in the designated marginal upland stratum.

4.5 Field survey results: boundaries

4.5.1 Overall, two-thirds (62%) of all grid points had a boundary within 100 m (Table 4.2). There was a clear difference between strata in the number of boundaries. The squares in the true upland strata had a lower proportion of field boundaries, showing the greater areas of unenclosed land (heathland and woodland). In the designated strata, and the non-designated marginal stratum, walls (with or without fences) formed the most frequent boundary type, followed by fences, but, in the non-designated true upland stratum, walls were less common and fences formed the predominant boundary type. Only 7% of boundaries included hedges. Further details are given in Appendix 1.

4.6 Summary of land cover and boundary results

4.6.1 There is a considerable difference between the designated and non-designated true uplands, the latter being dominated by woodland, in contrast to the designated stratum which is dominated by bog and moorland grass (Figure 4.3). The designated and non-designated marginal upland strata are also very different; the former have much more dwarf shrub heath and less, though still considerable, neutral/ improved grassland.

4.6.2 Most of the dwarf shrub heath and bog, and more of the moorland grass and acid grass/ bracken occurred in the designated strata. Flushes were only recorded in the

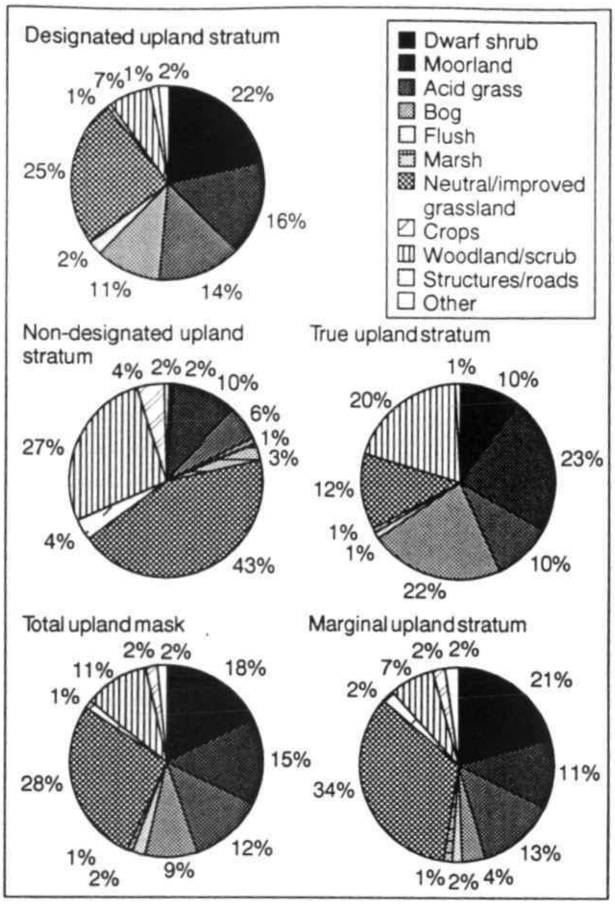


Figure 4.1 Estimates of the percentage area of each land cover type in the upland mask. Based on description of land cover at the 16 grid points in each sample square

designated strata. Woodland and neutral/improved grassland made up a higher proportion of the non-designated strata. Dwarf shrub heath was more common in the marginal uplands than the true uplands, whilst moorland grass and bog formed a higher proportion of the latter, suggesting that heather moorland is partly replaced by bog (in which heather may still be a significant component) in the higher-rainfall and poorer-draining soils of the true uplands. There was more neutral/improved grassland in the marginal uplands, but less woodland.

4.6.3 Comparison of the results from the sample squares used in the upland mask with results derived from the Countryside Survey 1990 (Table 4.3) shows that the proportions of each land cover type are similar (correlation coefficient = 0.95), although results from the present study give a lower estimate for the proportion of woodland, and a higher estimate for the proportion of neutral/improved grassland.

Table 4.2 Abundance of boundaries in the upland mask

Stratum	% of points Without boundaries	% of points With boundaries
Designated true uplands	51	49
Designated marginal uplands	33	67
Non-designated true uplands	60	40
Non-designated marginal uplands	21	79
Total	*38*	*62*

4.7 Vegetation sampling and analysis

4.7.1 The land cover data (as described in Section 4.3) represents the major vegetation categories and provides 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.

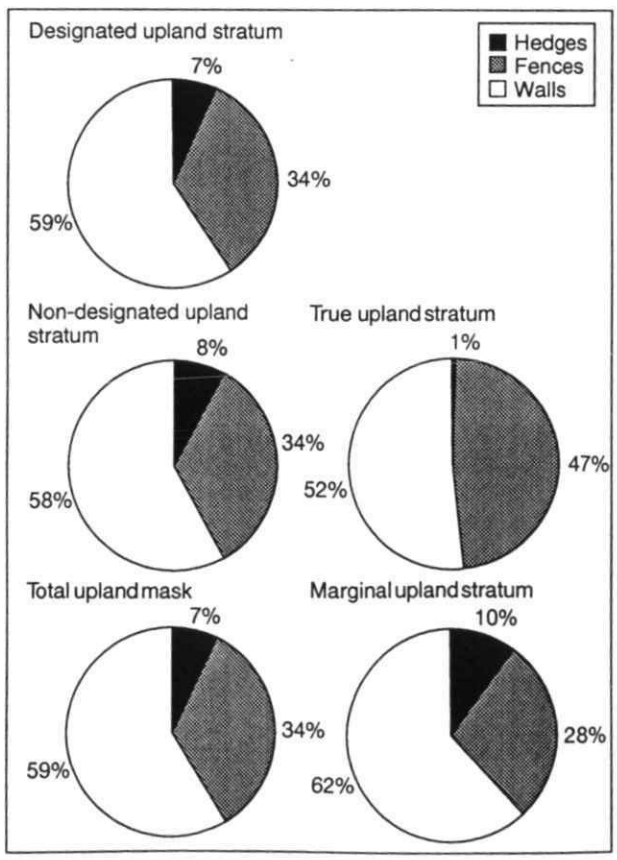


Figure 4.2 Proportion of boundary types in the upland mask

Table 4.3 Comparison of land cover estimates from grid points (this study) with those from whole-square mapping in Countryside Survey 1990

Land cover categories	Upland mask[1] Area (km²)	SE	%	Upland England[2] %
Dwarf shrub heath	2790	652	18	17
Moorland grass	2275	483	15	15
Acid grass/bracken	1934	357	12	11
Bog	1388	277	9	10
Flush/marsh	427	174	3	3
Neutral/improved grassland	4385	689	28	22
Crops	219	125	1	2
Woodland/scrub	1682	330	11	16
Structures/roads	276	71	2	2
Other	239	89	2	2
Total	*15616*			

[1] Figures are derived from land cover description of grid points in sample squares in the present study
[2] Figures are derived from land cover descriptions of mapped sample squares from CS1990, from the same land classes

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

4.7.2 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.

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

- Bog
- Flush
- Wet heath
- Dry heath
- Moorland grassland
- Acid grass/bracken
- Calcareous grassland
- Neutral/improved grassland
- Woodland/scrub
- Other

4.7.4 The quadrats were classified statistically into '**plot classes**' based on species composition (using a multivariate statistical classification, TWINSPAN – see hierarchy diagram in Appendix 1). This classification has been produced using data from all the upland squares surveyed in 1990 and 1993, as well as some squares from the survey of the calcareous landscape which fell within the definition of the uplands. These additional squares provide more replicates of calcareous upland vegetation. The plot classes have been given short descriptive names to aid interpretation (Table 4.4), and are ordered according to the principal gradient score (derived from the DECORANA analysis), from acid, wet conditions to less acid, drier conditions (see Figure 4.9). Further details of the plot classes are given in Appendix 1.

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

4.7.5 Species have been allocated to '**habitat indicator groups**', based on expert

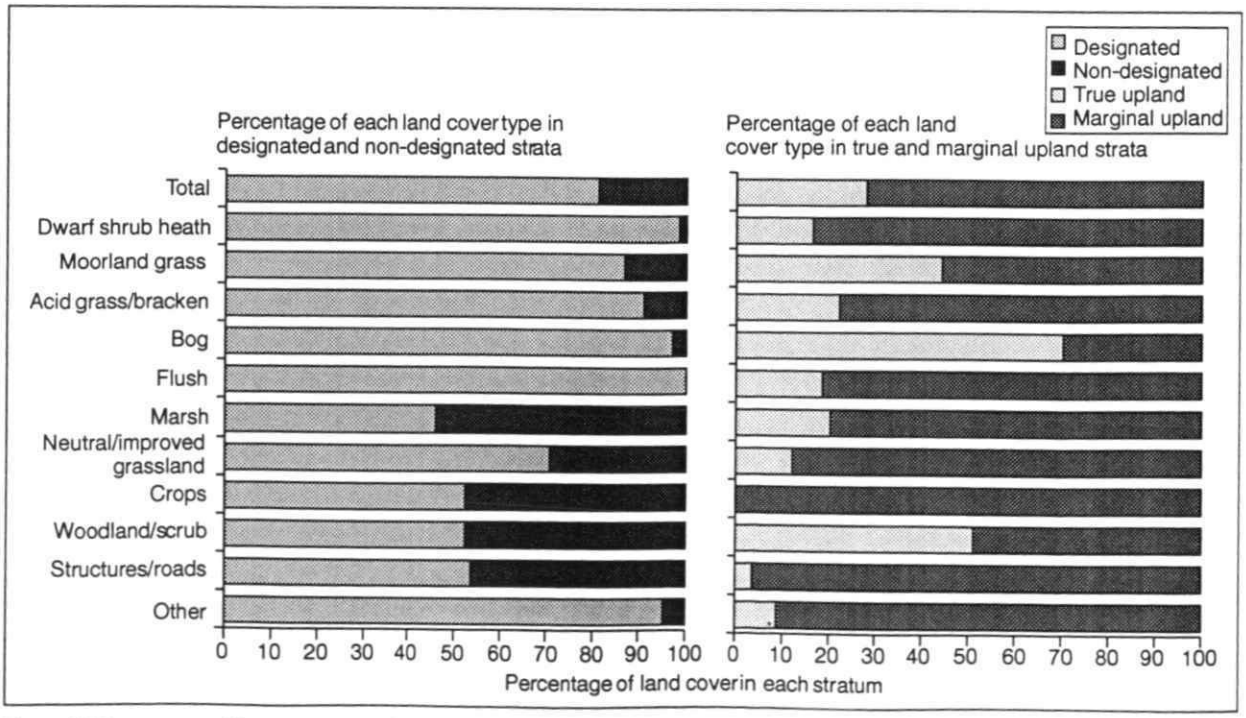


Figure 4.3 Percentage of land cover types in the upland mask

Box not referred to -

Box 4.1

Woodland/scrub species,
eg *Holcus mollis, Dryopteris dilatata*
Base-rich grass/flush species,
eg *Lotus corniculatus, Briza media*
Bog/acid flush species,
eg *Polytrichum commune, Eriophorum angustifolium*
Moorland species,
eg *Calluna vulgaris, Deschampsia flexuosa*
Upland grass species,
eg *Anthoxanthum odoratum, Agrostis capillaris*
Streamside/marsh species,
eg *Cirsium palustre, Galium palustre*
Neutral/improved grass species,
eg *Holcus lanatus, Rumex acetosa*
Weeds/alien species,
eg *Taraxacum* agg, *Poa annua*

knowledge, to identify the extent to which the species are associated with the uplands:

4.7.6 A multivariate statistical classification has been produced to group species into '**species groups**' which have similar distributions across the quadrat dataset, using DECORANA and Ward's Minimum Clustering. The rare species (frequency <5%) have been excluded from this classification, and the rest of the species have been split into two groups, and analysed independently:

i. dominant species (frequency >10%),
ii. subdominant species (frequency <10% and >2%).

These groups are shown in Table 4.5, ordered on the principal gradient.

Table 4.4 Upland landscape 'plot classes'
A classification derived from multivariate analysis of quadrat data (using TWINSPAN)

Plot class	Name
PCA	Neutral/calcareous woodlands (mainly ash)
PCB	Neutral permanent grassland
PCC	Moist woodlands (mainly alder)
PCD	Semi-improved grassland
PCE	Limestone grassland
PCF	Marshy streamsides
PCG	Acid woodlands (oak, sycamore and birch)
PCH	Enriched flushes
PCI	Acid grassland – short fine turf
PCJ	Wet rushy pasture
PCK	Damp acid pasture
PCL	Upland grassland
PCM	Acid flushes
PCN	Moorland streamsides
PCO	Moorland grass
PCP	Sitka planted on to moorland
PCQ	Dry heath
PCR	Mossy moorland
PCS	Acid wet heath (*Juncus squarrosus*)
PCT	Blanket bog
PCU	Wet heath/bog
PCV	Northern bog

Shaded plot classes (L–V) are those considered to be typical of the uplands = 'core' upland vegetation; non-shaded plot classes (A–K) are other vegetation types found within the mask = 'non-core' upland vegetation classes

4.7.7 Species have been identified as being sensitive to particular threats (based on expert knowledge):

i. drying out;
ii. succession, ie colonisation by trees species resulting in scrub or woodland;
iii. grazing, leading to dominance of graminaceous species;
iv. eutrophication, through runoff or deposition.

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

4.7.8 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.

4.7.9 The use of quality criteria to provide a comparative assessment of sites by other studies is discussed in Appendix I (Box A1.1). 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 upland landscape. Each criterion emphasises a particular aspect of quality, but they do inter-relate, and should

Table 4.5 Upland landscape species groups
A classification derived from multivariate analysis of quadrat data (using DECORANA)

Species groups	
SG1	Neutral grassland species
SG2	Grassland species on thin mineral soils
SG3	Marsh/streamside species
SG4	Bracken/shady banks species
SG5	Peaty flush species
SG6	Acid grassland species
SG7	Woodland species/humid mosses
SG8	Moorland/bog species

Shaded species groups (5–8) are those which are characteristic of the uplands = 'upland' species groups; unshaded species groups (1–4) are also found in the upland mask = 'non-upland' species groups

Table 4.6 Mean number of main plots recorded per square, by strata in the upland mask
(indicative of areas of acid semi-natural vegetation)

Strata	No. of squares	No. of plots	Mean no. of plots
Designated true upland	23	115	5.00
Designated marginal upland	24	108	4.50
Non-designated true upland	4	20	5.00
Non-designated marginal upland	13	44	3.38
Combined designated	47	223	4.65
Combined non-designated	17	64	3.68
Combined true upland	27	135	5.00
Combined marginal upland	37	152	4.26
Total	*64*	*287*	*4.47*

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 strata size

Table 4.7 Mean number of stream plots recorded per square, by strata in the upland mask
(indicative of areas of acid semi-natural vegetation)

Strata	No. of squares	No. of plots	Mean no. of plots
Designated true upland	23	112	4.87
Designated marginal upland	24	102	4.25
Non-designated true upland	4	20	5.00
Non-designated marginal upland	13	60	4.62
Combined designated	47	214	4.44
Combined non-designated	17	80	4.69
Combined true upland	27	132	4.89
Combined marginal upland	37	162	4.33
Total	*64*	*294*	*4.48*

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 strata size

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.

4.8 Vegetation quality: size/ abundance

4.8.1 Large size is usually considered a benefit, 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 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 local environments, reflected in a greater diversity of species. Size is also important in terms of landscape in that larger areas have a greater overall visual impact and are inherently more robust and less susceptible to landscape change.

Average area of acid semi-natural vegetation per km square

4.8.2 There was more acid semi-natural vegetation (ie meeting the criteria for recording quadrats) in squares in the true upland strata than in the marginal uplands, and designated strata had more of such vegetation than the undesignated counterparts (Table 4.6).

4.8.3 The occurrence of stream plots recorded per square was similar in all strata (Table 4.7).

Association between heathland, acid grassland and woodland

4.8.4 Figure 4.4 shows the number of squares containing one or more of three aggregated 'structural types': woodland (including conifer plantations, deciduous woodland and scrub), moorland (including bog, acid grassland and bracken) and grassland (neutral or improved). Moorland is the category most likely to occur on its own in a square (33% of squares), and many squares (22%) include all three land use types.

Relative abundance of structural types

4.8.5 In terms of structural types, both the designated strata have diverse vegetation types, with more heather-dominated vegetation (Tables 4.8 & 4.9). Dry heath was the category most frequently recorded by main plots in the designated marginal uplands, whilst the designated true uplands were dominated by bog and moorland grassland. Neutral/improved grassland was most common in the non-designated and marginal upland strata (Figure 4.5).

4.8.6 Bogs, flushes, wet and dry heath were only recorded as main plots in designated squares; however, these habitats were all recorded by habitat plots in the non-designated strata, indicating that they were present in non-designated squares, but much scarcer.

4.8.7 Over the upland landscape as a whole, 19% of plots (weighted by stratum size) were recorded as heath, 8% as bog, and 2% as flush. Of the remaining 71%, moorland grassland accounted for 21% and acid grassland/bracken for 16%. Neutral/improved grassland occupied 21% and woodland 13%. Streams were much more common than rivers and ditches, in all strata.

Summary of size/abundance as a quality criterion

4.8.8 The true uplands, although smaller in extent, had a higher proportion of semi-natural vegetation than the marginal uplands, particularly moorland vegetation, and were more varied in terms of the number of different vegetation types recorded by main plots. Dry heath was more common in the marginal uplands, with moorland grass, bog and wet heath occupying larger areas in the true uplands. The non-designated strata were more uniform, in terms of the more common vegetation types recorded by the main plots, compared to the designated strata. There was insufficient bog and heath vegetation to be recorded in main plots in the non-designated strata, but these types were recorded in habitat plots, although not as frequently as in the designated strata.

4.9 Vegetation quality: diversity

4.9.1 Diversity can be expressed both as the variety of vegetation types and the range 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, as 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 heathland site or one which is being invaded by grassland and/or woodland species. Dry heath tends to be poorer in species than wet heath and bog, which can be rich, particularly in lower plants. (See para 4.9.5 for discussion of species groups).

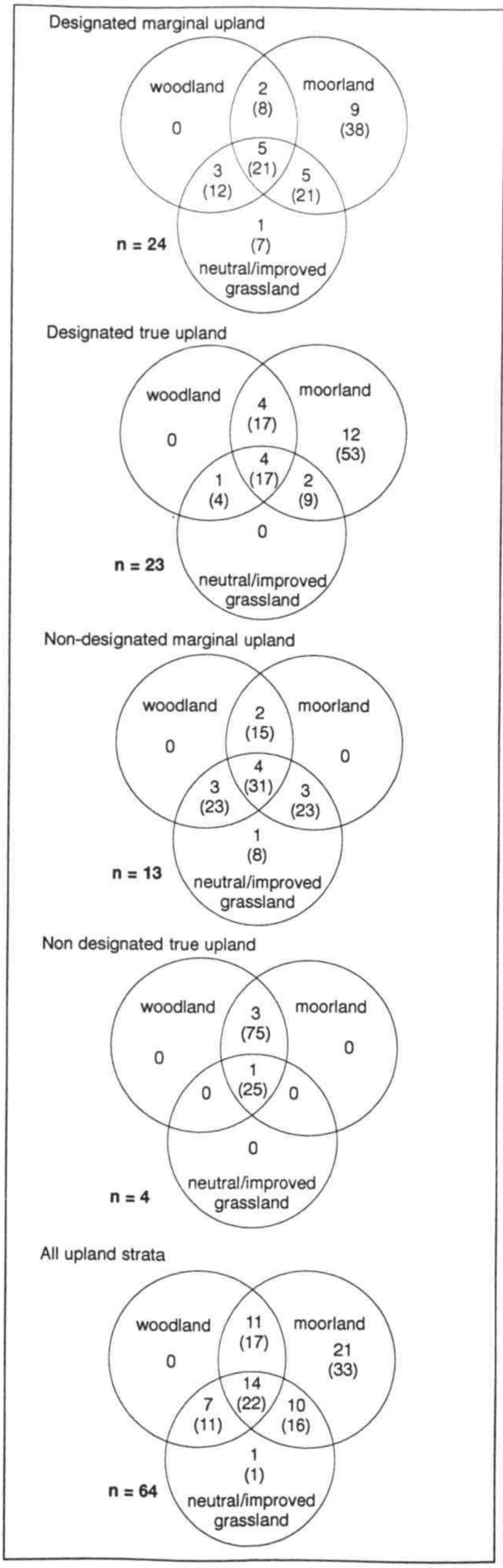


Figure 4.4 The association of woodland, moorland and neutral/improved grassland, shown by the number of survey squares with quadrats in one or more of these three categories in the upland mask. The woodland, moorland and neutral/improved grassland categories are groups of plot classes derived from statistical analysis of the quadrat data (TWINSPAN)

Table 4.8a Mean number of plots per square, for structural types, by strata

	Designated				Non-designated				Combined				Combined					
	True upland		Marginal		True upland		Marginal		Designated		Non-designated		True upland		Marginal		Total	
Structural type	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Main plots (200 m^2)																		
Bog	1.22	24	0.08	2	0.00	0	0.00	0	0.43	9	0.00	0	1.06	21	0.07	2	0.35	8
Flush	0.09	2	0.13	3	0.00	0	0.00	0	0.11	2	0.00	0	0.08	2	0.10	2	0.09	2
Wet heath	0.09	2	0.13	3	0.00	0	0.00	0	0.11	2	0.00	0	0.08	2	0.10	2	0.09	2
Dry heath	0.22	4	1.25	28	0.00	0	0.00	0	0.94	20	0.00	0	0.19	4	0.98	23	0.76	17
Moorland grassland	1.43	29	0.75	17	0.00	0	0.92	27	0.96	21	0.75	20	1.25	25	0.79	19	0.92	21
Acid grass/bracken	0.74	15	0.83	18	0.00	0	0.38	11	0.80	17	0.31	8	0.65	13	0.74	17	0.71	16
Calcareous grassland	0.00	0	0.08	2	0.00	0	0.00	0	0.06	1	0.00	0	0.00	0	0.07	2	0.05	1
Neutral/improved grassland	0.30	6	1.04	23	1.25	25	1.38	41	0.82	18	1.36	37	0.42	8	1.12	26	0.92	21
Woodland/scrub	0.91	18	0.21	5	3.75	75	0.54	16	0.42	9	1.14	31	1.27	25	0.28	7	0.56	13
Other	0.00	0	0.00	0	0.00	0	0.15	4	0.00	0	0.13	4	0.00	0	0.03	1	0.02	0
Total	*5.00*	*100*	*4.50*	*100*	*5.00*	*100*	*3.38*	*100*	*4.65*	*100*	*3.68*	*100*	*5.00*	*100*	*4.26*	*100*	*4.47*	*100*
Habitat plots (4 m^2)																		
Bog	1.26	25	0.71	14	0.50	10	0.15	3	0.88	18	0.22	4	1.17	23	0.59	12	0.75	15
Flush	0.74	15	0.63	12	0.00	0	0.46	9	0.66	13	0.38	8	0.65	13	0.59	12	0.61	12
Wet heath	0.35	7	0.21	4	0.25	5	0.00	0	0.25	5	0.05	1	0.34	7	0.16	3	0.21	4
Dry heath	0.26	5	0.50	10	0.50	10	0.31	6	0.43	9	0.34	7	0.29	6	0.46	9	0.41	8
Moorland grassland	0.61	12	0.42	8	0.75	15	0.08	2	0.47	9	0.20	4	0.63	13	0.34	7	0.42	8
Acid grass/bracken	0.83	17	0.67	13	0.25	5	0.46	9	0.71	14	0.42	8	0.75	15	0.62	12	0.66	13
Marsh/fen	0.00	0	0.46	9	0.00	0	0.92	18	0.32	6	0.75	15	0.00	0	0.56	11	0.40	8
Unmged grass/tall herb	0.09	2	0.13	3	0.00	0	0.38	8	0.11	2	0.31	6	0.08	2	0.18	4	0.15	3
Calcareous grassland	0.17	3	0.38	7	0.00	0	0.23	5	0.31	6	0.19	4	0.15	3	0.34	7	0.29	6
Neutral/improved grassland	0.48	10	0.54	11	0.50	10	0.92	18	0.52	10	0.84	17	0.48	10	0.62	12	0.58	12
Woodland/scrub	0.22	4	0.42	8	2.25	45	1.08	22	0.36	7	1.30	26	0.47	9	0.56	11	0.53	11
Total	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*
Stream plots (10 m x 1 m)																		
Rivers	0.09	2	0.25	6	0.00	0	0.69	15	0.20	5	0.56	12	0.08	2	0.34	8	0.27	6
Streams	4.04	83	3.21	76	3.00	60	3.00	65	3.46	78	3.00	64	3.91	80	3.16	73	3.37	75
Ditches	0.74	15	0.79	19	2.00	40	0.92	20	0.78	18	1.12	24	0.90	18	0.82	19	0.84	19
Total	*4.87*	*100*	*4.25*	*100*	*5.00*	*100*	*4.62*	*100*	*4.44*	*100*	*4.69*	*100*	*4.89*	*100*	*4.33*	*100*	*4.48*	*100*

The means for the combined strata are weighted by stratum area

Table 4.8b Mean number of plots per square, for structural types, by strata (main plots, habitat plots and stream plots combined)

	Designated				Non-designated				Combined				Combined					
	True upland		Marginal		True upland		Marginal		Designated		Non-designated		True upland		Marginal		Total	
Structural type	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Bog	2.48	17	0.79	6	0.50	3	0.15	1	1.30	9	0.22	2	2.23	15	0.66	5	1.10	8
Flush	0.83	6	0.75	5	0.00	0	0.46	4	0.77	5	0.38	3	0.72	5	0.69	5	0.70	5
Wet heath	0.43	3	0.33	2	0.25	2	0.00	0	0.36	3	0.05	0	0.41	3	0.26	2	0.30	2
Dry heath	0.48	3	1.75	13	0.50	3	0.31	2	1.37	10	0.34	3	0.48	3	1.44	11	1.17	8
Moorland grassland	2.04	14	1.17	9	0.75	5	1.00	8	1.43	10	0.95	7	1.88	13	1.13	8	1.34	10
Acid grass/bracken	1.57	11	1.46	11	0.25	2	0.85	7	1.49	11	0.74	6	1.40	9	1.33	10	1.35	10
Marsh/fen	0	0	0.46	3	0	0	1	8	0.32	2	0.81	6	0	0	0.57	4	0.41	3
Unmanaged grass/tall herb	0.09	1	0.13	1	0.00	0	0.46	4	0.11	1	0.38	3	0.08	1	0.20	1	0.16	1
Calcareous grassland	0.17	1	0.46	3	0.00	0	0.23	2	0.37	3	0.19	1	0.15	1	0.41	3	0.34	2
Neutral/improved grassland	0.78	5	1.58	11	1.75	12	2.31	18	1.34	10	2.20	16	0.90	6	1.74	13	1.50	11
Woodland/scrub	1.13	8	0.63	5	6.00	40	1.62	12	0.78	6	2.43	18	1.74	12	0.84	6	1.09	8
Streams/rivers	4.13	28	3.46	25	3.00	20	3.69	28	3.66	26	3.56	27	3.99	27	3.51	26	3.64	26
Ditches	0.74	5	0.79	6	2.00	13	0.92	7	0.78	6	1.12	8	0.90	6	0.82	6	0.84	6
Total	*14.87*	*100*	*13.75*	*100*	*15.00*	*100*	*13.00*	*100*	*14.09*	*100*	*13.37*	*100*	*14.89*	*100*	*13.59*	*100*	*13.95*	*100*

Table 4.9 Mean number of different plot classes represented per square

Strata	Main plots		Habitat plots		Stream plots	
	All PCs	*PCL–PCV*	All PCs	*PCL–PCV*	All PCs	*PCL–PCV*
Designated true upland	2.9	*2.0*	3.9	*2.5*	3.3	*1.0*
Designated marginal upland	2.4	*1.2*	3.5	*1.6*	3.0	*0.6*
Non-designated true upland	2.0	*1.8*	3.5	*2.0*	2.8	*1.0*
Non-designated marginal upland	2.4	*0.9*	4.1	*1.0*	2.8	*0.4*
Combined designated	2.5	*1.4*	3.7	*1.9*	3.1	*0.7*
Combined non-designated	2.3	*1.1*	4.0	*1.2*	2.8	*0.5*
Combined true upland	2.8	*2.0*	3.9	*2.4*	3.2	*1.0*
Combined marginal upland	2.4	*1.1*	3.7	*1.5*	2.9	*0.5*
Total	*2.5*	*1.4*	*3.7*	*1.8*	*3.0*	*0.7*

Plot classes (PC)L–V represent the upland types – see Table 4.5

Number of different plot classes

4.9.2 The classification of quadrats into 'plot classes' can be used to consider the average range of vegetation present in each square, ie the higher the mean number of classes present in squares in a strata, the greater the variety of acid semi-natural vegetation (Table 4.9). For the main plots (randomly located), the true uplands have both the highest number of different plot classes (in the designated stratum) and the lowest (in the non-designated stratum). This is in line with the information from the land cover estimates and relative abundance of structural types, which have all shown the non-designated true upland stratum to be very uniform (based on a small sample of squares). In the marginal uplands, there is little difference between the designated and non-designated strata.

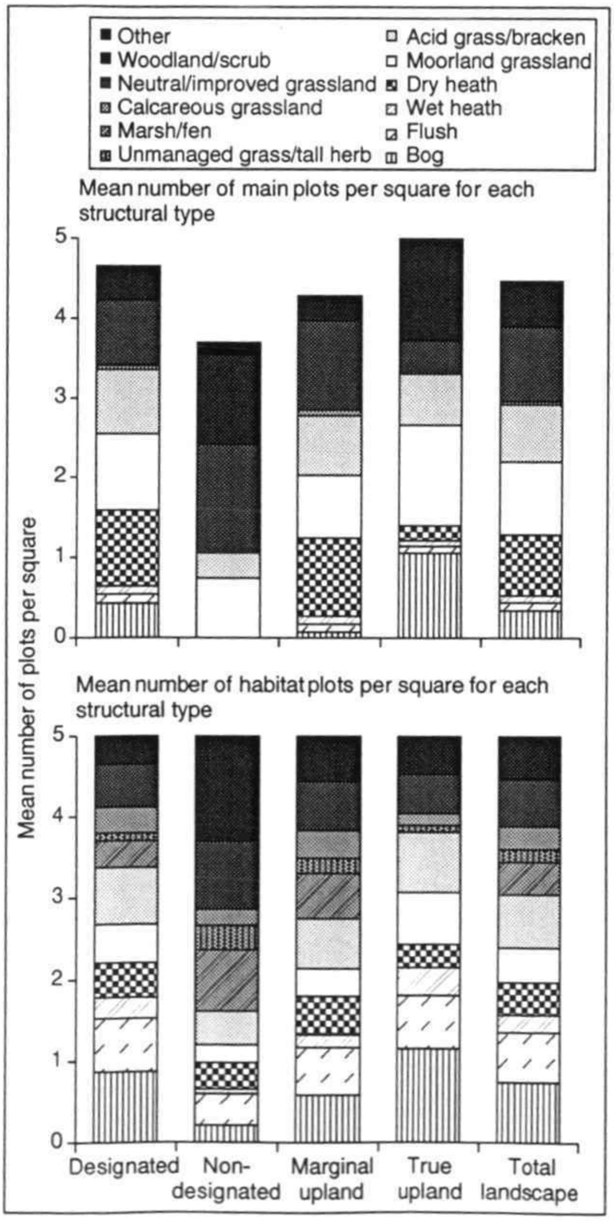


Figure 4.5 Abundance of structural types in the upland mask

4.9.3 The habitat plots show more diversity than the main plots, indicating that there are more habitats present, but some were too small to be represented by random plots. In this case, there is less difference between strata. The stream plots show a level of diversity intermediate between the main plots and habitat plots; streamsides in the designated and true upland strata are somewhat more diverse than those in the non-designated and marginal upland strata.

4.9.4 The number of different plot classes representing specific upland vegetation (PCL–PCV) shows a clearer relationship with the strata. In terms of these plot classes, the true uplands are significantly more diverse than the marginal uplands, and the designated than the non-designated strata. (See Section 4.11 below for discussion of differences in the composition of plot classes between strata).

Number of different species groups

4.9.5 Table 4.10 uses the classification of species into 'species groups' to consider the range of different types of species present in each square. There is no simple relationship between the number of species groups present in a square and designation or upland type. For the main plots, the

Table 4.10 Mean number of species groups represented per square

Strata	Main plots		Habitat plots		Stream plots	
	All SGs	*SG 5–8*	All SGs	*SG 5–8*	All SGs	*SG 5–8*
Combined non-designated	2.3	*1.1*	4.0	*1.2*	2.8	*0.5*
Designated true upland	6.5	*3.7*	6.6	*3.7*	7.2	*6.7*
Designated marginal upland	6.2	*3.1*	6.8	*3.4*	5.8	*5.3*
Non-designated true upland	5.3	*3.3*	6.8	*3.8*	6.5	*6.3*
Non-designated marginal upland	6.2	*2.9*	6.8	*3.2*	6.2	*4.7*
Combined designated	6.3	*3.3*	6.8	*3.5*	6.2	*5.7*
Combined non-designated	6.1	*3.0*	6.8	*3.3*	6.2	*5.0*
Combined true upland	6.4	*3.7*	6.6	*3.7*	7.1	*6.7*
Combined marginal upland	6.2	*3.1*	6.8	*3.3*	5.8	*5.1*
Total	*6.2*	*3.3*	*6.8*	*3.4*	*6.2*	*5.6*

Species groups (SG)5–8 represent the upland types – see Table 4.5

designated true uplands are the most diverse and the non-designated true uplands the least diverse – this is the same pattern as for the plot classes. The habitat plots are more diverse than the main plots (especially in view of their smaller size, 4 m^2 compared to 200 m^2), showing that there are some additional species groups present in the less common habitats. The stream plots (10 m x 1 m) are in some cases more diverse, in other less diverse, than the main and habitat plots. In terms of the more upland species groups (SG5–8), the true uplands are more diverse than the marginal uplands, and the designated strata than the non-designated. (See Section 4.11 for more detailed discussion of species group composition).

Summary of diversity as a quality criterion

4.9.6 In Britain as a whole, the marginal uplands are said to be more diverse than the true uplands (eg Barr *et al.* 1993), because they include both upland and lowland habitats in a small-scale pattern; this contrasts to the true uplands which have extensive areas of fairly uniform blanket bog, or heather moorland. However, the current analysis shows that, in England, higher species diversity is to be found in the true uplands, particularly of moorland vegetation types and species groups.

4.10 Vegetation quality: naturalness

4.10.1 'Natural' is a term sometimes applied to vegetation which is considered to be unmodified by human influence – it probably cannot be strictly applied to any habitat in England. The uplands include a number of semi-natural habitats of conservation interest, but the most widespread is moorland dominated by dwarf shrub heath, including areas of wet heath, bog and flush. Other important habitats, such as deciduous woodlands and upland tarns, occur too infrequently to be sufficiently represented in this dataset, so would need to be targeted specifically. 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 moorland. Too little 'modification' may allow succession to scrub and woodland, too much will move the vegetation towards grassland. Such modification or disturbance is indicated by the presence of species which are not normally associated with moorland, eg grassland species like rye-grass (*Lolium perenne*), which in a moorland context might indicate eutrophication and/or over-grazing. 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

4.10.2 The classification into 'habitat indicator types' has been used to examine the relative importance of species associated with different types of habitat. Table 4.11 shows the mean number of species of each 'habitat indicator type' per quadrat, for each stratum, for each plot type. For the main plots (representative of the more common habitats), the greatest differences were between true upland and marginal upland strata, the former having a greater proportion of species associated with moorland and bog/acid flushes and a lower proportion of neutral/improved grassland species. The designated strata also have more moorland species and fewer neutral/improved grassland species. The same pattern is shown by the habitat plots. The main difference between the habitat and main plots is the greater proportion of streamside/marsh species and base-rich grassland/flush species in the former, reflecting the inclusion of less common habitats. The stream plots included the same number of species groups as the main

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

	Designated				Non-designated				Total				Total					
	True upland		Marginal		True upland		Marginal		Designated		Non-designated		True upland		Marginal		Total	
Habitat indicator groups	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Main plots (200 m²)																		
Woodland/scrub species	2.1	*8*	1.7	*8*	1.5	*7*	2.3	*8*	1.8	*8*	2.1	*8*	2.0	*8*	1.8	*8*	1.9	*8*
Base-rich grassland/flush species	0.4	*2*	0.5	*2*	0.3	*1*	0.5	*2*	0.5	*2*	0.5	*2*	0.4	*2*	0.5	*2*	0.5	*2*
Bog/acid flush species	3.4	*13*	1.3	*6*	4.0	*19*	1.1	*4*	1.9	*9*	1.6	*6*	3.4	*14*	1.2	*6*	1.9	*8*
Moorland species	9.2	*37*	5.8	*27*	5.6	*27*	5.6	*21*	6.8	*30*	5.6	*22*	8.7	*36*	5.7	*25*	6.6	*29*
Upland grass species	4.3	*17*	3.7	*17*	2.2	*11*	4.5	*17*	3.9	*17*	4.1	*16*	4.0	*16*	3.9	*17*	3.9	*17*
Streamside/marsh species	1.2	*5*	0.9	*4*	1.0	*5*	1.6	*6*	1.0	*4*	1.5	*6*	1.2	*5*	1.0	*5*	1.1	*5*
Neutral/improved grassland species	3.8	*15*	6.5	*30*	5.2	*25*	9.8	*37*	5.7	*25*	9.0	*35*	4.0	*16*	7.2	*32*	6.3	*27*
Weeds/alien species	0.7	*3*	1.0	*5*	1.3	*6*	1.4	*5*	0.9	*4*	1.4	*5*	0.8	*3*	1.1	*5*	1.0	*4*
All	*25.0*	*100*	*21.3*	*100*	*20.9*	*100*	*26.7*	*100*	*22.4*	*100*	*25.6*	*100*	*24.5*	*100*	*22.5*	*100*	*23.0*	*100*
Habitat plots (4 m²)																		
Woodland/scrub species	1.2	*7*	1.3	*8*	2.3	*13*	1.9	*11*	1.3	*7*	2.0	*11*	1.3	*8*	1.4	*8*	1.4	*8*
Base-rich grassland/flush species	1.2	*7*	0.9	*5*	0.2	*1*	0.7	*4*	1.0	*6*	0.6	*4*	1.1	*7*	0.8	*5*	0.9	*5*
Bog/acid flush species	2.3	*14*	1.8	*11*	3.3	*18*	0.5	*3*	2.0	*12*	1.0	*6*	2.4	*14*	1.5	*9*	1.8	*10*
Moorland species	4.6	*27*	3.7	*22*	5.0	*28*	2.8	*16*	4.0	*24*	3.2	*18*	4.7	*28*	3.5	*21*	3.9	*23*
Upland grass species	2.7	*16*	2.4	*14*	2.2	*12*	2.4	*13*	2.5	*15*	2.3	*13*	2.7	*16*	2.4	*14*	2.4	*14*
Streamside/marsh species	1.1	*7*	1.8	*10*	1.3	*7*	2.4	*14*	1.6	*9*	2.2	*13*	1.1	*7*	1.9	*11*	1.7	*10*
Neutral/improved grassland species	3.5	*21*	4.7	*28*	3.3	*18*	6.2	*35*	4.3	*26*	5.6	*32*	3.4	*20*	5.0	*29*	4.6	*27*
Weeds/alien species	0.2	*1*	0.4	*2*	0.5	*3*	0.6	*3*	0.4	*2*	0.6	*3*	0.2	*1*	0.4	*3*	0.4	*2*
All	*16.9*	*100*	*16.9*	*100*	*17.9*	*100*	*17.5*	*100*	*16.9*	*100*	*17.6*	*100*	*17.0*	*100*	*17.1*	*100*	*17.1*	*100*
Stream plots (10 m x 1 m)																		
Woodland/scrub species	2.2	*9*	2.8	*12*	2.5	*13*	5.1	*19*	2.6	*11*	4.6	*18*	2.2	*9*	3.3	*14*	3.0	*12*
Base-rich grassland/flush species	0.8	*3*	0.3	*1*	0.3	*1*	0.5	*2*	0.5	*2*	0.5	*2*	0.8	*3*	0.3	*1*	0.5	*2*
Bog/acid flush species	2.5	*10*	2.0	*9*	2.1	*11*	0.8	*3*	2.1	*9*	1.0	*4*	2.5	*10*	1.7	*7*	1.9	*8*
Moorland species	5.6	*22*	4.6	*20*	4.0	*21*	2.5	*9*	4.9	*21*	2.8	*11*	5.4	*22*	4.1	*17*	4.5	*19*
Upland grass species	3.5	*14*	3.5	*15*	2.0	*11*	2.6	*9*	3.5	*15*	2.4	*10*	3.3	*13*	3.3	*14*	3.3	*14*
Streamside/marsh species	3.9	*15*	3.6	*16*	2.3	*12*	5.3	*19*	3.7	*16*	4.7	*18*	3.7	*15*	4.0	*17*	3.9	*16*
Neutral/improved grassland species	6.3	*25*	5.3	*23*	5.0	*26*	8.5	*31*	5.6	*24*	7.8	*30*	6.1	*25*	6.0	*25*	6.0	*25*
Weeds/alien species	0.7	*3*	0.8	*4*	0.9	*5*	2.0	*7*	0.8	*3*	1.8	*7*	0.7	*3*	1.1	*5*	1.0	*4*
All	*25.5*	*100*	*22.9*	*100*	*18.9*	*100*	*27.2*	*100*	*23.7*	*100*	*25.7*	*100*	*24.7*	*100*	*23.8*	*100*	*24.1*	*100*

and habitat plots, but with a greater proportion of the streamside/marsh species.

Summary of naturalness as a quality criterion

4.10.3 Upland vegetation in the designated true upland stratum was of higher 'quality', having a greater proportion of exclusively moorland and bog species, whilst in the marginal upland strata such habitats were more vulnerable to replacement by grassland species.

4.11 Vegetation quality: representativeness

4.11.1 Representativeness involves using a classification of the range of vegetation being considered, 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

4.11.2 Using the number of main plots per square (Table 4.12) as a measure, the designated true uplands were dominated by moorland grass (PCO) and bog (PCU, PCV), mossy moorland (PCR – dominated by wavy hair-grass (*Deschampsia flexuosa*) and sheep's fescue (*Festuca ovina*)) and damp acid pasture (PCK). The non-designated true uplands had a lot more Sitka spruce (*Picea sitchensis*) planted on to moorland (PCP) and semi-improved grassland (PCD).

4.11.3 The marginal uplands were dominated by semi-improved grassland (PCD), especially the non-designated areas. Moorland grass (PCO) was common in both designated and non-designated areas. Damp acid pasture (PCK) and northern bog (PCV) were important in the designated areas, whilst Sitka (PCP) was more prevalent in the non-designated areas.

4.11.4 Mossy moorland (PCR), acid wet heath (PCS) and blanket bog (PCT) were restricted to the designated strata, and northern bog (PCV), dry heath (PCQ), and moorland grass (PCO) were also more frequent in designated squares . By contrast, Sitka (PCP) and wet heath/bog (PCU) were more frequent in non-designated squares. Wet heath/bog (PCU) was recorded only in the true upland squares, where mossy moorland (PCR) was also more common.

4.11.5 In general, plot classes A–K, which include habitats also found in the lowlands, were more common only in the non-designated marginal upland stratum. Plot classes L–V, which were more exclusively upland in character, were more common in the other three strata, but especially in the true upland strata where more than 70% of the plots fell in these classes.

4.11.6 A slightly lower proportion of the habitat plots (Table 4.13) came from plot classes L–V, compared to the main plots. This suggests that the main plots usually fell in upland habitats (represented by plot classes L–V), and that the habitat plots, which were used to add diversity to the total plot sample were targeted towards the less common lowland habitats (PCA–PCK). More streamsides (PCF and PCN), wet rushy pasture (PCJ) and limestone grassland (PCE) were recorded in habitat plots.

4.11.7 The streamside plots (Table 4.14) also had a higher proportion of plots from the lowland group (PCA–PCK) compared to the main plots. There were more plots in the moist woodlands (PCC) and neutral/calcareous woodlands (PCA), as well as marshy streamsides (PCF), enriched flushes PCH) and moorland streamsides (PCN).

Relative abundance of species groups

4.11.8 The mean number of species per quadrat for each species group is given in Table 4.15. For the main plots, 'moorland/bog species' (SG8) were most common in the designated true uplands. The difference between designated and non-designated was much more apparent for the true uplands. 'Peaty flush species' (SG5) were more common in the true uplands than the marginal uplands, with little difference between designated and non-designated strata. 'Acid grassland species' (SG6) and those on 'thin mineral soils' (SG2) were less common in the non-designated true uplands, but present at similar frequency in the other strata. 'Neutral grassland species' (SG1) were more common in the marginal uplands.

4.11.9 The habitat plots show quite similar patterns to the main plots, with species

Table 4.12 Mean number of main plots per square, in each plot class, by strata

Plot class	Description	Designated True upland Mean	%	Designated Marginal Mean	%	Non-designated True upland Mean	%	Non-designated Marginal Mean	%	Total Designated Mean	%	Total Non-designated Mean	%	Total True upland Mean	%	Total Marginal Mean	%	Total Mean	%
A	Neutral/calcareous woodlands (mainly ash)	0.00	*0*	0.04	*1*	0.00	*0*	0.00	*0*	0.03	*1*	0.00	*0*	0.00	*0*	0.03	*1*	0.02	*1*
B	Neutral permanent grassland	0.00	*0*	0.00	*0*	0.00	*0*	0.08	*2*	0.00	*0*	0.06	*2*	0.00	*0*	0.02	*0*	0.01	*0*
C	Moist woodlands (mainly alder)	0.09	*2*	0.00	*0*	0.00	*0*	0.00	*0*	0.03	*1*	0.00	*0*	0.08	*2*	0.00	*0*	0.02	*0*
D	Semi-improved grassland	0.22	*4*	1.00	*22*	1.25	*25*	1.15	*34*	0.76	*16*	1.17	*32*	0.35	*7*	1.03	*24*	0.84	*19*
E	Limestone grassland	0.13	*3*	0.17	*4*	0.00	*0*	0.08	*2*	0.16	*3*	0.06	*2*	0.11	*2*	0.15	*3*	0.14	*3*
F	Marshy streamsides	0.00	*0*	0.00	*0*	0.00	*0*	0.08	*2*	0.00	*0*	0.06	*2*	0.00	*0*	0.02	*0*	0.01	*0*
G	Acid woodlands (oak, sycamore and birch)	0.04	*1*	0.17	*4*	0.00	*0*	0.08	*2*	0.13	*3*	0.06	*2*	0.04	*1*	0.15	*3*	0.12	*3*
H	Enriched flushes	0.09	*2*	0.00	*0*	0.00	*0*	0.08	*2*	0.03	*1*	0.06	*2*	0.08	*2*	0.02	*0*	0.03	*1*
I	Acid grassland – short fine turf	0.04	*1*	0.04	*1*	0.00	*0*	0.00	*0*	0.04	*1*	0.00	*0*	0.04	*1*	0.03	*1*	0.03	*1*
J	Wet rushy pasture	0.00	*0*	0.08	*2*	0.00	*0*	0.15	*5*	0.06	*1*	0.13	*3*	0.00	*0*	0.10	*2*	0.07	*2*
K	Damp acid pasture	0.57	*11*	0.63	*14*	0.00	*0*	0.31	*9*	0.61	*13*	0.25	*7*	0.49	*10*	0.56	*13*	0.54	*12*
L	Upland grassland	0.09	*2*	0.25	*6*	0.25	*5*	0.31	*9*	0.20	*4*	0.30	*8*	0.11	*2*	0.26	*6*	0.22	*5*
M	Acid flushes	0.17	*3*	0.13	*3*	0.50	*10*	0.08	*2*	0.14	*3*	0.16	*4*	0.21	*4*	0.11	*3*	0.14	*3*
N	Moorland streamsides	0.04	*1*	0.00	*0*	0.00	*0*	0.08	*2*	0.01	*0*	0.06	*2*	0.04	*1*	0.02	*0*	0.02	*1*
O	Moorland grass	1.22	*24*	0.67	*15*	0.00	*0*	0.38	*11*	0.83	*18*	0.31	*9*	1.06	*21*	0.61	*14*	0.73	*16*
P	Sitka planted on to moorland	0.43	*9*	0.04	*1*	1.00	*20*	0.38	*11*	0.16	*3*	0.50	*14*	0.51	*10*	0.12	*3*	0.22	*5*
Q	Dry heath	0.17	*3*	0.38	*8*	0.00	*0*	0.08	*2*	0.31	*7*	0.06	*2*	0.15	*3*	0.31	*7*	0.27	*6*
R	Mossy moorland	0.52	*10*	0.04	*1*	0.00	*0*	0.00	*0*	0.19	*4*	0.00	*0*	0.46	*9*	0.03	*1*	0.15	*3*
S	Acid wet heath (*Juncus squarrosus*)	0.04	*1*	0.04	*1*	0.00	*0*	0.00	*0*	0.04	*1*	0.00	*0*	0.04	*1*	0.03	*1*	0.03	*1*
T	Blanket bog	0.13	*3*	0.17	*4*	0.00	*0*	0.00	*0*	0.16	*3*	0.00	*0*	0.11	*2*	0.13	*3*	0.13	*3*
U	Wet heath/bog	0.65	*13*	0.00	*0*	1.50	*30*	0.08	*2*	0.20	*4*	0.34	*9*	0.76	*15*	0.02	*0*	0.22	*5*
V	Northern bog	0.35	*7*	0.67	*15*	0.50	*10*	0.00	*0*	0.57	*12*	0.09	*3*	0.37	*7*	0.52	*12*	0.48	*11*
Plot classes A–K (overlap with lowlands)		1.17	*23*	2.13	*47*	1.25	*25*	2.00	*59*	1.84	*40*	1.86	*51*	1.18	*24*	2.10	*49*	1.84	*41*
Plot classes L–V (more exclusively upland)		3.83	*77*	2.38	*53*	3.75	*75*	1.38	*41*	2.81	*61*	1.82	*50*	3.82	*76*	2.16	*51*	2.63	*59*
All		*5.00*	*100*	*4.50*	*100*	*5.00*	*100*	*3.38*	*100*	*4.65*	*100*	*3.68*	*100*	*5.00*	*100*	*4.26*	*100*	*4.47*	*100*

Table 4.13 Mean number of habitat plots per square, in each plot class, by strata

Plot class	Description	Designated True upland Mean	%	Designated Marginal Mean	%	Non-designated True upland Mean	%	Non-designated Marginal Mean	%	Total Designated Mean	%	Total Non-designated Mean	%	Total True upland Mean	%	Total Marginal Mean	%	Total Mean	%
A	Neutral/calcareous woodlands (mainly ash)	0.00	*0*	0.21	*4*	0.00	*0*	0.15	*3*	0.15	*3*	0.13	*3*	0.00	*0*	0.20	*4*	0.14	*3*
B	Neutral permanent grassland	0.13	*3*	0.13	*3*	0.25	*5*	0.31	*6*	0.13	*3*	0.30	*6*	0.15	*3*	0.16	*3*	0.16	*3*
C	Moist woodlands (mainly alder)	0.04	*1*	0.04	*1*	0.00	*0*	0.08	*2*	0.04	*1*	0.06	*1*	0.04	*1*	0.05	*1*	0.05	*1*
D	Semi-improved grassland	0.17	*3*	0.58	*12*	0.25	*5*	0.85	*17*	0.46	*9*	0.74	*15*	0.18	*4*	0.64	*13*	0.51	*10*
E	Limestone grassland	0.39	*8*	0.33	*7*	0.00	*0*	0.15	*3*	0.35	*7*	0.13	*3*	0.34	*7*	0.29	*6*	0.31	*6*
F	Marshy streamsides	0.04	*1*	0.33	*7*	0.00	*0*	0.54	*11*	0.25	*5*	0.44	*9*	0.04	*1*	0.38	*8*	0.28	*6*
G	Acid woodlands (oak, sycamore and birch)	0.00	*0*	0.17	*3*	0.50	*10*	0.62	*12*	0.12	*2*	0.59	*12*	0.06	*1*	0.26	*5*	0.21	*4*
H	Enriched flushes	0.35	*7*	0.08	*2*	0.00	*0*	0.23	*5*	0.16	*3*	0.19	*4*	0.30	*6*	0.11	*2*	0.17	*3*
I	Acid grassland – short fine turf	0.22	*4*	0.17	*3*	0.25	*5*	0.15	*3*	0.18	*4*	0.17	*3*	0.22	*4*	0.16	*3*	0.18	*4*
J	Wet rushy pasture	0.04	*1*	0.50	*10*	0.00	*0*	0.62	*12*	0.36	*7*	0.50	*10*	0.04	*1*	0.52	*10*	0.39	*8*
K	Damp acid pasture	0.26	*5*	0.13	*3*	0.75	*15*	0.23	*5*	0.17	*3*	0.33	*7*	0.32	*6*	0.15	*3*	0.20	*4*
L	Upland grassland	0.17	*3*	0.25	*5*	0.25	*5*	0.15	*3*	0.23	*5*	0.17	*3*	0.18	*4*	0.23	*5*	0.22	*4*
M	Acid flushes	0.13	*3*	0.29	*6*	0.00	*0*	0.15	*3*	0.24	*5*	0.13	*3*	0.11	*2*	0.26	*5*	0.22	*4*
N	Moorland streamsides	0.43	*9*	0.08	*2*	0.25	*5*	0.08	*2*	0.19	*4*	0.11	*2*	0.41	*8*	0.08	*2*	0.17	*3*
O	Moorland grass	0.83	*17*	0.38	*8*	0.25	*5*	0.31	*6*	0.51	*10*	0.30	*6*	0.75	*15*	0.36	*7*	0.47	*9*
P	Sitka planted on to moorland	0.13	*3*	0.04	*1*	0.25	*5*	0.15	*3*	0.07	*1*	0.17	*3*	0.15	*3*	0.07	*1*	0.09	*2*
Q	Dry heath	0.13	*3*	0.21	*4*	0.00	*0*	0.08	*2*	0.18	*4*	0.06	*1*	0.11	*2*	0.18	*4*	0.16	*3*
R	Mossy moorland	0.13	*3*	0.04	*1*	0.00	*0*	0.15	*3*	0.07	*1*	0.13	*3*	0.11	*2*	0.07	*1*	0.08	*2*
S	Acid wet heath (*Juncus squarrosus*)	0.09	*2*	0.25	*5*	0.00	*0*	0.00	*0*	0.20	*4*	0.00	*0*	0.08	*2*	0.20	*4*	0.16	*3*
T	Blanket bog	0.26	*5*	0.13	*3*	0.25	*5*	0.00	*0*	0.17	*3*	0.05	*1*	0.26	*5*	0.10	*2*	0.14	*3*
U	Wet heath/bog	0.65	*13*	0.25	*5*	1.75	*35*	0.00	*0*	0.37	*7*	0.33	*7*	0.79	*16*	0.20	*4*	0.36	*7*
V	Northern bog	0.39	*8*	0.42	*8*	0.00	*0*	0.00	*0*	0.41	*8*	0.00	*0*	0.34	*7*	0.33	*7*	0.33	*7*
Plot classes A–K (overlap with lowlands)		1.65	*33*	2.67	*53*	2.00	*40*	3.92	*78*	2.36	*47*	3.57	*71*	1.70	*34*	2.94	*59*	2.59	*52*
Plot classes L–V (more exclusively upland)		3.35	*67*	2.33	*47*	3.00	*60*	1.08	*22*	2.64	*53*	1.43	*29*	3.30	*66*	2.06	*41*	2.41	*48*
All		*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*	*5.00*	*100*

Table 4.14 Mean number of streamside plots per square, in each plot class, by strata

Plot class	Description	Designated True upland Mean	%	Designated Marginal Mean	%	Non-designated True upland Mean	%	Non-designated Marginal Mean	%	Total Designated Mean	%	Total Non-designated Mean	%	Total True upland Mean	%	Total Marginal Mean	%	Total Mean	%
A	Neutral/calcareous woodlands (mainly ash)	0.00	*0*	0.29	*7*	0.00	*0*	0.54	*12*	0.20	*5*	0.44	*9*	0.00	*0*	0.34	*8*	0.25	*6*
B	Neutral permanent grassland	0.17	*4*	0.00	*0*	0.00	*0*	0.23	*5*	0.05	*1*	0.19	*4*	0.15	*3*	0.05	*1*	0.08	*2*
C	Moist woodlands (mainly alder)	0.17	*4*	0.25	*6*	0.25	*5*	0.85	*18*	0.23	*5*	0.74	*16*	0.18	*4*	0.38	*9*	0.32	*7*
D	Semi-improved grassland	0.04	*1*	0.13	*3*	0.75	*15*	0.46	*10*	0.10	*2*	0.52	*11*	0.13	*3*	0.20	*5*	0.18	*4*
E	Limestone grassland	0.04	*1*	0.00	*0*	0.00	*0*	0.08	*2*	0.01	*0*	0.06	*1*	0.04	*1*	0.02	*0*	0.02	*1*
F	Marshy streamsides	0.09	*2*	0.13	*3*	0.75	*15*	0.38	*8*	0.11	*3*	0.45	*10*	0.17	*3*	0.18	*4*	0.18	*4*
G	Acid woodlands (oak, sycamore and birch)	0.17	*4*	0.08	*2*	0.00	*0*	0.15	*3*	0.11	*3*	0.13	*3*	0.15	*3*	0.10	*2*	0.11	*3*
H	Enriched flushes	0.57	*12*	0.13	*3*	0.00	*0*	0.15	*3*	0.26	*6*	0.13	*3*	0.49	*10*	0.13	*3*	0.23	*5*
I	Acid grassland – short fine turf	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*
J	Wet rushy pasture	0.22	*4*	0.75	*18*	0.00	*0*	0.69	*15*	0.59	*13*	0.56	*12*	0.19	*4*	0.74	*17*	0.58	*13*
K	Damp acid pasture	1.17	*24*	0.83	*20*	0.25	*5*	0.46	*10*	0.94	*21*	0.42	*9*	1.06	*22*	0.75	*18*	0.84	*19*
L	Upland grassland	0.17	*4*	0.17	*4*	0.00	*0*	0.08	*2*	0.17	*4*	0.06	*1*	0.15	*3*	0.15	*3*	0.15	*3*
M	Acid flushes	0.30	*6*	0.08	*2*	0.75	*15*	0.00	*0*	0.15	*3*	0.14	*3*	0.36	*7*	0.07	*2*	0.15	*3*
N	Moorland streamsides	0.52	*11*	0.50	*12*	0.75	*15*	0.38	*8*	0.51	*11*	0.45	*10*	0.55	*11*	0.48	*11*	0.50	*11*
O	Moorland grass	0.26	*5*	0.04	*1*	0.00	*0*	0.00	*0*	0.11	*2*	0.00	*0*	0.23	*5*	0.03	*1*	0.09	*2*
P	Sitka planted on to moorland	0.09	*2*	0.00	*0*	0.25	*5*	0.08	*2*	0.03	*1*	0.11	*2*	0.11	*2*	0.02	*0*	0.04	*1*
Q	Dry heath	0.00	*0*	0.29	*7*	0.00	*0*	0.00	*0*	0.20	*5*	0.00	*0*	0.00	*0*	0.23	*5*	0.16	*4*
R	Mossy moorland	0.04	*1*	0.08	*2*	0.00	*0*	0.00	*0*	0.07	*2*	0.00	*0*	0.04	*1*	0.07	*2*	0.06	*1*
S	Acid wet heath (*Juncus squarrosus*)	0.22	*4*	0.21	*5*	0.00	*0*	0.00	*0*	0.21	*5*	0.00	*0*	0.19	*4*	0.16	*4*	0.17	*4*
T	Blanket bog	0.22	*4*	0.04	*1*	0.00	*0*	0.00	*0*	0.09	*2*	0.00	*0*	0.19	*4*	0.03	*1*	0.08	*2*
U	Wet heath/bog	0.30	*6*	0.00	*0*	0.75	*15*	0.08	*2*	0.09	*2*	0.20	*4*	0.36	*7*	0.02	*0*	0.11	*3*
V	Northern bog	0.09	*2*	0.21	*5*	0.50	*10*	0.00	*0*	0.17	*4*	0.09	*2*	0.14	*3*	0.16	*4*	0.16	*4*
Plot classes A–K (overlap with lowlands)		2.65	*54*	2.58	*61*	2.00	*40*	4.00	*87*	2.60	*59*	3.63	*77*	2.57	*53*	2.89	*67*	2.80	*63*
Plot classes L–V (more exclusively upland)		2.22	*46*	1.63	*39*	3.00	*60*	0.62	*13*	1.80	*41*	1.06	*23*	2.32	*47*	1.41	*33*	1.66	*37*
All		*4.87*	*100*	*4.21*	*100*	*5.00*	*100*	*4.62*	*100*	*4.41*	*100*	*4.69*	*100*	*4.89*	*100*	*4.30*	*100*	*4.46*	*100*

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

Species group	Description	Designated True upland Mean	%	Designated Marginal Mean	%	Non-designated True upland Mean	%	Non-designated Marginal Mean	%	Total Designated Mean	%	Total Non-designated Mean	%	Total True upland Mean	%	Total Marginal Mean	%	Total Mean	%
Main plots (200 m²)																			
1	Neutral grassland species	1.9	*9*	3.6	*22*	3.1	*18*	5.2	*25*	3.1	*18*	4.8	*24*	2.0	*10*	3.9	*23*	3.4	*19*
2	Grassland species on thin mineral soils	0.6	*3*	0.5	*3*	0.4	*2*	0.7	*3*	0.5	*3*	0.6	*3*	0.5	*3*	0.5	*3*	0.5	*3*
3	Marsh/streamside species	1.3	*7*	1.9	*12*	1.5	*9*	2.7	*13*	1.8	*10*	2.4	*12*	1.3	*7*	2.1	*12*	1.9	*11*
4	Bracken/shady banks species	1.9	*10*	2.1	*13*	1.4	*8*	3.0	*15*	2.0	*12*	2.7	*14*	1.8	*9*	2.3	*13*	2.2	*12*
5	Peaty flush species	0.7	*4*	0.4	*2*	0.6	*4*	0.4	*2*	0.5	*3*	0.4	*2*	0.7	*4*	0.4	*2*	0.5	*3*
6	Acid grassland species	4.7	*23*	3.3	*20*	1.9	*11*	4.0	*20*	3.7	*21*	3.6	*18*	4.3	*22*	3.4	*20*	3.7	*21*
7	Woodland species/humid mosses	2.9	*15*	1.2	*7*	3.4	*20*	1.5	*7*	1.7	*10*	1.8	*9*	3.0	*15*	1.2	*7*	1.7	*10*
8	Moorland/bog species	6.1	*30*	3.3	*20*	4.7	*28*	3.0	*14*	4.2	*24*	3.3	*17*	5.9	*30*	3.2	*19*	4.0	*22*
All		*20.1*	*100*	*16.2*	*100*	*16.7*	*100*	*20.4*	*100*	*17.4*	*100*	*19.7*	*100*	*19.7*	*100*	*17.1*	*100*	*17.8*	*100*
Habitat plots (4 m²)																			
1	Neutral grassland species	1.7	*13*	2.1	*17*	1.4	*10*	2.6	*21*	2.0	*16*	2.4	*19*	1.7	*13*	2.2	*18*	2.0	*16*
2	Grassland species on thin mineral soils	0.9	*7*	0.6	*5*	0.2	*1*	0.5	*4*	0.7	*6*	0.4	*3*	0.8	*6*	0.6	*5*	0.7	*5*
3	Marsh/streamside species	1.0	*8*	1.9	*15*	1.5	*11*	2.6	*21*	1.6	*13*	2.4	*19*	1.0	*8*	2.0	*16*	1.7	*14*
4	Bracken/shady banks species	1.2	*9*	1.4	*11*	2.0	*14*	2.2	*18*	1.3	*11*	2.1	*17*	1.3	*10*	1.5	*12*	1.5	*12*
5	Peaty flush species	0.6	*5*	0.8	*6*	0.6	*4*	0.3	*3*	0.7	*6*	0.4	*3*	0.6	*5*	0.7	*6*	0.7	*5*
6	Acid grassland species	2.8	*22*	2.3	*19*	2.1	*15*	2.1	*17*	2.5	*20*	2.1	*17*	2.7	*21*	2.3	*18*	2.4	*19*
7	Woodland species/humid mosses	1.2	*9*	0.7	*5*	1.8	*13*	0.5	*4*	0.8	*6*	0.8	*6*	1.2	*10*	0.6	*5*	0.8	*6*
8	Moorland/bog species	3.4	*27*	2.7	*22*	4.3	*31*	1.3	*11*	2.9	*23*	1.9	*15*	3.5	*27*	2.4	*19*	2.7	*22*
All		*12.7*	*100*	*12.4*	*100*	*13.8*	*100*	*12.1*	*100*	*12.5*	*100*	*12.4*	*100*	*12.8*	*100*	*12.4*	*100*	*12.5*	*100*
Streamside plots (10 m x 1 m)																			
1	Neutral grassland species	2.4	*12*	1.9	*11*	2.0	*14*	3.0	*17*	2.1	*12*	2.8	*16*	2.3	*12*	2.1	*12*	2.2	*12*
2	Grassland species on thin mineral soils	0.7	*4*	0.5	*3*	0.3	*2*	0.6	*3*	0.6	*3*	0.5	*3*	0.6	*3*	0.5	*3*	0.6	*3*
3	Marsh/streamside species	3.6	*18*	3.1	*18*	2.2	*15*	4.3	*24*	3.3	*18*	3.9	*23*	3.4	*18*	3.4	*20*	3.4	*19*
4	Bracken/shady banks species	2.7	*14*	3.2	*19*	3.2	*22*	5.4	*30*	3.1	*17*	5.0	*29*	2.8	*15*	3.7	*21*	3.4	*19*
5	Peaty flush species	1.2	*6*	1.1	*7*	0.7	*5*	0.5	*3*	1.2	*6*	0.6	*3*	1.2	*6*	1.0	*6*	1.0	*6*
6	Acid grassland species	3.9	*20*	3.2	*19*	1.4	*10*	2.0	*11*	3.4	*19*	1.8	*11*	3.6	*19*	2.9	*17*	3.1	*18*
7	Woodland species/humid mosses	0.9	*5*	0.5	*3*	1.1	*8*	0.4	*2*	0.6	*3*	0.5	*3*	0.9	*5*	0.5	*3*	0.6	*3*
8	Moorland/bog species	4.0	*21*	3.5	*20*	3.7	*25*	1.7	*9*	3.6	*20*	2.1	*12*	4.0	*21*	3.1	*18*	3.3	*19*
All		*19.5*	*100*	*17.1*	*100*	*14.6*	*100*	*17.9*	*100*	*17.8*	*100*	*17.2*	*100*	*18.8*	*100*	*17.3*	*100*	*17.7*	*100*

groups recorded in similar proportions. The streamside plots have a greater proportion of 'marsh/streamside species' (SG3) and 'bracken/shady bank species' (SG4). These were most common in the non-designated marginal upland stratum.

Summary of representativeness as a quality criterion

4.11.10 The upland mask was dominated by moorland and bog vegetation, and acid grasslands, but also included a variety of more lowland habitats. The true upland strata were dominated by the specifically upland plot classes (PCL–PCV), whilst the non-designated marginal upland stratum had a higher proportion of vegetation types which are also found in the lowlands (PCA–PCK). For each upland type, the designated stratum had a higher proportion of moorland vegetation. The same pattern was reflected by the species groups, with more moorland and bog species in the true uplands and more neutral grassland species in the marginal uplands.

4.12 Rarity

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

4.12.2 Species rarity: the vascular species recorded have been checked against the *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). No *Red Data Book* species were recorded but the following 'Nationally scarce' species were recorded: bog-rosemary (*Andromeda polifolia*), shady horsetail (*Equisetum pratense*), wood fescue (*Festuca altissima,) Homalothecium nitens* (moss), vernal sandwort (*Minuartia verna*), bird's eye primrose (*Primula farinosa*), blue moor-grass (*Sesleria albicans*)

4.13 Fragility

4.13.1 Fragility reflects the degree of sensitivity of vegetation types and species to environmental change. Four types of change have been considered which may adversely affect upland vegetation:
- succession;
- grazing;
- drying out;
- eutrophication (see Chapter 2).

4.13.2 Upland species, especially in moorlands, which are sensitive to each of these four 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. For all four processes, and all plot types, the designated strata

Table 4.16 Mean number of species per plot, for each fragility type, by strata

Threat	Plot type	Designated True upland	Designated Marginal upland	Non-designated True upland	Non-designated Marginal upland	Total Desig	Total Non-desig	Total True upland	Total Marginal upland	Total
Succession	Main plots (200 m²)	0.99	0.90	0.65	0.59	0.93	0.60	0.95	0.83	0.86
	Habitat plots (4 m²)	0.43	0.39	0.35	0.28	0.40	0.29	0.42	0.37	0.38
	Stream plots (10 m x 1 m)	0.23	0.39	0.45	0.18	0.34	0.23	0.26	0.35	0.32
Grazing	Main plots (200 m²)	0.46	0.42	0.35	0.09	0.43	0.14	0.45	0.35	0.37
	Habitat plots (4 m²)	0.26	0.29	0.55	0.11	0.28	0.19	0.30	0.25	0.26
	Stream plots (10 m x 1 m)	0.24	0.26	0.15	0.03	0.26	0.06	0.23	0.22	0.22
Drying out	Main plots (200 m²)	4.87	2.32	4.85	2.66	3.09	3.07	4.87	2.40	3.09
	Habitat plots (4 m²)	3.30	2.83	4.25	1.68	2.97	2.16	3.42	2.59	2.82
	Stream plots (10 m x 1 m)	4.19	3.45	3.40	1.90	3.67	2.18	4.09	3.12	3.39
Eutrophication	Main plots (200 m²)	14.70	9.87	9.55	10.39	11.33	10.23	14.05	9.98	11.12
	Habitat plots (4 m²)	8.29	6.74	8.65	5.26	7.21	5.89	8.33	6.42	6.96
	Stream plots (10 m x 1 m)	10.04	8.82	6.55	5.02	9.19	5.30	9.61	8.01	8.46

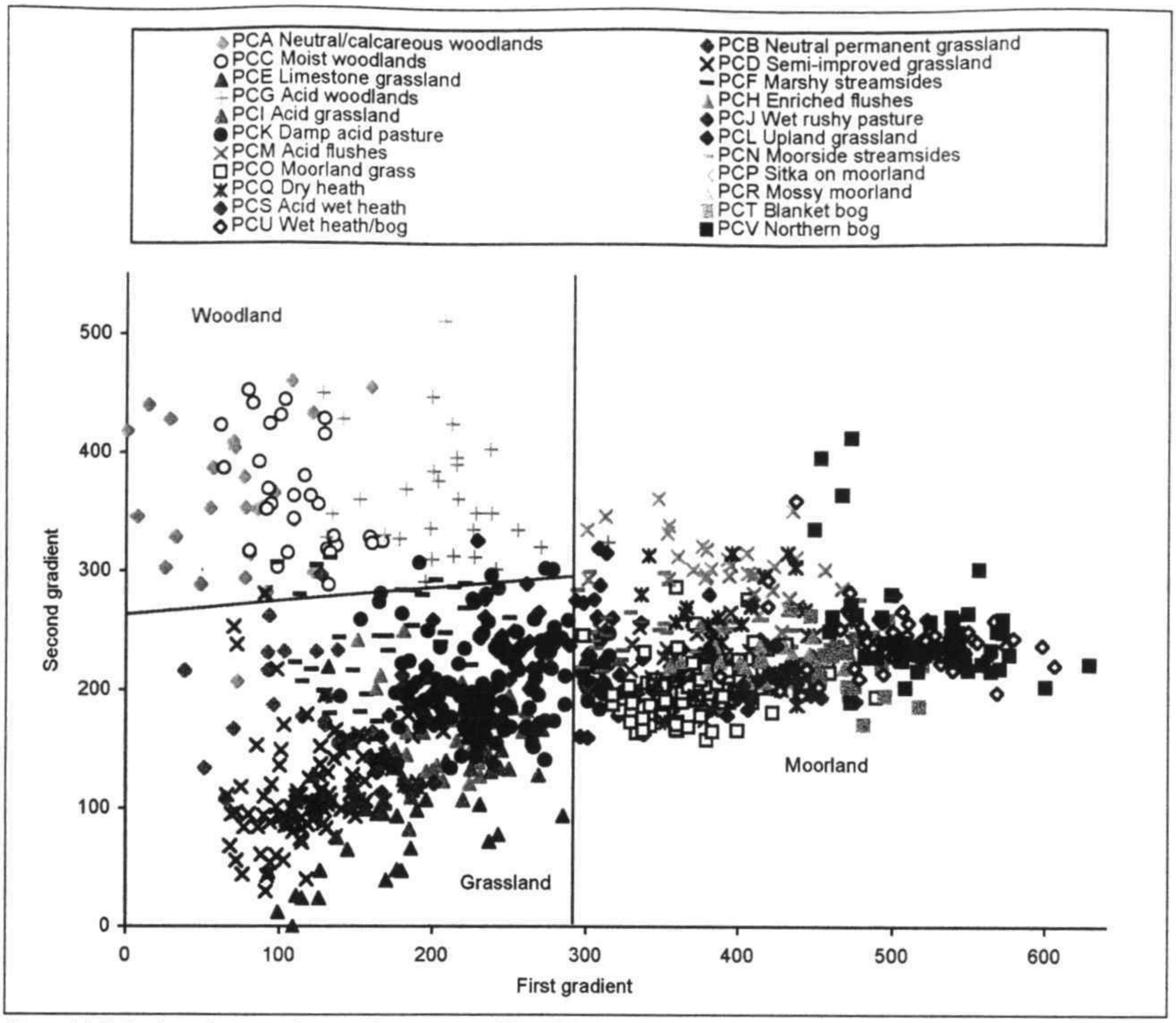


Figure 4.6 Upland quadrats – ordination diagram using DECORANA scores

tended to have a higher proportion of the sensitive species than the non-designated strata (Table 4.16). The true uplands also had a higher proportion than the marginal uplands.

4.14 Vegetation quality: potential value

4.14.1 The value of upland vegetation depends on the current vegetation type and on its potential for enhancement and restoration, the latter being affected by all the criteria discussed above.

4.14.2 'Non-upland elements' of the upland landscape can be divided into two types:.

i. Land cover types which have received high management inputs and whose vegetation no longer contains any moorland species (eg arable fields, improved grassland); although moorland 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 habitat creation schemes are shown in Appendix 1.

ii. Habitats which are derived from moorland or include heath species – if these are on appropriate soils, then moorland restoration may be feasible, and the process will incorporate the heath 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 heath vegetation was dominant.

4.14.3 The classification of quadrats into 'plot classes' can be used to separate acid bogs and moorland vegetation from more neutral or calcareous vegetation and woodland from grassland (Figure 4.6). By plotting the position of each quadrat on the first and second gradients, the relationship between plot classes can be shown. The right-hand side of the graph represents the moorland plot classes which are clearly separated from the rest, with overlap restricted to 'wet rushy pasture' (PCJ) and 'damp acid pasture' (PCK). This implies that those quadrats to the left of the graph represent environmental situations which are unsuitable for moorland vegetation. The plot classes on the 'moorland' (right-hand side) of the graph represent considerable variation, including grass-dominated vegetation and Sitka plantations.

4.14.4 It seems likely that it is the grass-dominated vegetation and Sitka plantations which offer the best opportunity for conversion or restoration to heather-dominated moorland. In some cases this might be achieved by reducing grazing pressure (eg from moorland grass (PCO) and mossy moorland (PCR) areas) or removing trees (from Sitka on moorland (PCP)). It is difficult to generalise as to the possibilities, because the soils, topography and management history vary considerably between, for example, the Cumbrian mountains, the Pennines and the North York Moors.

4.15 Quality criteria – ranking of heathland strata

4.15.1 Table 4.17 shows the results of ranking the four strata in terms of the quality measures discussed above. The true upland strata rank highest for all criteria, the designated stratum being ranked highest for 12 of the 17 criteria. Similarly, the designated marginal upland stratum, which is the largest stratum overall, and contains the greatest area of moorland vegetation, ranks consistently higher than its undesignated counterpart. In three criteria involving habitat plots, the non-designated true uplands were ranked top, suggesting that, where semi-natural upland vegetation exists in this stratum, it is of similar quality to that in the designated areas.

4.15.2 This form of non-parametric comparison is useful in terms of identifying the priorities for further upland habitat protection, although it does not, by definition, give measures of the relative importance of each stratum in terms of quality.

Table 4.17 Summary of upland strata ranked by quality criteria

	Designated		Non-designated	
Quality measures	True upland	Marginal upland	True upland	Marginal upland
Size				
Estimated area of upland vegetation	2	1	4	3
Number of main plots per square	1	3	1	4
Diversity				
Number of upland plot classes per square – main plots	1	3	2	4
Number of upland plot classes per square – habitat plots	1	3	2	4
Number of upland species groups per square – main plots	1	3	2	4
Number of upland species groups per square – habitat plots	2	3	1	4
Naturalness				
Number of moorland/bog habitat-indicator species – main plots	1	3	2	4
Number of moorland/bog habitat-indicator species – habitat plots	2	3	1	4
Representativeness				
Number of plots in upland plot classes – main plots	1	3	2	4
Number of plots in upland plot classes – habitat plots	1	3	2	4
Number of species in moorland/bog species groups – main plots	1	3	2	4
Number of species in moorland/bog species groups – habitat plots	2	3	1	4
Fragility				
Number of species sensitive to succession	1	2	3	4
Number of species sensitive to grazing	1	2	3	4
Number of species sensitive to drying out	1	4	2	3
Number of species sensitive to eutrophication	1	3	4	2
Number of criteria ranked first	12	1	4	0
Number of criteria ranked second	4	2	8	1
Number of criteria ranked third	0	12	2	2
Number of criteria ranked fourth	0	1	2	13

Table 4.18 Number of 1 km squares including designations in the upland mask

Designation	True upland No.	True upland *% of stratum*	Marginal upland No.	Marginal upland *% of stratum*	Upland mask No.	Upland mask *% of mask*
SSSI	891	*20*	1474	*13*	2365	*15*
NNR	112	*3*	56	*1*	168	*1*
ESA	218	*5*	897	*8*	1115	*7*
NP	1922	*44*	5683	*51*	7605	*49*
AONB	1774	*41*	2087	*19*	3861	*25*
HC	0	*0*	5	+	5	+
G Belt	23	*1*	997	*9*	1020	*7*
Any design	8832	*100*	3826	*100*	12658	*81*

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

4.16 Designations

4.16.1 The above discussion has considered designations as a whole, but clearly different types of designation may have different effects. Within the upland landscape, National Parks cover the largest area in the true upland stratum with AONBs also very significant; in the marginal uplands, National Parks are the most frequent designation, and AONBs are still significant (Table 4.18). SSSIs are important in both landscapes, but are more prevalent in the marginal uplands, whilst NNRs are more common in the true uplands. ESAs are also more common in the marginal uplands, Green Belts being largely restricted to them. Heritage Coasts are not a feature of the upland mask.

4.16.2 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 4.19). From a comparison of Tables 19 and 20 it will be noted that while the number of sample squares are in the same proportion to the overall stratum size, some categories are over-represented in the sample (SSSIs and National Parks in the true upland stratum), whilst others are under-represented (ESAs in the true upland stratum and SSSIs in the marginal upland stratum). This is because the sample was not stratified by designation type, and was not large enough to be fully representative; this needs to be considered in interpreting the results.

Table 4.19 Number of survey squares including designations

Designation	True upland No.	True upland *% of stratum*	Marginal upland No.	Marginal upland *% of stratum*	Upland mask No.	Upland mask *% of mask*
SSSI	7	*26*	3	*8*	10	*16*
NNR	1	*4*	0	*0*	1	*2*
ESA	0	*0*	3	*8*	3	*5*
NP	13	*48*	17	*47*	30	*47*
AONB	11	*41*	6	*17*	17	*27*
HC	0	*0*	0	*0*	0	*0*
G Belt	0	*0*	1	*3*	1	*2*
Any design	24	*100*	23	*100*	47	*73*

Table 4.20 Overlap between designations for sample squares

Designation						% of designated squares
SSSI	NNR	AONB				2%
SSSI			NP			19%
		AONB	NP			2%
		AONB				32%
			NP	ESA		6%
			NP			36%
					G Belt	2%

4.16.3 In addition, the situation is complicated by the overlap between designations (Table 4.20). Of the sample squares in the designated strata, 30% have more than one designation.

4.17 Conclusions

4.17.1 The upland mask (ie area with the potential for upland vegetation) was defined as an area of 15616 km^2; 81% of these 1 km squares contained one or more of the specified designations. Of this landscape, about 56% (8682 km^2) was estimated to be upland vegetation (ie vegetation types found mostly or exclusively in the uplands), 93% of which occurred in designated 1 km squares.

4.17.2 Analysis of the quadrat data showed that the true uplands, although smaller in extent, had a higher proportion of upland semi-natural habitats than the marginal uplands, and were more varied in terms of the number of different vegetation types recorded in random quadrats. Dry heath was more common in the marginal uplands, while the true uplands were dominated by moorland grass, bog and wet heath.

4.17.3 In addition to the true upland vegetation, modified upland vegetation types were identified which had been colonised or planted with trees, or converted to grass-dominated types. These areas occurred throughout the upland landscape, but were more common in undesignated areas. They may provide the best opportunity for expanding true moorland vegetation.

Chapter 5 HISTORICAL CHARACTERISTICS OF THE UPLAND MASK

5.1 Introduction

5.1.1 The archaeological study was designed to provide an 'evaluation of distribution of historic (archaeological) features in the upland mask 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 upland landscape;
ii. to assess the relationship between features and designations in the upland landscape;
iii. to develop recommendations for modifying designations to improve the protection of features.

5.2 Methodology

5.2.1 Two distinct types of archaeological data gathering were carried out: information 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; and
- 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

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

	Prehistoric	Palaeo	Mesolithic	Neolithic	Bronze Age	Iron Age	Roman	Early Medieval	Medieval	Post Medieval	Modern	Unknown
Agriculture and subsistence			1		1		1		2	7		26
Domestic	2				3		1		3	4		3
Civil												1
Recreation												2
Garden and parks										1		4
Commemorative												
Religious, ritual and funerary	1				5	1	1					3
Commercial												1
Industrial							1			23		20
Transport							1			2		2
Water and drainage												3
Maritime												
Defence									1	1		2
Object	1		1	1	1							1
Unassigned	2		2		1	1	1		2	1		20

* Royal Commission on the Historical Monuments of England

Table 5.2 Quality of features – form groups by period for the uplands

Form group	Prehis-toric	Palaeo	Meso-lithic	Neo-lithic	Bronze Age	Iron Age	Roman	Early Med-ieval	Med-ieval	Post Med-ieval	Mod-ern	Un-known
A-Structure	5								2	8		5
B-Ruin									2	1		2
C-Underground										1		
D-Feature										3		4
E-Earthwork			3		10	2	4		3	4		24
F-Crop/soil												
G-AP												6
H-Find	1		1	1	1							1
I-Doc/Oral							1		1	23		46
J-Exc/Rem							1					
Unspecified												

and its value was assessed. A work programme is shown in Appendix 2, together with a description of the available archaeological data

5.3 Analysis and results

The distribution of archaeological sites in the upland mask

5.3.1 The quantity of archaeological monuments is presented in Table 5.1 (with further details in Appendix 2). These data suggest that the uplands is characterised as follows.

- Prehistoric periods are poorly represented by 'find' sites (ie where objects have been found) together with Bronze Age hut circles and barrows.
- The Roman period is also poorly represented, with few features of various types.
- Representation of the Early Medieval period is absent.
- The Medieval period has some settlement sites, together with farms and field systems.
- The Post Medieval period is represented by a scattering of farms and a large amount of industrial activity in the form of extractive and lime-burning industries.

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.

5.3.2 Although some reference to the current condition of monuments is present in some SMR/NMR entries, it is widely variable and the only option is to examine 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 2, Table A2.3) for different archaeological periods (Table 5.2) shows a broad pattern, as might be expected. Structures and ruins are generally of recent date (the Prehistoric sites are standing stones). Earthworks form a significant group, with many undated. Crop/soil sites, AP sites and find sites are rare. Sites identified from documentary sources form the biggest group, 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 165 sites, 102 occur in 22 designated squares (4.6 km^{-2}), with 63 in ten non-designated squares (6.3 km^{-2}) (see Tables 5.3 & 5.4). There appears to be no correlation between designation status and density of sites.

5.3.5 Only four sites are Scheduled Ancient Monuments (SAMs), two of which were in National Parks. The four sites represent 2.4% of the total number of sites in the upland dataset.

5.3.6 Condition information was, as expected, severely limited. The location of this information within SMR structures is very variable and there is 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, such that recording over future decades will allow such analyses to be undertaken. Indeed, English Heritage is currently funding the Monuments at Risk Survey (MARS) project to compile precisely 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.

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

Data source	Designation	Total of sites	Mean km^{-2}
SMR/NMR	Yes	67	3.0
	No	36	3.6
Field survey	Yes	35	1.6
	No	27	2.7
Combined	Yes	102	4.6
sources	No	63	6.3

Table 5.4 Number of sites per square for each designation for the uplands

Designation	No. of sites	No. of squares	Sites km^{-2}
G Belt			
AONB	399	10	3.9
SSSI	13	5	2.6
NP	67	13	5.2
HC			
NNR			
ESA			

- 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 analysis of aerial photography and the fieldwork carried out as part of the current project were too limited to be of much 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 upland mask contains features from most historic periods, although representation of the Early Medieval period was absent. 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.

Chapter 6 PRESSURES FOR CHANGE: ATMOSPHERIC POLLUTION

6.1 Introduction

6.1.1 In Chapter 2 the existing and potential causes of change in the uplands are summarised (Section 2.9). Atmospheric pollution is considered here in detail, 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.

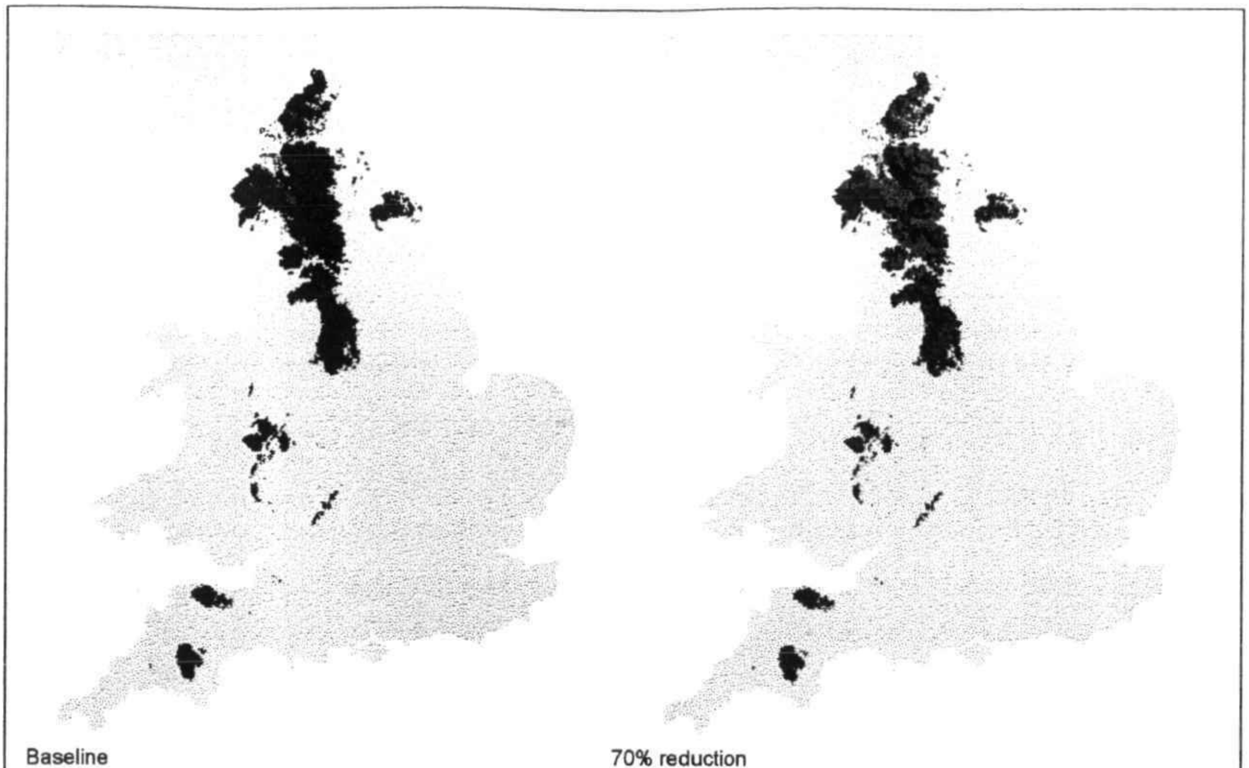
Results

6.2.4 As stated in Chapter 3, upland soils are generally acidic in nature and are relatively sensitive to acid deposition; as a result, they have low critical load values (Figure 6.1). During the period 1989–91, 95% of all areas within the upland mask was in exceeded areas. By comparison, in lowland England (as defined in Chapter 3), the soil acidity critical load was exceeded in only 57% of the total area.

6.2.5 The emissions reduction scenarios, as derived by HARM, appear to be relatively ineffective at protecting the upland areas of England (Table 6.1). Although the 70%

Table 6.1 Areas within the upland mask and lowland England affected by acid deposition. Figures show the percentage of 1 km squares in each area in which acid deposition exceeds the soils critical loads

Scenario	Marginal uplands Designated	Marginal uplands Non-desig	True uplands Designated	True uplands Non-desig	Total upland mask	Lowland England
Baseline: 1989–91 emissions	95%	92%	98%	94%	95%	57%
70% reduction from 1989–91 baseline	38%	17%	52%	37%	38%	11%
80% reduction from 1989–91 baseline	27%	14%	52%	34%	31%	7%
Total no. of 1 km squares	*8,832*	*2,408*	*3,826*	*550*	*15,616*	*115,759*



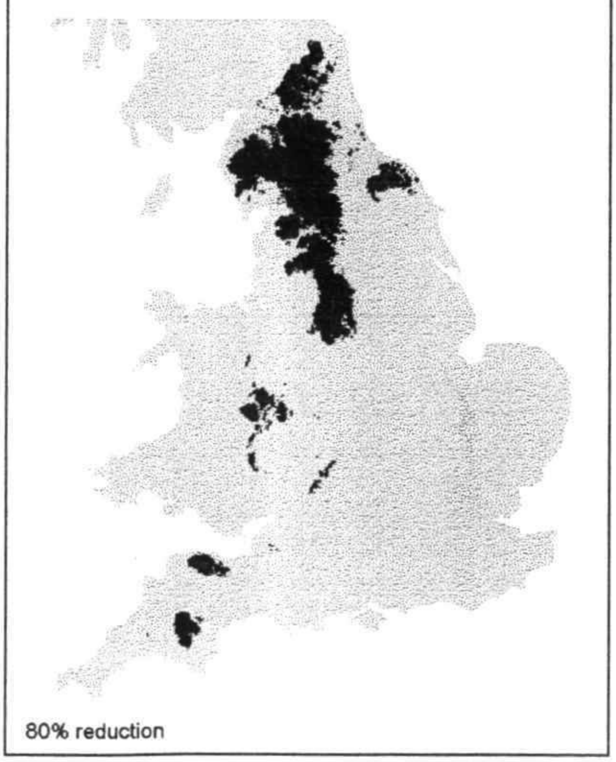


Figure 6.1 Areas within the upland mask where acidic deposition exceeds the critical load for soils under (i) 1989–91 baseline, (ii) 70% reduction by 2005 scenario, and (iii) 80% reduction by 2010. Black = exceeded areas, green = unexceeded areas (data source: CLAG Soils Sub-Group)

UNECE emissions reduction scenario would reduce the exceeded areas to 11% of lowland England (as defined by the ITE land classes), 38% of upland areas are still estimated to be at risk. An emission reduction of 80% would leave 7% of lowland England and 31% of the upland areas at risk. The main reason is that upland soils are often the most sensitive to acidification. The low critical loads threshold for these areas is consequently still exceeded, even though sulphur deposition may have been substantially reduced.

6.2.6 True upland squares containing designations are likely to benefit least from the emission reductions (Table 6.1). Under the 80% reduction scenario, the proportion of 1 km squares in the exceeded area fell by 46%, from 98% to 52%, compared to, say, a fall of 78%, from 92% to 14%, in marginal upland squares without designation.

6.2.7 There is insufficient quantitative information on the effects of sulphur deposition on upland fauna and flora to be certain of how damaging these exceedances will be to upland ecosystems as a whole. The critical load for individual species or assemblages may differ from the site critical load as determined from soils; for instance, many upland species are adapted to acid soils and may not be as disadvantaged by moderate increases in the levels of acid deposition. An indication of this effect comes from current work, where the critical loads approach is currently being developed for a range of species including heather, using a mass balance model (CLAG 1994). Preliminary results from this model (Figure 6.1) indicate that acid deposition, under the baseline scenario, will exceed the critical load for

Table 6.2 Areas within the upland mask and lowland England affected by acid deposition. Figures in the body of the Table show the percentage of 1 km squares in each area where acid deposition exceeds the critical load for heather

Scenario	Marginal uplands Designated	Marginal uplands Undesignated	True uplands Designated	True uplands Undesignated	Total upland mask
Baseline: 1989–91 emissions	27%	15%	47%	32%	30%
Total no. of 1 km squares	*8,832*	*2,408*	*3,826*	*550*	*15,616*

Table 6.3 Inputs of total atmospheric nitrogen to upland habitats in England

Region			% of 1 km squares receiving total atmospheric nitrogen (kg ha^{-1} yr^{-1}) >15	>20	>25	>30	>35
Upland mask	Marginal uplands	Designated	97%	80%	52%	37%	16%
		Undesignated	88%	67%	42%	20%	3%
	True uplands	Designated	97%	77%	46%	24%	20%
		Undesignated	85%	65%	20%	6%	0%
	All uplands		96%	76%	48%	30%	14%
Lowland England			82%	31%	4%	1%	0%

heather in 30% of the upland area (Table 6.2).

6.2.8 The impacts of acid deposition on upland vegetation have also been modelled using the TRISTAR approach. 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 upland areas 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 upland areas is 26 kg nitrogen ha^{-1} yr^{-1}, which is similar to the average for England (19 kg N ha^{-1} yr^{-1}). Over 96% of upland areas receive more than 15 kg N ha^{-1} yr^{-1}, and 76% receive over 20 kg N ha^{-1} yr^{-1} (Table 6.3; Figure 6.2).

6.3.3 Upland squares with designations are more likely to be receiving over 20 kg nitrogen ha^{-1} yr^{-1} than those in undesignated squares (Table 6.3).

6.3.4 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 the uplands of England. However, although not strictly comparable, experimental results from grasslands on peat

Figure 6.2 Areas of the upland mask receiving >20 kg N ha^{-1} yr^{-1} (light green), 20–30 kg N ha^{-1} yr^{-1} (dark green), or > 30 kg N ha^{-1} yr^{-1} (black) (data source: CLAG Soils Sub-Group)

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 the uplands, with gradual nutrient enrichment leading to a loss of plant species diversity. This is consistent with the conclusions of an international workshop held at Lokeberg, Sweden (Grennfelt & Thornelof 1992) which proposed that the critical load for nitrogen on lowland dry/heathland, as indicated by a transition from heather to grass, is in the range of 15–20 kg N ha^{-1} yr^{-1}.

6.3.5 The impacts of nitrogen deposition have been modelled using TRISTAR (TRIangular STrAtegic Rules for British herbaceous vegetation) (Hunt *et al.* 1991). Results from this work are described in Chapter 7.

6.4 Summary

6.4.1 The uplands tend to have soils which are relatively sensitive to the effects of acid deposition. Under the UNECE Convention to reduce atmospheric acid deposition by 70% by the year 2005, soils in 38% of the upland mask will remain at risk from excessive deposition, compared to 11% in lowland England. There is, however, some uncertainty about the consequences of this scenario for upland vegetation. The uplands are also at some risk from excessive atmospheric nitrogen deposition. Preliminary data show that they are receiving an average of 26 kg of atmospheric nitrogen ha^{-1} yr^{-1} and that, at this rate, gradual enrichment of upland soils leading to a loss of plant species and a transition from heather to grass is likely.

6.4.2 These and other potential pressures on the uplands 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 UPLAND 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 upland 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 22 plot classes as described in Chapter 4 (Section 4.4).

7.2.2 For each plot, one of 19 functional types (see Appendix 3) 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.

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 3 provides details of the

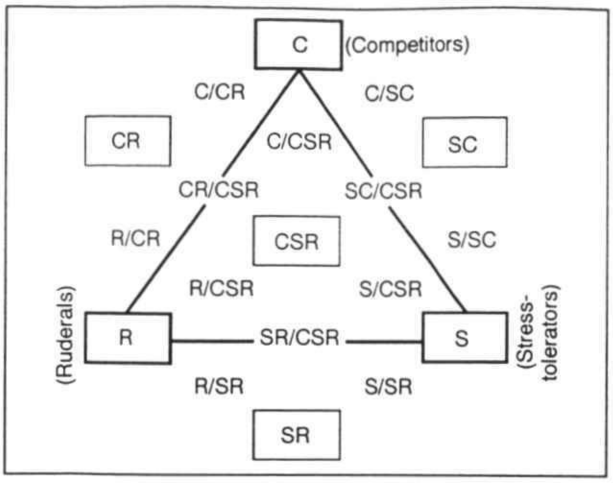


Figure 7.1 The C-S-R triangle ordination, showing the three principal functional types and intermediate positions

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, the English uplands are areas of low-growing vegetation and peat found at higher altitudes. In terms of vegetation, they comprise a diverse blend of fell, moor, meadow, pasture and woodland. A number of dwarf shrubs, particularly heather, are characteristic of the uplands as classically described.

7.2.7 Because the survey was of a broad upland mask, it contains a variety of habitat types. For the purposes of analysis of functional types, several plot classes do not conform to 'heathland' even in strategic terms and these have been divided into three groupings that relate to habitat type: woodland (PCA, PCC, PCG and PCP), grassland (PCB, PCD, PCE, PCI, PCK, PCL, PCO, PCQ and PCR), and wetland (PCF, PCH, PCJ, PCM, PCN and PCS–PCV). Grassland is further subdivided into relatively productive (PCB and PCD), with a high representation of functional type competitor/stress-tolerator/ruderal, and unproductive (PCE, PCI, PCK, PCL, PCO, PCQ and PCR) with high representation of type stress-tolerator. Unproductive includes both calcareous (PCE) and acidic grassland and heathland.

7.2.8 Of the woodland plot classes, PCA (neutral/calcareous woodlands – mainly ash) has the smallest representation of stress-tolerator species, a type which, in the context of woodland, is often associated with shade tolerance, and most species of type competitor. PCC (moist woodlands – mainly alder) has the greatest percentage of stress-tolerator/ruderal, and presumably most vernal species. Because the major check on growth of understorey species is shade, all woodland plot classes have a similar species composition in terms of functional types. However, there are probably inherent differences in the potential productivity of the soils. Woodlands on base-rich soils (PCA, PCC) are likely to be associated with greater levels of potential productivity than those on less acidic ones (PCG and PCP).

7.2.9 The more productive grassland classes (PCB and PCD) have a high representation of type competitor/stress-tolerator/ruderal and little of type stress-tolerator. In the remainder, 'unimproved' unproductive grassland (PCE, PCI, PCK, PCL, PCO, PCQ and PCR), type stress-tolerator is prevalent. PCE (limestone grassland), PCI (acidic grassland – short fine turf) and PCK (damp acidic pasture), with a high representation of competitor/stress-tolerator/ruderal, are perhaps the only three closely grazed variants of unproductive grassland. The remainder (PCL, PCO, PCQ and PCR) have a high representation of type stress-tolerator/competitor, a reflection of the presence of heather and related low shrubs and of a lower intensity or absence of grazing.

7.2.10 Wetland habitats (PCF, PCH, PCJ, PCM, PCN and PCS–PCV) are mostly unproductive with a predominance of types stress-tolerator/competitor and stress-tolerator. The most extreme in this respect are PCM and PCS–PCV. The only relatively productive class is PCF (marshy streamsides), with a high percentage of types competitor/ruderal and competitor/stress-tolerator/ruderal. The presence of type competitor/ruderal, and to a lesser extent type ruderal, may relate to disturbance due to flooding. These types are also well represented in PCH (enriched flushes). Type competitor/ruderal will include a number of species from near the water's edge, such as watercress (*Rorippa nasturtium-aquaticum*), which are able to regenerate from shoot fragments following damage associated with flooding. PCJ (wet rushy pasture) also has a high representation of types competitor/ruderal and ruderal. However, the class is somewhat intermediate between mire and grassland. It contains many competitor/stress-tolerator/ruderal species, the type most characteristic of grazed habitats.

7.2.11 In summary, the wide range of 'core' upland (unproductive) vegetation types was composed of stress-tolerator and stress-tolerator/competitor species. 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 3. Within this Chapter, summary results for only the core upland plot classes (PCL–PCV, as defined in Chapter 4 and omitting PCP, Sitka plantations) are described.

Scenario 1. Decreased disturbance and no change in eutrophication

7.3.4 Possible causes of this scenario, as it affects the core upland vegetation, include cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires, and less flooding. 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.

7.3.5 With respect to functional types, in the least productive grassland where growth rates are slow, small changes are expected, with stress-tolerator/ competitor the beneficiary at the expense of all other classes. For less productive, wetter habitats, stress-tolerator/competitor species are also likely to increase.

Scenario 2. Decreased disturbance and increased eutrophication

7.3.6 Possible causes of this scenario, as it affects the core upland vegetation, include cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires, together with increased fertilizer runoff or atmospheric deposition, and more flooding (although a reduction in flooding and subsequent scouring effects may be cause reduced disturbance in wetland habitats).

7.3.7 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). Taller, faster-growing vegetation should be produced and overall losses of types stress-tolerator and ruderals and an increased representation by type competitor are predicted. In neutral grassland there would be a loss of types stress-tolerator and of ruderals, together with an increased representation by type competitor, while in the less productive grassland types change will be slower, and competitor/stress-tolerator/ruderal and stress-tolerator/competitor will tend to increase at the expense of type stress-tolerator. For eutrophic wetland habitats, again an increase in type competitor is predicted. As in less productive grassland, type stress-tolerator/ competitor and competitor/stress-tolerator/ruderal, rather than type competitor, tend to increase in less productive mires.

Scenario 3. No change in disturbance and decreased eutrophication

7.3.8 Possible causes of this scenario, as it affects the core upland vegetation, include decreased usage and pollution from fertilizers; reduced flooding, if this did not affect the level of disturbance, could reduce nutrient inputs into the system.

7.3.9 Grassland and wetland habitats are expected to increases in type stress-tolerator and decrease in competitor, competitor/stress-tolerator/ruderal and ruderals (eg competitor/ruderal). However, any increase in type stress-tolerator, which grows very slowly, will take a considerable period and results may be less marked than predicted. In less productive vegetation, growth rates will already be slow and a major shift to type stress-tolerator is expected.

Scenario 4. No change in disturbance and increased eutrophication

7.3.10 Possible causes of this scenario, as it affects the core upland vegetation, include increased fertilizer runoff or atmospheric deposition and increased flooding (in the absence of appreciable disturbance).

7.3.11 Increased eutrophication is one of the most important scenarios to consider with respect to changing land use. In less productive grassland and wetland habitats, growth rates are slower and the predicted shift is away from type stress-tolerator and stress-tolerator/competitor.

Scenario 5. Increased disturbance and decreased eutrophication

7.3.12 Possible causes of this scenario, as it affects the core upland vegetation, include increased grazing or cutting, reduced incidence of fires, and increased recreational pressure, with less fertilizer runoff or atmospheric deposition. This scenario assumes only modest changes in disturbance and eutrophication.

7.3.13 In less productive grassland and wetland habitats, opportunities for species with short life cycles are more restricted. Type stress-tolerator/ruderal, particularly low-growing bryophytes, would be expected to be the main beneficiary of disturbance but little change is predicted here for many of the plot classes. The main impact of decreased eutrophication should be an increase in type stress-tolerator. However, this type grows very slowly and many species are poor colonists.

Scenario 6. Increased disturbance and increased eutrophication

7.3.14 Possible causes of this scenario, as it affects the core upland vegetation, include increased incidence of fires, more grazing, more recreational pressure, and increased flooding, with increased eutrophication fertilizer runoff or atmospheric deposition

7.3.15 For neutral grassland and wetland habitats, these impacts will particularly involve losses of competitor, stress-tolerator/competitor and competitor/stress-tolerator/ruderal type species and an increase in types ruderal and competitor/ruderal. However, in less productive grassland and acidic vegetation, greater losses of type stress-tolerator are predicted.

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 3 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 3 and a summary is given in Table 7.1.

7.4.3 Scenarios 1–4 all have low total indices of vulnerability, even where eutrophication increases. Within each scenario, some individual plot classes show moderate levels of vulnerability), specifically PCE (limestone grassland, PCH (enriched flushes) and PCI (acid grassland) (see Appendix 3).

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	-0.13	Low
2	Decreased disturbance; increased eutrophication (eg decline in grazing pressure with an increase in fertilizers)	0.13	Low
3	No change in disturbance; decreased eutrophication (eg no change in grazing pressure but a decrease in fertilizers)	-0.13	Low
4	No change in disturbance; increased eutrophication (eg no change in grazing pressure but an increase in fertilizers)	0.13	Low
5	Increased disturbance; decreased eutrophication (eg increase in grazing pressure with fewer fertilizers)	0.00	Low
6	Increased disturbance; increased eutrophication (eg increase in grazing pressure and an increase in fertilizers)	0.20	Medium

7.4.4 For scenario 5 (increased disturbance; decreased eutrophication), there is a wide range of susceptibilities. Although the mean index score is 0, moderate vulnerability is shown by classes PCB (neutral permanent grassland), PCC (moist woodlands, mainly alder), PCD (semi-improved grassland), PCF (marshy streamsides), PCG (acid woodlands), PCH (enriched flushes), PCI (acid grassland), PCJ (wet rushy pasture) , PCK (damp acid pasture) and PCU (wet heath/bog).

7.4.5 For scenario 6 (increased disturbance; increased eutrophication), over half of the classes have at least moderate values for index of vulnerability. Classes C (moist woodlands, mainly alder), E (limestone grassland), H (enriched flushes) and I (acid grassland) show high vulnerability.

7.5 Summary of modelling results

7.5.1 The upland mask includes a heterogeneous grouping of wetland, grassland and woodland. However, the individual vegetation types all have one thing in common; they are relatively unproductive. Ecological theory would suggest that all the 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 one class reaches '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 some plot classes showing high vulnerability.

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

Low/moderate impacts

- Disturbance decreased; eutrophication same (lowest impact)
- Disturbance same; eutrophication decreased
- Disturbance increased; eutrophication decreased
- Disturbance decreased; eutrophication increased
- Disturbance same; eutrophication increased

High impacts

- Disturbance increased; eutrophication increased (highest impact)

7.5.3 Although the differences between habitat groupings are relatively slight, grassland classes appear to be among the most vulnerable and woodland among the least vulnerable, with heath (both wet and dry) occupying an intermediate position. This sequence accords with expectation. Plot classes PCM (damp acid grassland) and PCI (grassy heath) have greatest average vulnerability, and PCH (dry heath often planted), PCL (plantation over bracken/ heath) and PCO (plantation often open) the least. However, vulnerability of individual plot classes differs markedly between scenarios. Predicted responses of particular plot classes must therefore be related to specific scenarios.

7.5.4 The uplands consist of a heterogeneous grouping of wetland, grassland and woodland vegetation, all 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 few classes of vegetation reaching even 'moderate' vulnerability. There is no significant difference in vulnerability between grassland, woodland or moorland vegetation in general, although both short, acid grassland and enriched flushes have higher vulnerability than most.

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 the uplands, reviews existing policy instruments, and assesses threats to this landscape type.

8.1.2 Upland landscapes are an attractive English landscape type supporting a variety of characteristic and nationally important habitat types, including heather moorland, bogs, springs and gills, flush and marsh, montane cliff, and native woodland. Hay meadows are also found in some valley bottoms and are a rare habitat, but are not included in this landscape mask. Some habitats only occur in very specialised environmental conditions and habitats such as blanket peat bogs are highly valued internationally. Dwarf shrub heath has international conservation significance, and, although widespread in a landscape shaped by the upland farming system of open moor, enclosed moorland allotment or in-takes and sheltered in-bye land, is largely confined to the British Isles and western seaboard of Europe.

8.1.3 Upland landscapes are often strongly marked by traditional and historic field boundaries such as stone walls and old hedges, and are highly valued for their recreational and amenity value. The visibility at the surface, often dramatic in nature and spiritual character, of archaeological remains in the uplands landscape is both a valuable attribute of the uplands' importance and a contribution to the public perception of them as special, different places.

8.1.4 The nature conservation importance of moorland habitats also relates to associated bird interests, with *Red Data Book* species including the hen harrier (*Circus cyaneus*), golden eagle (*Aquila chrysaetos*), merlin (*Falco columbarius*), red grouse (*Lagopus lagopus*), black grouse (*Lyrurus tetrix*), dotterel (*Eudromias morinellus*), golden plover (*Pluvialis apricaria*), *whimbrel* (*Numenius phaeopus*) and curlew (*Numenius arquata*).

8.2 Key findings of the survey

Field survey

8.2.1 Table 8.1 summarises the key findings of the survey. This shows that the upland landscape mask in England is extensive and covers an estimated 15 616 km². Some 881 000 ha of this is upland heath and grassland (groups 1–5 in Table 8.1). This figure is very similar to previous estimates made by English Nature (850 000 ha of uplands including bog, grassy moor and bracken cover) and ADAS mapping (800 000

Table 8.1 Extent of upland landscape mask by structural and habitat type (km²)

	Designated*		Non-designated		
	Marginal	True	Marginal	True	Total
1 Dwarf shrub heath (heather)	2300	447	35	9	2790
2 Moorland grass (incl hay meadows)	966	1008	301	0	2275
3 Bog	391	956	23	17	1387
4 Flush and marsh	276	72	70	9	427
5 Acid grass/bracken	1334	426	174	0	1934
6 Neutral/improved grassland	2691	416	1158	120	4385
7 Woodland/scrub	414	468	405	395	1682
Total	*8832*	*3826*	*2408*	*550*	*15616*

* Each 1 km square was allocated to the designated strata if any part of the square was designated

ha of upland moor and other habitats). While extensive areas of heather have certainly been lost (Royal Society for the Protection of Birds (RSPB) 1993a), a large area of good-quality (or high-potential) heather moorland remains.

8.2.2 The field survey also includes some 160 000 ha of woodland, of which the countryside agencies suggest that some 25 000 ha (15%) is wooded gill.

8.2.3 Based on the ITE Land Classification, the total upland landscape mask is broken down according to true and marginal uplands, which differ substantially as to vegetation cover, land use and policy options.

True uplands

8.2.4 True uplands are defined in England as ITE land classes 21, 22, 23, 24 and occur above the limit of mechanised farming (rather than a specific altitude threshold). True moorlands typically have high rainfall (>100 cm yr^{-1}) and poor-draining, nutrient-poor soils; they include areas such as the Pennines, Cumbrian mountains and Kielder. True uplands cover some 400 000 ha (28% of the total upland landscape) and comprise extensive areas of semi-natural vegetation (moorland grass and blanket bog covered by dwarf shrub). Some 90% of the true uplands have one or more protective designations (see para 8.4.1). Outside designated areas plant communities tend to be less diverse, reflecting the fact that much of the area is under conifer plantations (such as Kielder Forest) or improved grasslands. Much of the area is grazed by sheep or under management for grouse or red deer (*Cervus elaphus*).

Marginal uplands

8.2.5 Marginal uplands (defined as ITE land classes 17, 18,19, 20 and 28 in England) tend to be those below the limit of mechanised farming, with lower rainfall and dominated by mixed land use (low-intensity arable and cattle/sheep and forestry) and semi-natural vegetation (predominantly dwarf shrub heath and neutral/improved grassland in designated areas). Marginal uplands cover some 1 100 000 ha (72% of the total upland landscape) and include such areas as Dartmoor, the North York Moors, Peak District and Lake District. Nearly 80% of the total marginal uplands are designated. Marginal uplands appear to have more diverse plant communities overall than true uplands because they include a mix of both true upland and lowland vegetation cover and farming systems and habitats.

Threats

8.2.6 High-quality upland heath may be characterised by a high percentage coverage of dwarf shrub cover supporting a typical range of flora and fauna. At lower altitude, moors are susceptible to invasion by bracken, scrub and woodland which replaces moorland vegetation. Heather and shrub cover are slow-growing and, while they require some disturbance to avoid invasion by faster-growing species, are susceptible to excessive disturbance from grazing, supplementary feeding of livestock (which may lead to poaching) or burning regimes; they are also susceptible to nutrient build-up (from runoff or atmospheric deposition) as summarised in Table 8.2. Biodiversity Challenge (RSPB 1993b) reports that an estimated 67% of the total UK heather moorland has less than 50% heather dominance. This would suggest a total remaining area of 92 000 ha of high-quality heather, compared to an estimated 100 000 ha in the mid- to late-1970s.

8.2.7 However, remaining areas of heather moorland could potentially be restored to mosaics of greater structural and species diversity through simple changes in management. The potential for improvement in the true uplands is enhanced by the fact that remaining areas of moorland tend to be in large blocks, adding to their overall quality and likelihood of containing specific rare habitats.

8.2.8 The key threats to upland habitats were identified by a meeting of experts (convened as part of this project). Exogeneous threats to vulnerable species in uplands are associated with:

- **atmospheric pollution**, which is often concentrated in uplands because of the high rainfall and occult deposition; some species will be particularly sensitive to acid rain, and eutrophication may result from nitrogen deposition;
- **climate change**, which may impact on the most sensitive upland communities through rising temperatures and seasonal changes in rainfall, leading to drying out and loss of some rare montane and bog habitats.

8.2.9 However, the major threats are endogeneous relating to land use and management practices as follows.

- Gross changes in grazing levels: over-grazing causes loss of dwarf shrubs in favour of species-poor grassland, while under-grazing leads to scrub encroachment and ultimately afforestation. Over-grazing is most common in the uplands because of the payment of headage-based subsidies in marginal economic conditions. Common land ownership may also lead to unco-ordinated grazing of different flocks.

- Changes in burning regimes are also a problem as lack of burning leads to scrub encroachment, while frequent fires kill all vegetation and may speed erosion processes.

- Drying out of wet moorland and bog: in the past, the building of drainage ditches supported with agricultural grants, and land preparation for afforestation supported with tax concessions and grants have been major contributors to the loss of upland wet habitats.

- Ploughing up has also been encouraged by agricultural improvement grants and afforestation grants in the past, with irreversible impacts on some rare habitats such as blanket bog.

- Eutrophication resulting from fertilizer application on improved grasslands increases growth rates of competitors at the expense of slow-growing shrubs (see Table 8.2).

Table 8.2 Summary of UCPE scenario findings

Potential threat	Possible causes	Interpretation of results
Scenarios which might improve upland habitat quality		
Decreased disturbance and no change in eutrophication	Reduced grazing on grassland and wetland; reduced incidence of fires on woodland and grassland; less flooding on all habitat types	Grass and wetlands would experience increased growth of denser tall sward and increase in biomass; combustible material could lead to increased incidence of fire; impacts on woodlands are expected to be slight. The overall impacts on nature conservation interest are expected to be slightly positive
No change in disturbance and decreased eutrophication	Decreased usage of/pollution from fertilizers on all habitat types	Growth of strategic species, particularly heather, at expense of competitors – however, where heather dominance is low and there is no persistent seed bank in soil, then heather may not regenerate naturally; this also applies to wetlands which start with higher nutrient levels
Decreased disturbance and increased eutrophication	Reduced grazing on grassland and wetland; reduced incidence of fires on woodland and grassland; more flooding; increased fertilizer runoff and/or atmospheric deposition (nitrogen or sulphur)	Likely increase in invaders (coarse grasses, tall herbs, bracken, etc) at the expense of strategic species and ruderals, with most rapid change in the eutrophic classes; low-productive (true?) uplands may be more sensitive
Increased disturbance and decreased eutrophication	Increased grazing, cutting or incidence of fire on wetland/grassland and thinning or fire in woodland; less fertilizer runoff on all habitat types	Increased cutting or fire will allow strategic competitors to become established in eutrophic grassland (plot class B and D and wetland (PCF), but regular grazing will be less damaging to species of conservation interest than intermittent ploughing, as annuals will be less able to get established; on less productive moorland increased disturbance and reduced eutrophication could lead to slow regeneration of dwarf shrub heather
Scenarios which would reduce upland habitat quality		
No change in disturbance and increased eutrophication	No change in stocking rates but increased flooding, fertilizer runoff and/or atmospheric deposition (nitrogen or sulphur) on all habitat types	Fast-growing perennials and annuals within improved grasslands and wetlands will get a boost at the expense of slower-growing species of conservation interest. Plot class E (calcareous perennials) is particularly vulnerable and plot classes G–I, R and T have moderate values
Increased disturbance and increased eutrophication	Increased grazing, cutting or fire; increased flooding, fertilizer runoff and/or atmospheric deposition on all habitat types	This scenario has the greatest impact on acidic moor lands (PCM, PCO and PCP), with increased dominance of tall competitive herbs and grasses or bracken. PCC, PCE, CCH and PCI also show high vulnerability

8.2.10 A number of different farming scenarios have been modelled by UCPE (see Chapter 7; Table 8.2). The implications suggest that the most beneficial agricultural management practices for true uplands will be those which introduce appropriate stocking levels and burning regimes (which provide moderate levels of disturbance) and reduce eutrophication, particularly on nutrient-poor peaty soils.

8.2.11 Non-agricultural uses of moorland such as deer and grouse management, military use or recreation (walking, riding and skiing), which involve disturbance in the form of trampling and fire, pose both conservation opportunities, by providing incentives for the maintenance of characteristic landscapes and vegetation cover, and conservation threats. For example, in the case of grouse management, gamekeepers may be tempted to persecute raptors illegally to protect game.

8.2.12 The extraction of peat is a serious, but localised, threat to bogs, particularly in marginal uplands, and is thought to have resulted in losses of large areas of a habitat of European importance.

Opportunities for restoration and re-creation

8.2.13 The appropriate management of uplands under agricultural or forestry use appears to offer the greatest scope for improved management of heather moorland through a regime of grazing and burning. Opportunities for restoring improved grasslands, arable or forest land will depend on the soils, the length of time since conversion (more than ten years is less viable), and the vegetation cover (more than 70% bracken is difficult). Conservation of discrete habitats, such as flushes, montane cliffs and hay meadows, will require more intensive or complex management.

Conservation objectives

8.2.14 The survey does not provide information on the ownership of the uplands or how past and current policies have affected their extent and quality. Information from other sources including non-departmental public nodies and non-governmental organisations (NGOs) has been collected to assist in the assessment of existing policies. As a starting point, it was necessary to establish policy objectives for the uplands against which policies could be assessed.

8.2.15 Taking the UK *Biodiversity Action Plan* (DOE 1994) as a starting place, the expert group agreed the following hierarchy of objectives for upland areas.

- To protect and maximise habitats which are rare within a European context; in the uplands, rare habitats include flushes, montane features, cliffs and raised mires which should be protected through designation and specific conservation measures.

- To maintain and enhance existing upland habitats and to improve management of wider heather moorland and grassland by:
  - promoting sustainable agricultural management (adjustment of stocking densities and management practices through a whole-farm management approach which takes into account socio-economic objectives, stocking rates and the use of inputs);
  - actively managing for the restoration of low-dominance heather moorland.

- To restore or re-create former upland heath by removing improved grassland or Sitka spruce plantations.

- To remedy existing damaging activities such as drainage.

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

- **Ownership and management**. A high, but unknown, proportion of upland heath is owned or influenced by the Forestry Commission, which has been responsible for widespread conversion to conifer plantations. While this area is subject to increasingly challenging environmental standards, it is unlikely to be reverted to heather moorland.

- **Economic viability**. The viability of appropriate upland farming depends almost entirely on the agricultural support regime. Changes to the Common Agricultural Policy are likely to have far greater impact on true uplands than any other set of policies.

- **Fragmentation**. Marginal upland sites are more likely to be small, part of mixed farming systems, close to urban areas, and vulnerable to pressures from change in land use.

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 (CAP) 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 upland habitats

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 European designations under the Birds and Habitats Directives respectively, and are intended to strengthen national nature protection designations such as SSSI.

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

- Other designations such as Environmentally Sensitive Areas (ESA) are not protective but delineate areas where incentives for positive management practices are available (see para 8.4.2).

8.3.3 The vast majority of true uplands have some designation – SSSI, NNR, AONB, ESA and Green Belt. National Parks cover the largest area, while AONB is also very significant. Only 10% of true upland is not designated, and this is believed to be mainly in Kielder Forest, which is owned by Forest Enterprise. In the marginal uplands, some 80% are designated, and again National Parks and AONBs cover most of the area. SSSIs provide important nature conservation protection for discrete features and small areas in both landscapes, but are more prevalent in the marginal uplands, whilst NNRs are more common in the true uplands which tend to cover large areas of particularly valued habitats, such as the calcareous mires of Mallam NNR. A large part of true uplands are covered by farming designations (ESA and Less Favoured Areas).

8.3.4 Designation of National Parks appears to have prevented large-scale land use change from agriculture to conifer plantation forestry – which has been a major cause of moorland loss in other upland areas of the UK. A number of Special Protection Areas have also been designated in the uplands under the Birds Directive, but persecution of raptors by game managers is still reported as a problem at some adjoining sites.

8.3.5 Given the large areas involved, SSSI or other nature designations are probably not the most appropriate tool for achieving better management of extensively farmed upland landscapes. They are more suited for smaller, rarer habitats within the overall upland landscape, many of which will require very careful management.

Agricultural economic instruments

8.3.6 Given the nature of the upland landscape, the policy measures which have had and continue to have the greatest impact are agricultural and forestry policies. The CAP provides the context within which farmers operate through a variety of commodity-related and accompanying measures.

Less Favoured Areas (LFAs)

8.3.7 The most important measure in relation to uplands is the Less Favoured Areas Directive (EC Directive 75/268/EEC), under which farming areas suffering from depopulation, harsh climatic or geographic circumstances are eligible for special assistance. In the UK, the LFA Directive is implemented under the Hill Land Compensation Allowances (HLCA) scheme, under which payments are available to top up payments under the Beef Special Premium scheme, the Suckler Cow Premium scheme and the Sheep Annual Premium scheme. In England LFAs are almost exclusively upland areas (including Cornwall, Devon, Cumbria, Northumberland, and the Pennines). In the past, policies attempted to increase farmers' income levels by increasing livestock production through grants for capital investment in land reclamation, buildings and handling facilities, and headage payments per animal, with no upper limits on the number of livestock by area. In uplands the incentive was to drain land and increase stocking rates to maximum viable levels, leading to over-grazing, and the loss of moorland vegetation of the greatest conservation value.

8.3.8 Since 1992, CAP reforms have tried to tackle incentives for over-production. Extensification of livestock headage schemes offer a premium for stocking ratios below 1.4 LU ha^{-1} (a livestock unit (LU) is equivalent to one cow). This notional ratio is calculated on the basis of total forage area of the holding divided by total number of livestock on which livestock premiums are claimed (ie ewes and suckler cows and beef eligible for premiums). However, the relationship between grazing ratios and the area of land is complex and means that, in some cases, suggested ratios will not provide any incentive for reducing stocking rates.

8.3.9 In the true uplands (where sheep predominate), hill cattle numbers have fallen while sheep numbers have risen steadily, changing the cattle/sheep ratio (1 cow is equivalent to 8 sheep) in grazing terms and leading to further over-grazing of rough pasture and accelerated loss of heather and invasion by bracken.

Cross-compliance

8.3.10 In order to address over-grazing, cross-compliance clauses (over-grazing and unsuitable supplementary feeding in areas such as Exmoor) are able to tie LFA premiums to compliance with improvements to management practice. MAFF is now starting to identify areas which appear over-grazed and to determine the number of animals eligible for subsidy. The provisions enable subsidy payments to be reduced or withheld where significant over-grazing or unsuitable supplementary feeding is occurring. However, cross-compliance will involve large initial transaction costs for MAFF and its agencies, who are required to identify over-grazed areas, carry out assessments and determine appropriate stocking levels and/or grazing regimes. A number of notifications have been given to farmers and many assessments have been carried out.

8.3.11 While cross-compliance may be effective in the short term in increasing knowledge about appropriate management practices and encouraging their uptake, the scheme is likely to be time-consuming to implement and enforce in the next few years. However, cross-compliance measures may be effective in removing financial incentives, from livestock subsidies, to over-stock land.

8.3.12 In the longer term, both MAFF and the countryside agencies are seeking a broader reform of livestock support measures which would replace the current headage payment system by other support mechanisms which would not provide an incentive to over-stock.

Agri-environment schemes

8.3.13 The 1992 CAP reform contained options to introduce agri-environment schemes which provide financial aid to farmers in order to adopt environmentally friendly practices, including long-term set aside and reductions in pesticide use and in livestock grazing densities. The three schemes of relevance to upland landscapes in England are the ESA scheme, Moorland Scheme and Countryside Stewardship Scheme, all of which focus on adjustment of livestock densities and grazing practices, reduced use of inputs, and the creation or restoration of wildlife habitats and landscape and historic features.

Environmentally Sensitive Areas (ESA) scheme

8.3.14 Box 8.1 outlines the workings of the ESA scheme in relation to uplands. Eight of the existing 22 ESAs include upland areas. The success of ESAs in meeting upland objectives depends on the level of detail of prescriptions, which face similar problems to those described for the over-grazing clause above, and the level of incentives in relation to the overall CAP grant context. For instance, ESAs and LFAs overlap in the Lake District, Pennine Dales, Dartmoor and Exmoor, but MAFF reports that only 4% of the total LFA area has been entered in ESA agreements because incentives do not encourage farmers to extensify livestock management in relation to LFA grants.

Box 8.1 Environmentally Sensitive Area scheme

The Ministry of Agriculture, Fisheries and Food (MAFF) is the implementing agency for the Environmentally Sensitive Areas (ESA) scheme, which is intended to target landscapes of conservation or historic value that are susceptible to changes in farming practices. The scheme provides grants which will encourage traditional or environmentally preferred practices. Participants enter into a ten-year management agreement, reviewed after five years. Each designated area has its own distinctive character and payments offered relate to specific requirements supporting and promoting local diversity. There are currently eight upland ESAs:

- Lake District
- South West Peak
- North Peak
- Pennine Dales (with a focus on hay meadows)
- Shropshire Hills
- Clun
- Exmoor
- Dartmoor

Under an Environmentally Sensitive Areas scheme, the farmer receives a modest annual flat-rate payment in return for a standard set of conditions and the preparation of a plan which identifies certain features of conservation value. Second-tier payments are then made on the extent of conservation features and for positive management in accordance with standard guidelines. The main objective in upland heath and moorland is to ensure low-intensity grazing levels, but avoid under- or over-grazing.

8.3.15 MAFF reports that common land ownership, particularly in the Lake District ESA, has presented major problems because the agreement of all commoners is needed to negotiate management plans. This also applies to the Moorland Scheme outlined below.

Moorland Scheme

8.3.16 The Moorland Scheme provides incentives for farmers outside ESA areas. The Scheme provides payments for each ewe removed from the flock and managing the land in order to improve the condition of heather and other shrubby moorland. However, the impacts of the Scheme are reported to have been disappointing so far because it is in direct competition to the existing headage support schemes. Furthermore, Moorland payments can not be used as a transitionary support to encourage LFA farmers to meet the conditions required by ESA, as it only applies to land outside ESAs.

Countryside Stewardship Scheme

8.3.17 The Countryside Stewardship Scheme (CSS) provides incentives for moorland restoration and for positive management of hay meadows and in-take or in-bye land where these will bring significant environmental benefits, as described in Box 8.2. Given the extent of the upland landscape in comparison to other habitats covered by the Scheme, the CSS currently focuses on demonstrating 'optimum' management below the current grazing limits of the CAP, which can be used to support cross-compliance and provide a model for wider reforms to agricultural policies.

8.3.18 Table 8.3 shows that a total of 32 000 ha has been entered into various management tiers of the Scheme, covering an estimated total area of 24 000 ha. This is equivalent to some 1.5% of the total high potential upland moor landscape. Total average spending on the uplands in 1994 was £0.78M, an average cost of £32 ha^{-1} yr^{-1}, showing that the majority of land has been entered in the lower management tiers. However, disaggregated figures for the south-west, which includes Dartmoor, Exmoor and Bodmin, show that almost half of the 340 ha entered into the Scheme are eligible for two tiers of payments, averaging about £53 ha^{-1} yr^{-1}. Much of this area (67%) is designated as National Park or AONB; ESA and LFA cover over a third of the area. As suggested by the field survey, SSSI designations are limited and apply to only 7% of the total.

Wildlife Enhancement Scheme

8.3.19 The Wildlife Enhancement Scheme (WES) is targeted at improving management in priority areas not already covered by other management schemes in the uplands. Box 8.3 describes how WES operates on the North Pennine Moorlands; similar options will be extended nationally in future.

Forestry economic instruments and policy

8.3.20 Forestry policy and particularly tax concessions and afforestation grants have

Table 8.4. Areas of land covered by Countryside Stewardship Scheme agreement in 1991–93 and the payments available

	1991	1992	1993	Payment rates
Regeneration of suppressed heather on moorland	4536	3719	1814	£50 ha^{-1} for 5 yr plus £15 ha^{-1} yr^{-1}
Regeneration of heather moor on improved land	251	224	84	£15 ha^{-1} for 5 yr plus £50 ha^{-1} yr^{-1}
Restoration/management of hay meadows/pastures	2938	2754	2826	£80 ha^{-1} for 5 yr plus £50 ha^{-1} yr^{-1}
Boundary fencing to restore gills	na	na	75	£0.80 m^{-1}

concentrated large plantations of exotic conifers on bare ground in the uplands. Such plantations have affected peatlands (land preparation and drainage), eliminated open-ground moorland and upland bird communities, and had adverse impacts on the landscape. The extent of the upland area lost to afforestation in England is unknown but, given the size of Kielder Forest alone, is thought to exceed 100 000 ha.

8.3.21 However, recent plantations still contain residues of moorland heath and grasses and experience suggests that heather could be regenerated naturally with clearfelling and appropriate management. Restoration of moorland on private forestry land is unlikely as all felling currently requires a licence which stipulates replanting. Forest Enterprise itself may consider clearfelling and restoring heather moorland where conifer plantations have proved least viable – on thin, waterlogged soils in areas with high windblow risk. However, the extent of such planting in England (as compared to northern Scotland) is thought to be limited.

8.3.22 The Woodland Grant Scheme (WGS) offers grants to cover the capital costs of planting and a special management grant of £35 ha^{-1} yr^{-1}, and has produced a series of advisory guides on the management of ancient and semi-natural woodlands. In Wales the broadleaved element of the Habitat Scheme aims to encourage regeneration of native woodlands by excluding livestock, but WGS grants available in England are widely considered too low to encourage a similar approach.

8.3.23 In terms of re-creating open habitats, the best opportunities are likely to be the restoration of high-value habitats, such as flushes, hay meadows and open spaces for particular species (such as golden eagle and goshawks (*Accipiter gentilis*)) through the creation of small interlinking areas of moorland and deer lawns, clearance of waterways, restoration of wetlands and special conservation programmes, which are all part of the Forest Enterprise's management policies for plantations approaching maturity and requiring

Box 8.2. Countryside Stewardship Scheme

The Countryside Stewardship Scheme, introduced in 1991, covers five different landscape types. Objectives for the uplands are:

- to regenerate heather and other moorland vegetation on enclosed and agriculturally improved moorland;
- to re-create heather and grassy moorland from improved pasture where this is feasible;
- to support and re-introduce traditional management on hay meadows and pastures;
- to restore and protect characteristic landscape features, including historic and archaeological features, and rebuild traditional field boundary networks to enhance and strengthen local distinctiveness;
- to create and improve opportunities for people to enjoy the landscape and its wildlife.

The landowner enters into a ten-year agreement selecting a combination of measures from a menu of management options and capital works. Payments are made annually in arrears, and reviewed on a three-year cycle.

- £15 ha^{-1} yr^{-1} plus £50 ha^{-1} yr^{-1} for the first five years: restoration of moorland vegetation on enclosed intake or allotment land (where heather has declined to less than 25% of ground cover as a result of grazing pressure or management change)
- £50 ha^{-1} yr^{-1} plus £50 ha^{-1} yr^{-1} for the first five years: return of selected improved land to moorland, particularly where maintaining improvement is uneconomic;
- £80 ha^{-1} yr^{-1} plus £50 ha^{-1} supplementary payment for initial work to establish or re-introduce beneficial management): management and restoration of flower-rich hay meadows and lightly grazed pasture on poor-quality improved grassland.

Landowners may also propose a programme of landscape improvements over the rest of the land, including hedge planting and restoration of traditional walls.

Box 8.3 Wildlife Enhancement Scheme

The Wildlife Enhancement Scheme (WES) provides grants for positive management to landowners and tenants of valued habitats.

The Scheme has also been operating in upland, mainly limestone grassland (Craven limestone and Yorkshire Dales) areas for a number of years. There are two main elements to widening the Scheme's coverage:
- targeting new areas not already covered by positive management schemes;
- transferring land from Section 15 management agreements which may operate on a compensatory basis for owners or managers of designated SSSIs.

A new Scheme has recently been launched in the North Pennine Moorlands in collaboration with MAFF's Moorland Scheme. Payment rates differ according to the type of land use and amount of land entered into the scheme, up to a maximum of £5,000 per landholding, as follows:
- payments to farmers for reducing stocking density of £15 ha^{-1} yr^{-1} for the first 100 ha, £10 ha^{-1} yr^{-1} for the next 100 ha, and £1 ha^{-1} yr^{-1} for any additional area;
- payments to game managers for burning heather and drainage remediation, etc, of £10 ha^{-1} yr^{-1} for the first 100 ha, £5 ha^{-1} yr^{-1} for the next 100 ha, and £1 ha^{-1} yr^{-1} for any additional area.

All areas other than those covered by ESA or the Countryside Stewardship Scheme, or under ownership of Forestry Commission or MOD (unless land has been licensed or rented to NGOs or private farmers) are eligible. English Nature aims to widen the Scheme nationwide with local teams having discretion in applying the Scheme within an overall framework, and national co-ordination.

restructuring. Opportunities for replanting with native broadleaves and restoring gills are also good on Forestry Commission land.

Advice and technical support

8.3.24 Because of the heterogeneity of landscape types and individual upland farms, it is difficult to be prescriptive about the best management practices and stocking rates. Many organisations provide information and advice about conservation management in the uplands, including the Agricultural Development and Advisory Service (ADAS), National Trust, Farming and Wildlife Group (FWAG), Game Conservancy, National Parks, AONB Management Services and the Moorland Association, which publishes a leaflet for the promotion of better management of heather.

8.3.25 Management advice varies according to the existing level of heather dominance. Where heather is already established, it should be possible to regenerate to 50–70% heather dominance over a ten-year period by initial cutting of old/woody heather and ongoing bracken control (which may be done mechanically), and changes to grazing regimes. It may require the exclusion of livestock during the winter, and avoiding supplementary feeding on regenerating moorland. Gradually light winter grazing can be re-introduced as heather cover increases and overall stocking rates gradually increased during both summer (1.5 ewes ha^{-1}) and winter (75 ewes ha^{-1}).

8.3.26 In order to create links between existing heather areas on agriculturally improved moorland (which has been converted in the last ten years), more intensive methods are required, including exposure of topsoil, planting of heather cuttings in the first year, and complete exclusion of livestock until at least 40–50% heather cover is achieved.

8.3.27 There is currently limited experience of how to reduce the localised damage caused by drainage ditches. As long as drainage has not caused a lowering of the water table, then it should be possible to remediate damage simply by filling in ditches. However, little information is available on the most successful techniques or costs.

8.4 Policy development

8.4.1 The survey results indicate that the upland landscape mask in England comprises some 1.56 Mha of which an extensive area (nearly 0.89 Mha) is still dominated by highly valued slow-growing shrub habitats (*Calluna* and *Erica* species) containing a mosaic of smaller and rare habitats (such as montane cliffs, flushes and bogs). As rarer species are often at the limits of their tolerance, upland habitats are likely to prove more vulnerable to climate change and atmospheric pollution than other key habitats.

8.4.2 The survey findings strengthen earlier estimates made by others, such as EN and ADAS. Losses of heather-dominant upland have been extensive since the 1970s, mainly due to changes in use or management of agricultural or forested land. However, unlike other habitat types considered in this study, large areas of good-quality (or currently degraded but with high potential) upland heath remain.

8.4.3 An estimated 300 000 ha of upland landscape require improved management. Expanding current environment schemes to restore or re-create upland habitats would be very costly, even if payments per hectare continued at the current low levels offered through the CSS, ESA, Moorland or WES schemes. Thus, the route being pursued by MAFF and the countryside agencies in the short term is to apply cross-compliance clauses to existing livestock headage schemes, which set maximum stocking levels, and to use the existing environment schemes to encourage good practice and to support farmers who opt for 'optimal' stocking rates.

8.4.4 Despite growing experience and advice offered by a number of agencies, it is difficult to make general recommendations because of the wide variety of habitats involved, the complexity of different habitats which may be found on each farm, the impacts that reducing stocking rates will have on farmers' incomes, and the complexities of common land ownership. In order to achieve conservation objectives, it will be necessary to place even greater emphasis on training and advice to farmers for sustainable farm management.

8.4.5 In the longer term, both MAFF and the countryside agencies are seeking a broader reform of livestock support measures which would replace the current headage payment system by other support mechanisms which would not provide economic incentives to over-stocking.

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 the uplands are developed and publicised. More work is needed to evaluate and extend existing experience and develop guidelines for landowners and managers (particularly of forestry 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 upland habitat, the level of invasive species, the climatic conditions, and size and location.

8.6 Conclusions

8.6.1 The uplands comprise a valuable landscape, dominated by a non-climax vegetation type maintained by agricultural and sporting management practices. Because the vegetation is non-climax, intervention is required to prevent heathland turning into scrub/woodland; heathland therefore requires management to maintain its condition. The survey results indicate that, of the area within the upland landscape (15 616 km^2), about 881 000 ha is upland heath and grassland and about 160 000 ha is woodland.

8.6.2 The present study helps to define the upland 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).

8.6.3 If further work indicates that these objectives are justifiable, 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 Forestry Commission land.

8.6.4 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 the uplands 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, upland vegetation types. This objective was achieved by use of the ITE Land Classification. Those 1 km squares which had been classified (using combinations of environmental attributes) as either 'marginal' or 'true' upland (as reported in the Countryside Survey 1990 Main Report), and which occurred in England, were included in the map, or mask.

9.2.2 Because of the use of a 1 km resolution, and a broad definition of uplands, the area identified for the field sampling programme covers more than the whole upland resource in England. However, it does provide a good sampling framework for assessing the current status of the upland resource.

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; 32 squares surveyed in 1992, plus data from 32 squares surveyed in Countryside Survey 1990, have been used, to give a total sample of 64. The results were extrapolated from the sample squares to the upland 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, 200 m^2 nested quadrats were recorded at up to five randomly chosen grid points where the vegetation was indicative of upland conditions, thus excluding most arable fields and fertilized, sown or neutral grasslands. In addition, five 4 m^2 habitat plots were also recorded in each survey square, in the less common habitats which were not represented by the main plots and five 10 m x 1 m streamside plots were recorded adjacent to rivers, streams or ditches.

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 165 archaeological sites in 32 sample squares drawn from 10 counties. 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 upland mask and for strata within it. In relation to the 'core' upland vegetation types, 18% of the mask was composed of dwarf shrub heath vegetation (dominated by *Calluna*, *Erica* and/or *Vaccinium*), most of which was in the designated strata, with a higher proportion in marginal upland compared with true upland. Bog vegetation was mostly found in the true uplands, particularly in designated squares. Flushes were recorded only in designated strata, where they were more common in the marginal uplands. Moorland grass was more ubiquitous, as was acid grassland and bracken.

9.2.8 In addition to the core upland vegetation types, modified neutral/improved grassland, agricultural crops and woodland/scrub were recorded. Most of the undesignated true upland areas were planted with conifers (mainly in Kielder Forest). About 80% of the woodland recorded throughout the upland landscape was conifers or mixed.

9.2.9 Objective measures of vegetation have been related to quality criteria, to provide an empirical evaluation of the quality of upland vegetation in different parts of the upland 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, the designated true uplands ranked highest for most measures (12 out of 17) and the undesignated true upland was ranked higher than the marginal upland strata.

Historical aspects

9.2.11 Most periods of history, except the Early Medieval, are represented by archaeological features in the uplands. Prehistoric periods are poorly represented by 'find' sites (ie where objects have been found), together with Bronze Age hut circles and barrows. The Roman period is also poorly represented but with a range of features. The Medieval period has some settlement sites together with farms and field systems, and the Post Medieval period is represented by a scattering of farms and a large amount of industrial activity in the form of extractive and lime-burning industries.

Designation

9.2.12 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 upland vegetation and some form of designation were because the designation had been effective, or whether the designation was made because of the quality of the habitats. The approach adopted in this study was to stratify the field sample according to designation status.

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 upland landscape, National Parks cover the largest area in the true uplands where NNRs are also important. In the marginal uplands, AONBs, ESAs and Green Belts are more significant. SSSIs are important in both.

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 To identify areas likely to be affected by excessive atmospheric acid deposition, the uplands 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 showing areas. The effects of various change scenarios, compared to the 1989–91 baseline, have been evaluated in terms of the proportion of the areas where the soils' critical loads are exceeded. During the period 1989–91, 95% of all areas within the upland mask was in exceeded areas (ie where the pollutant deposition exceeds the weathering rate of the soil). In lowland England, the soil acidity critical load was exceeded in 57% of the total area.

9.2.15 Current emission reduction scenarios appear to be relatively ineffective at protecting the upland areas of England. Although the 70% UNECE emission reduction scenario would reduce the exceeded areas to 11% of lowland England, 38% of upland areas are estimated to be at risk. An emission reduction of 80% would leave 7% of lowland England and 31% of upland areas at risk. Upland squares containing designations were shown to be likely to benefit least from the emission reductions.

9.2.16 Average atmospheric deposition of nitrogen (NO_x and NH_x) in upland areas is 26 kg nitrogen ha^{-1} yr^{-1}, which is similar to that received by other parts of England (19 kg N ha^{-1} yr^{-1}). Over 96% of upland areas receive more than 10 kg N ha^{-1} yr^{-1}, and 76% receive over 20 kg N ha^{-1} yr^{-1}. Uplands in designated squares are more likely to be receiving over 20 kg nitrogen ha^{-1} yr^{-1} than those in undesignated squares.

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 uplands in Britain. However, it is likely that the low rates of atmospheric N will have a significant effect on community composition in upland vegetation, 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' upland vegetation is composed of stress-tolerator and stress-tolerator/ competitor 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 uplands consists of a heterogeneous grouping of moorland, bog, grassland and woodland vegetation, all of which are relatively unproductive. There is no significant difference in vulnerability between grasssland, woodland or moorland vegetation in general, although both short, acid grassland and enriched flushes have higher vulnerability than most.

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 measure.

9.2.21 The uplands comprise a valuable landscape, dominated by a non-climax vegetation type maintained by agricultural and sporting management practices. Because the vegetation is non-climax, intervention is required to prevent habitat such as moorland turning into scrub/ woodland; these habitats therefore require management to maintain their condition. The survey results indicate that, of the area within the upland landscape (15 616 km^2), about 881 00 ha is upland heath and grassland and about 160 000 ha is woodland.

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 remedy existing damaging activities such as drainage;
- to protect and maximise habitats which are rare within a European context; in uplands rare habitats include flushes, montane features, cliffs and raised mires which should be protected through designation and specific conservation measures;
- to maintain and enhance existing upland habitats, and to improve management of wider heather moorland and grassland by the promotion of sustainable agricultural management and active management for restoration of low-dominance heather moorland;
- to restore or re-create former upland heath by removing improved grassland or Sitka spruce plantations.

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 and implementing re-creation on Forestry Commission 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 the uplands 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 upland mask

9.3.2 At the start of the study there was no national map of upland habitats. To study areas with potential to become 'better' upland habitats, a broad definition of the uplands was necessary (in which to study change).

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. The 1 km squares were capable of including land which was not 'upland' in character, leading to some inefficiency and wasted effort. The approach did allow the calculation of national estimates but, for reasons of matching sample number to 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 land 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 'true upland' and 'marginal upland' strata 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 the uplands were 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 approach to 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 agri-environment schemes, and others. 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 the uplands 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 habitats in the uplands are interesting in terms of fragmentation and connectedness. If habitat creation (and management) is to lead to maximum moorland quality, for example, then the spatial characteristics of potential areas need to be known. Will increasing the areas of existing moorland be adequate, or are there crucial links or 'stepping stones' that need to be made? The landscape ecology of the uplands needs further investigation, especially in relation to the identification and characterisation of habitats with potential for ecological improvement, as defined in this project.

ACKNOWLEDGMENTS

The authors are grateful to the following members of the DOE's project Steering Group for their guidance during the project and for comments on drafts of this Report:

Mrs Enid Barron, DOE
Dr Janet Dwyer, Countryside Commission
Mr Graham Fairclough, English Heritage
Dr Mark Felton, English Nature
Mr Alan Hooper, ADAS
Dr Richard Jefferson, English Nature
Dr Gy Ovenden, DOE
Dr Andrew Stott, DOE
Dr Sarah Webster, DOE

Dr Richard Jefferson, Dr Terry Wells, Dr Bob Bunce, Dr Andrew Stott, Dr Gy Ovenden, Dr Karen Raymond, Anna MacGillivray and Cerion Morris are gratefully acknowledged for their contributions during the 'Expert Review' meeting.

Mr Adrian Oliver, Mr Jason Wood, Mr Richard Newman, Mr Richard Bridges and Mr Malcolm Harrison all contributed to the work reported in Chapter 5 (Historical characteristics of the heathland mask). Mr Andy Fulton and Mr Mark Bell provided information on the MARS project.

The authors are particularly indebted to the following field surveyors who spent long and arduous hours of toil in the field, collecting valuable information which has gone to form a unique and irreplaceable database:

Henry Adams
Tanya Barden
Liz Biron
Roger Cummins
John Davis
John Day
Richard Hewison
Gabby Levine
Mandy Marler
Liz McDonnell
Karen Pollock
Sam Walters
Mike Webb

Finally, grateful acknowledgment is made of the contribution of Chris Benefield in creating the artwork for the front cover, and of Penny Ward and Karen Goodsir in preparing the final copy.

REFERENCES AND BIBLIOGRAPHY

References cited in text are given, together with a select bibliography of recent references directly relevant to the subject matter of this Report. Various categories of literature are largely not included, as follows.

- The extensive pre-1980 literature on the uplands
- Purely scientific literature on ecological processes in the uplands
- Phytosociological literature on the uplands
- Literature dealing with the practical detail of upland habitat management (for conservation)
- Amenity management and amenity issues in the uplands
- Agricultural use of the uplands (ie the agri-science side of the literature)

Adams, W.M. 1990. The changing uplands. In: *Britain's changing environment from the air*, edited by T. Bayliss-Smith & S. Owens, 15–47. Cambridge: Cambridge University Press.

Aerts, R., Wallen, B. & Malmer, N. 1992. Growth-limiting nutrients in *Sphagnum*-dominated bogs subject to low and high atmospheric nitrogen supply. *Journal of Ecology*, **80**, 131–140.

Appleby, M. 1994. Agriculture and the environment: opportunities in the UK under the agri-environment regulation. *RSPB Conservation Review*, **8**, 10–18.

Austin, M.P. & Heyligers, P.C. 1989. Vegetation survey design for conservation: gradsect sampling of forests in north-eastern New South Wales. *Biological Conservation*, **50**, 13–32.

Barber, K.E. 1985. Peat stratigraphy and climatic change: some speculations. In: *The climatic scene*, edited by M.J. Tooley & G.M. Sheail, 175–185. London: Allen & Unwin.

Barr, C.J., Bunce, R.G.H., Clarke, R.T., Fuller, R.M., Furse, M.T., Gillespie, M.K., Groom, G.B., Hallam,C.J., Hornung, M., Howard, D.C. & Ness, M.J. 1993. *Countryside Survey 1990: main report*. London: HMSO.

Bayfield, N.G., Watson, A. & Miller, G.R. 1988. Assessing and managing the effects of recreational use on British hills. In: *Ecological change in the uplands*, edited by M.B. Usher & D.B.A. Thompson, 399–414. Oxford: Blackwell Scientific.

Bell, N. 1994. *The ecological effects of increased aerial deposition of nitrogen*. Montford Bridge: Field Studies Council.

Birks, H.J.B. 1988. Long-term ecological change in the British uplands. In: *Ecological change in the uplands*, edited by M.B. Usher & D.B.A. Thompson, 37–56. Oxford: Blackwell Scientific.

Bishop, K.H., Grip, H. & Piggott, E.H. 1990. Spate-specific flow pathways in an episodically acid stream In: *The Surface Waters Acidification Programme*, edited by B.J. Mason, 107–120. Cambridge: Cambridge University Press.

Brown, A., Birks, H.J.B. & Thompson, D.B.A. 1993. A new biogeographical classification of the Scottish uplands I: Vegetation-environment relationships. *Journal of Ecology*, **81**, 231–251.

Brown, A., Horsfield, D. & Thompson, D.B.A. 1993. A new biogeographical classification of the Scottish uplands I: Descriptions of the vegetation blocks and their spatial variation. *Journal of Ecology*, **81**, 207–230.

Bunce, R.G.H. 1981. The scientific basis of evaluation. In: *Values and evaluation*, edited by C.I.Rose, 22–27 (Discussion paper in conservation no. **36**). London:, University College of London.

Bunce, R.G.H. & Barr, C.J. 1988. The extent of land under different management regimes in the uplands and the potential for change. In: *Ecological change in the uplands*, edited by M.B. Usher & D.B.A. Thompson, 415–426. Oxford: Blackwell Scientific.

Bunce, R.G.H. & Heal, O.W. 1984. Landscape evaluation and the impact of changing land use on the rural environment: the problem and an approach. In: *Planning and and ecology*, edited by R.D. Roberts & T.M. Roberts, 164–188. London: Chapman and Hall.

Bunce, R.G.H., Barr, C.J., Clarke, R.T., Howard, D.C. & Lane, A.M.J. 1996. Land classification for strategic ecological survey. *Journal of Environmental Management*, **47**, 37–60.

Carter, R.N. & Prince, S. 1985. The effect of climate on plant distributions. In: *The climatic scene*, edited by M.J. Tooley & G.M. Sheail, 235–254. London: Allen & Unwin.

Chapman, S.B. & Rose, R.J. 1991. Changes in the vegetation at Coom Rigg Moss National Nature Reserve within the period 1958–86. *Journal of Applied Ecology*, **28**, 140–153.

Coulson, J.C., Butterfield, J.E.L. & Henderson, E. 1990. The effect of open drainage ditches on the plant and invertebrate communities of moorland and on the decomposition of peat. *Journal of Applied Ecology*, **27**, 549–561.

Critical Loads Advisory Group. 1994. *Critical loads of acidity in the United Kingdom*. London: Department of Environment.

Crowe, T.M. 1993. Evaluation for nature conservation: principles and criteria. *South African Journal of Science*, **89**, 2–5.

Darvill, T. 1987. *Ancient monuments in the countryside: an archaeological management review*. (English Heritage Archaeological Report no **5**.) London: Historic Buildings and Monuments Commission for England.

Darvill, T., Fulton, A. & Bell, M. 1993. *Monuments at risk survey: Briefing Paper 1.* Bournemouth: University of Bournemouth.

Department of Environment. 1994. *Biodiversity: the UK action plan.* (Cmd 2428.) London: HMSO.

Edwards, M.E. 1986. Disturbance histories of four Snowdonian woodlands and their relationship to Atlantic bryophyte distribution. *Biological Conservation,* **37**, 301-320.

Fowler, D., Cape, J.N. & Unsworth, M.H. 1989. Deposition of atmospheric pollutants on forests. In: *Forests, weather and climate,* edited by P.G. Jarvis, J.L. Monteith, W.J. Shuttleworth & M.H. Unsworth, 73–91. London: The Royal Society.

Gee, A.S. & Stoner, J.H. 1988. The effects of afforestation and acid deposition on the water quality and ecology of upland Wales. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 273–288. Oxford: Blackwell Scientific.

Good, J.E.G., Bryant, R. & Carlill, P. 1990. Distribution, longevity and survival of upland hawthorn (*Crataegus monogyna*) scrub in North Wales in relation to sheep grazing. *Journal of Applied Ecology,* **27**, 272–283.

Gorham, E. 1990. Biotic impoverishment in northern peatlands. In: *The earth in transition,* edited by G.M. Woodwell, 273–288. Cambridge: Cambridge University Press.

Grace, J. & Unsworth, M.H. 1988. Climate and microclimate in the uplands. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 137–150. Oxford: Blackwell Scientific..

Grace, J. 1989. Tree lines. In: *Forests, weather and climate,* edited by P.G. Jarvis, J.L. Monteith, W.J. Shuttleworth & M.H. Unsworth, 59–71. London: The Royal Society.

Graham, G.G. 1988. *The flora and vegetation of County Durham.* Durham: Durham Flora Committee.

Grant, S.A. & Maxwell, T.J. 1988. Hill vegetation and grazing by domesticated herbivores: the biology and definition of management options. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 201–214. Oxford: Blackwell Scientific.

Grime, J.P. 1974. Vegetation classification by reference to strategies. *Nature,* **250**, 26–31.

Grime, J.P. 1979. *Plant strategies and vegetation processes.* Chichester: Wiley.

Grime, J. P., Hodgson, J. G., Hunt, R. 1988. *Comparative plant ecology : a functional approach to common British species.* London: Unwin Hyman.

Harrison, A.F., Taylor, K., Hatton, J.C. & Howard, D.M. 1994. Role of nitrogen in herbage production by *Agrostis-Festuca* hill grassland. *Journal of Applied Ecology,* **31**, 351–360.

Hill, M.O., Evans, D.F. & Bell, S.A. 1992. Long-term effects of excluding sheep from hill pastures in North Wales. *Journal of Ecology,* **80**, 1–13.

Hobbs, A.M. 1988. Conservation of leafy liverwort-rich *Calluna vulgaris* heath in Scotland. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, ?–?. Oxford: Blackwell Scientific.

Hodgetts, N.G. 1992. *Guidelines for the selection of biological SSSIs: non-vascular plants.* Peterborough: Joint Nature Conservation Committee.

Hornung, M., Bull, K.R., Cresser, M., Hall, J., Langan, S.J., Loveland, P. & Smith, C. 1995. An empirical map of critical loads of acidity for soils in Great Britain. *Environmental Pollution,* **90**, 301–310.

Hughes, J. & Huntley, B. 1988. Upland hay meadows in Britain – their vegetation, management and future. In: *The cultural landscape – past, present and future,* edited by H.H. Birks, H.J.B. Birks, P.E. Kaland & D. Moe, 91–110. Cambridge: Cambridge University Press.

Hunt, R., Middletone, D.A.J., Grime, J.P. & Hodgson, J.G. 1991. TRISTAR: an expert system for vegetation processses. *Expert Systems,* **8**, 219–226.

Institute of Terrestrial Ecology. 1991. *Changes in key habitat: a tender for research to the Department of the Environment.*

Lee, J.A., Tallis, J.H. & Woodin, S.J. 1988. Acidic deposition and British upland vegetation. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 151–164. Oxford: Blackwell Scientific.

Legg, C.J., Maltby, E. & Proctor, M.C.F. 1992. The ecology of severe moorland fire on the North York Moors: seed distribution and seedling establishment of *Calluna vulgaris.* *Journal of Ecology,* **80**, 737–752.

Liddle, M.J. 1977. An approach to objective collection and analysis of data for comparison of landscape character. *Regional Studies,* **10**, 173–181.

Margules, C.R. 1989. Introduction to some Australian developments in conservation evaluation. *Biological Conservation,* **50**, 1–11.

Margules, C.R. & Usher, M.B. 1981. Criteria used in assessing wildlife conservation potential: a review. *Biological Conservation,* **21**, 79–109.

Marrs, R.H., Rizand, A. & Harrison, A.F. 1989. The effects of removing sheep grazing on soil chemistry, above-ground nutrient distribution, and selected aspects of soil fertility in long-term experiments at Moor House National Nature Reserve. *Journal of Applied Ecology,* **26**, 647–661.

Miles, J. 1988. Vegetation and soil change in the uplands. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 57–70. Oxford: Blackwell Scientific.

Miller, G.R., Miles, J. & Heal, O.W. 1984. *Moorland management: a study of Exmoor.* Cambridge: Institute of Terrestrial Ecology.

Nature Conservancy Council. 1986. *Nature conservation and afforestation in Britain.* Peterborough: NCC.

Nature Conservancy Council. 1989. *Guidelines for the selection of biological SSSIs. Detailed guidelines for habitats and species groups.* Peterborough: NCC.

Newson, M.D. & Calder, I.R. 1989. Forests and water resources: problems of prediction on a regional scale. In: *Forests, weather and climate,* edited by P.G. Jarvis, J.L. Monteith, W.J. Shuttleworth & M.H. Unsworth, 104–124. London: The Royal Society.

Paterson, S. 1993. Peat: the capaign review. *Natural World,* **37**, 12–14.

Pielou, E.C. 1991. The many meanings of diversity. In: *Diversidad Biologica. Symposium international celebrado en Madrid en Noviembre y Diciembre de 1989, promovido por la Fundacion Ramon Areces, ADENA-WWF y SCOPE,* edited by F.D Pineda, M.A. Casado, J.M. de Miguel & J. Montalvo, 113–115. Madrid: Fundacion Ramon Areces.

Pressey, R.L. & Nicholls, A.O. 1989. Efficiency in conservation evaluation: scoring versus iterative approaches. *Biological Conservation,* **50**, 199–218.

Ratcliffe, D.A. ed. 1977. *A nature conservation review, Vols 1 and 2.* Cambridge: Cambridge University Press.

Ratcliffe, D.A. & Thompson, D.B.A. 1988. The British uplands: their ecological character and international significance. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 9–36. Oxford: Blackwell Scientific.

Rebolo, A.G. & Siegfried, W.R. 1990. Protection of fynbos vegetation: ideal and real-world options. *Biological Conservation,* **54**, 15–31.

Robinson, D.G., Laurie, I.C., Wager, J.F. & Traill, A.L., eds. 1976. *Landscape evaluation: the landscape evaluation research project 1970–1975.* Manchester: Centre for Urban and Regional Research, University of Manchester.

Rodwell, J.S. 1991a. *British plant communities 1: Woodlands and scrub.* Cambridge: Cambridge University Press.

Rodwell, J.S. 1991b. *British plant communities 2: Mires and heaths.* Cambridge: Cambridge University Press.

Rodwell, J.S. 1992. *British plant communities 3: Grasslands and montane communities.* Cambridge: Cambridge University Press.

Rose, C.I., ed. 1981. *Values and evaluation.* (Discussion Papers in Conservation, **36**.) London: University College.

Royal Commission on the Historical Monuments of England/English Heritage. 1992. *Thesaurus of archaeological site types.* London: RCHME/EH.

Royal Commission on the Historical Monuments of England. 1993. *Recording England's past: a review of national and local sites and monuments records in England.* London: RCHME.

Royal Society for the Protection of Birds. 1993a. *Dorset heathlands – a crisis report.* Sandy: RSPB.

Royal Society for the Protection of Birds. 1993b. *Biodiversity challenge.* Sandy: RSPB.

Salt, C.A. & Mayes, R.W. 1993. Plant uptake of radiocaesium on heather moorland grazed by sheep. *Journal of Applied Ecology,* **30**, 235–246.

Salt, C.A., Mayes, R.W., Colgrave, P.M. & Lamb, C.S. 1994. The effects of season and diet composition on the radiocaesium intake by sheep grazing in heather moorland. *Journal of Applied Ecology,* **31**, 125–136.

Smith, R.S. & Charman, D.J. 1988. The vegetation of upland mires within conifer plantations in Northumberland, northern England. *Journal of Applied Ecology,* **25**, 579–594.

Smith, R.S. & Jones, L. 1991. The phenology of mesotrophic grassland in the Pennine Dales, Northern England: historic hay cutting dates, vegetation variation and plant species phenologies. *Journal of Applied Ecology,* **28**, 42–59.

Smith, R.S. & Rushton, S.P. 1994. The effects of grazing management on the vegetation of mesotrophic (meadow) grassland in Northern England. *Journal of Applied Ecology,* **31**, 13–24.

Smith, R.S. 1988. Farming and conservation of traditional meadowland in the Pennine Dales Environmentally Sensitive Area. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 183–200. Oxford: Blackwell Scientific.

Stevens, P.A., Adamson, J.K., Anderson, M.A. & Hornung, M. 1988. Effects of clearfelling on surface water quality and site nutrient status. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 289–294. Oxford: Blackwell Scientific.

Stewart, A.J.A. & Lance, A.N. 1991. Effects of moor-draining on the hydrology and vegetation of northern Pennine blanket bog. *Journal of Applied Ecology,* **28**, 1105–1117

Swan, G.A. 1993. *Flora of Northumberland.* Newcastle upon Tyne: The Natural History Society of Northumbria.

Sydes, C. & Miller, G.R. 1988. Range management and nature conservation in the British uplands. In: *Ecological change in the uplands,* edited by M.B. Usher & D.B.A. Thompson, 323–338. Oxford: Blackwell Scientific.

Sykes, J.M., Lowe, V.P.W. & Briggs, D.R. 1989. Some effects of afforestation on the flora and fauna of an upland sheepwalk during 12 years after planting. *Journal of Applied Ecology*, **26**, 299–320.

Tansley, A.G. 1939. *The British islands and their vegetation.* Cambridge: Cambridge University Press.

Trueman, M.R.G. & Williams, J. 1993. *Index record for industrial sites: recording the industrial heritage.* Ironbridge: Association for Industrial Archaeology.

United Kingdom Review Group on Impacts of Atmospheric Nitrogen. 1994. *Impacts of nitrogen deposition in terrestrial ecosystems.* London: Department of Environment.

Usher, M.B., ed. 1986. *Wildlife conservation evaluation.* London: Chapman and Hall.

Usher, M.B. 1991. Biodiversity: a scientific challenge for resource managers in the 1990s. In: *Symposium international celebrado en Madrid en Noviembre y Diciembre de 1989, promovido por la Fundacion Ramon Areces, ADENA-WWF y SCOPE,* edited by F.D. Pineda, M.A. Casado, J.M. de Miguel & J. Montalvo, 113–115. Madrid: Fundacion Ramon Areces.

Wallace, H.L., Good, J.E.G. & Williams, T.G. 1992. The effects of afforestation on upland plant communities: an application of the British National Vegetation Classification. *Journal of Applied Ecology*, **29**, 180–194.

Wheater, H.S. Laoan, S.J., Miller, J.D., Ferriet, R.C., Jenkins,A., Tuck, S., & Beck, M.B. 1990. Hydrological processes on the plot and hillslope scale. In: *The Surface Waters Acidification Programme*, edited by B.J. Mason, 121–136. Cambridge: Cambridge University Press.

Williams, G. & Green, R. 1993. Towards an upland habitat action plan. *RSPB Conservation Review*, **8**.

Woodin, S.J. 1988. Acidic deposition and upland conservation: an overview and the way ahead. In: *Ecological change in the uplands*, edited by M.B. Usher & D.B.A. Thompson, 355–363. Oxford: Blackwell Scientific.

Appendix 1 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 A1.1).

Box A1.1 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 A1.1 Upland landscapes – estimates of land cover types
based on descriptions of land cover at 16 grid points, in each survey square

Land cover categories	Designated						Non-designated					
	True upland			Marginal upland			True upland			Marginal upland		
	Area (km^2)	SE	%	Area (km^2)	SE	%	Area (km^2)	SE	%	Area (km^2)	SE	%
Dwarf shrub heath	447.1	179.3	*11.7*	2300.0	626.7	*26.0*	8.6	8.6	*1.6*	34.7	18.3	*1.44*
Moorland grass	1008.5	188.9	*26.4*	966.0	399.1	*10.9*	0.0	0.0	*0.0*	301.0	196.6	*12.50*
Acid grass/bracken	426.3	118.3	*11.1*	1334.0	325.4	*15.1*	0.0	0.0	*0.0*	173.7	85.0	*7.21*
Bog	956.5	218.9	*25.0*	391.0	167.7	*4.4*	17.2	17.2	*3.1*	23.2	15.7	*0.96*
Flush	52.0	25.8	*1.4*	230.0	114.7	*2.6*	0.0	0.0	*0.0*	0.0	0.0	*0.00*
Marsh	20.8	20.8	*0.5*	46.0	31.7	*0.5*	8.6	8.6	*1.6*	69.5	40.4	*2.88*
Neutral/improved grassland	415.9	168.9	*10.9*	2691.0	621.1	*30.5*	120.3	120.3	*21.9*	1157.7	214.4	*48.08*
Crops	0.0	0.0	*0.0*	115.0	115.0	*1.3*	0.0	0.0	*0.0*	104.2	49.4	*4.33*
Woodland/scrub	467.9	187.5	*12.2*	414.0	153.2	*4.7*	395.3	110.9	*71.9*	405.2	195.3	*16.83*
Structures/roads	10.4	10.4	*0.3*	138.0	59.9	*1.6*	0.0	0.0	*0.0*	127.4	37.5	*5.29*
Other	20.8	14.4	*0.5*	207.0	86.7	*2.34*	0.0	0.0	*0.00*	11.6	11.6	*0.48*
Total	*3826.0*		*100.0*	*8832.0*		*100.0*	*550.0*		*100.0*	*2408.0*		*100.0*

Land cover categories	Total designated (True + marginal)			Total non-designated (True + marginal)			Total true upland (Designated + non-desig)			Total marginal upland (Designated + non-desig)			All strata		
	Area (km^2)	SE	%	Area (km^2)	SE	%	Area (km^2)	SE	%	Area (km^2)	SE	%	Area (km^2)	SE	%
Dwarf shrub heath	2747.1	651.8	*21.7*	43.3	20.2	*1.5*	455.7	179.5	*10.4*	2334.7	626.9	*20.8*	2790.4	652.09	*17.9*
Moorland grass	1974.5	441.6	*15.6*	301.0	196.6	*10.2*	1008.5	188.9	*23.0*	1267.0	444.9	*11.3*	2275.5	483.29	*14.6*
Acid grass/bracken	1760.3	346.2	*13.9*	173.7	85.0	*5.9*	426.3	118.3	*9.7*	1507.7	336.3	*13.4*	1933.9	356.52	*12.4*
Bog	1347.5	275.7	*10.6*	40.3	23.3	*1.4*	973.7	219.6	*22.3*	414.2	168.4	*3.7*	1387.8	276.74	*8.9*
Flush	282.0	117.5	*2.2*	0.0	0.0	*0.0*	52.0	25.8	*1.2*	230.0	114.7	*2.0*	282.0	117.57	*1.8*
Marsh	66.8	38.0	*0.5*	78.1	41.3	*2.6*	29.4	22.5	*0.7*	115.46	51.4	*1.0*	144.9	56.11	*0.9*
Neutral/improved grassland	3106.9	643.6	*24.5*	1278.0	245.9	*43.2*	536.2	207.4	*12.3*	3848.7	657.1	*34.2*	4384.9	688.93	*28.1*
Crops	115.0	115.0	*0.9*	104.2	49.4	*3.5*	0.0	0.0	*0.0*	219.2	125.2	*2.0*	219.2	125.13	*1.4*
Woodland/scrub	881.9	242.1	*7.0*	800.5	224.7	*27.1*	863.2	217.8	*19.7*	819.2	248.3	*7.3*	1682.4	330.24	*10.8*
Structures/roads	148.4	60.7	*1.2*	127.4	37.5	*4.3*	10.4	10.4	*0.2*	265.4	70.6	*2.4*	275.7	71.44	*1.8*
Other	227.8	87.9	*1.8*	11.6	11.55	*0.4*	20.8	14.36	*0.5*	218.6	87.5	*1.9*	239.4	88.66	*1.5*
Total	*12658.0*		*100.0*	*2958.0*		*100.0*	*4376.0*		*100.0*	*11240.0*		*100.0*	*15616.0*		*100.0*

The figures for the combined strata are weighted by stratum size
As there were only four sample squares in the non-designated true upland stratum, the SE for this stratum are high

Table A1.2 Upland: proportion of boundary types by strata
based on nearest non-curtilage boundary (within 100 m) to each grid point.

Boundaries	Designated		Non-designated		Total		Total		
	True uplands	Marginal	True uplands	Marginal	Des	Non-des	True uplands	Marginal	Total
	%	%	%	%	%	%	%	%	%
% of points without boundary	51	33	60	21	41	28	52	28	38
% of points with boundary	49	67	40	79	59	72	48	72	63
% of points with a boundary:									
Bank		+			+			+	+
Fence	43	25	74	29	32	34	47	27	33
Fence/bank	1	2			2		1	1	1
Hedge		3		2	2	2		3	2
Hedge/bank		1			1			1	1
Hedge/fence		4	5	5	3	5	1	5	4
Hedge/fence/bank		2			1			1	1
Hedge/wall		+			+			+	+
Hedge/wall/fence				1		1		+	+
Wall	31	38	11	41	35	38	29	39	36
Wall/bank		+			+			+	+
Wall/fence	25	23	11	22	24	21	23	23	23
Total	*100*	*99*	*100*	*100*	*99*	*100*	*100*	*99*	*99*

Table A1.3 Classification of quadrats from the waterside 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. Numbers in italics indicate maximum score for left hand-side of division

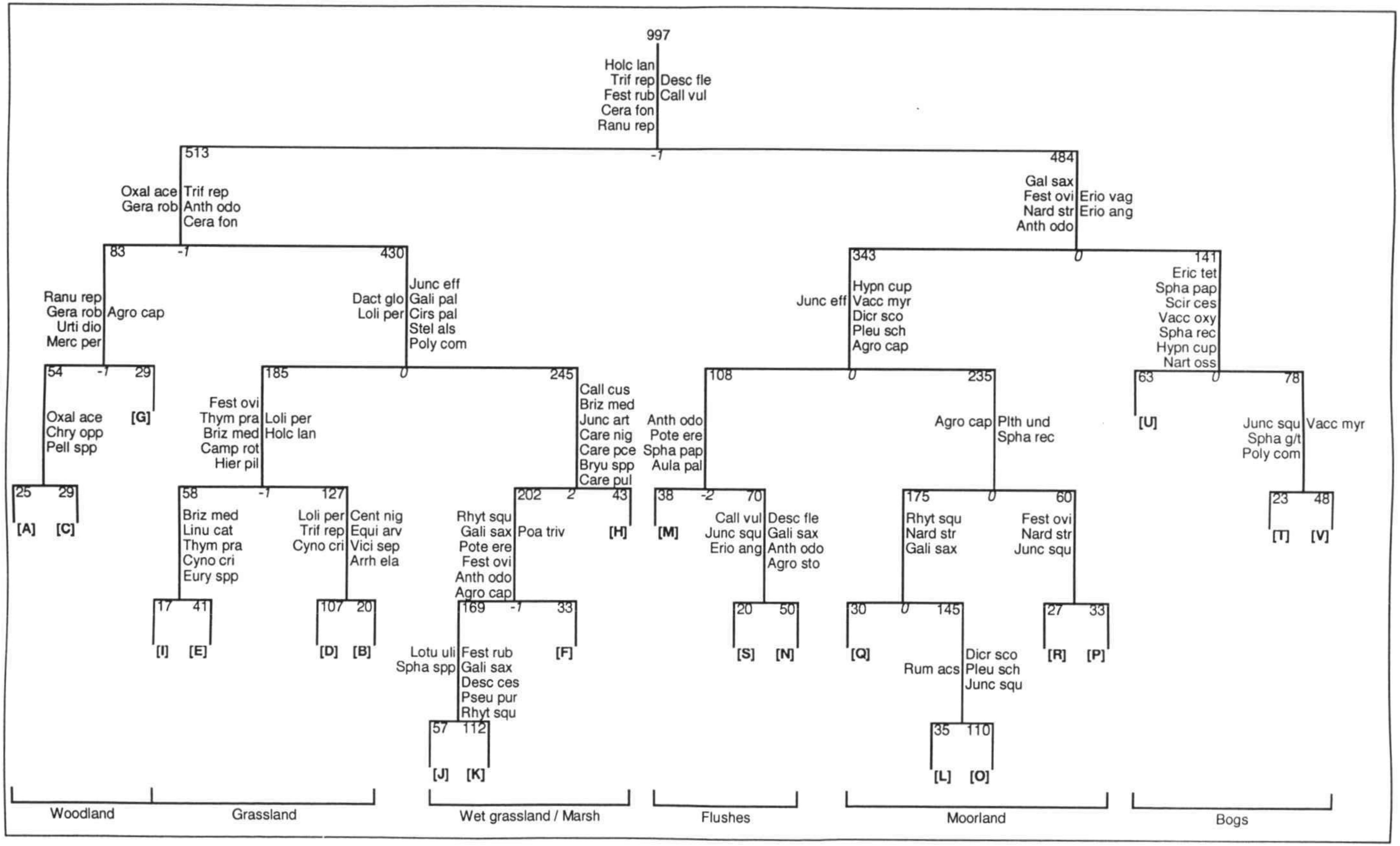


Table A1.4 Upland landscapes - TWINSPAN plot classes

Plot class	Total no. of plots	Main plots No.	Main plots %	Habitat plots No.	Habitat plots %	Stream plots No.	Stream plots %	Description	% of plots with stock grazing	% of plots with shade Full	% of plots with shade Part	Land class group	Predominant Land uses	Preferential species	Constant species	Dominant species
PCA	25	2	*8*	9	*36*	14	*56*	Neutral/calcareous woodlands (mainly ash)	8	40	44	Marginal 25 Uplands 0	Woodland Streamside	*Urti dio* *Gera rob* *Rubu fru*	*Urti dio* *Agro sto* *Gera rob*	*Urti dio* *Merc per* *Agro sto*
PCB	20	1	*5*	12	*60*	7	*35*	Neutral permanent grassland	25	0	45	Marginal 12 Uplands 8	Impr/neut grass	*Dact glo* *Fest rub* *Cent nig*	*Fest rub* *Dact glo* *Holc lan*	*Fest rub* *Arrh ela* *Dact glo*
PCC	29	2	*7*	5	*17*	22	*76*	Moist woodlands (mainly alder)	21	59	38	Marginal 17 Uplands 8	Woodland Streamside	*Oxal ace* *Gera rob* *Chry opp*	*Oxal ace* *Gera rob* *Chry opp*	*Holc mol* *Poa tri* *Agro sto*
PCD	107	61	*57*	33	*31*	13	*12*	Semi-improved grassland	68	0	10	Marginal 85 Uplands 22	Impr/neut grass	*Loli per* *Trif rep* *Cyno cri*	*Holc lan* *Trif rep* *Loli per*	*Loli per* *Holc lan* *Fest rub*
PCE	41	12	*29*	27	*66*	2	*5*	Limestone grassland	80	0	10	Marginal 27 Uplands14	Calc grass Impr/neut grass	*Briz med* *Thym pra* *Lotu cor*	*Fest ovi* *Agro cap* *Briz med*	*Fest ovi* *Fest rub* *Thym pra*
PCF	33	1	*3*	19	*58*	13	*39*	Marshy streamsides	48	0	27	Marginal 26 Uplands7	Marsh Streamside	*Ranu rep* *Poa tri* *Stel als*	*Ranu rep* *Junc eff* *Poa tri*	*Junc eff* *Holc lan* *Ranu rep*
PCG	29	6	*21*	15	*52*	8	*28*	Acid woodlands (oak, sycamore and birch)	17	62	28	Marginal 22 Uplands7	Woodland Streamside	*Oxal ace* *Mniu hor* *Holc mol*	*Oxal ace* *Holc mol* *Mniu hor*	*Holc mol* *Dryo dil* *Agro cap*
PCH	43	3	*7*	22	*51*	18	*42*	Enriched flushes	84	0	1	Marginal 16 Uplands 27	Flush	*Call cus* *Junc art* *Care pan*	*Call cus* *Holc lan* *Anth odo*	*Care pan* *Nard str* *Fest rub*
PCI	17	3	*18*	14	*82*	0	*0*	Acid grassland - short fine turf	76	0	6	Marginal 10 Uplands 7	Acid grassland	*Rhyt squ* *Fest ovi* *Hier pil*	*Fest ovi* *Rhyt squ* *Agro cap*	*Agro cap* *Fest ovi* *Rhyt squ*
PCJ	57	4	*7*	21	*37*	32	*56*	Wet rushy pasture	63	0	14	Marginal 51 Uplands 6	Streamside Flush	*Gali pal* *Junc eff* *Cirs pal*	*Junc eff* *Holc lan* *Anth odo*	*Junc eff* *Holc lan* *Agro cap*
PCK	112	36	*32*	22	*20*	54	*48*	Damp acid pasture	67	0	16	Marginal 53 Uplands 59	Acid grassland Moorland grass Streamside	*Junc eff* *Rume ace* *Holc lan*	*Anth odo* *Junc eff* *Holc lan*	*Junc eff* *Agro cap* *Anth odo*

Table A1.4 continued

Plot class	Total no. of plots	Main plots No.	Main plots %	Habitat plots No.	Habitat plots %	Stream plots No.	Stream plots %	Description	% of plots with stock grazing	% of plots with shade Full	% of plots with shade Part	Land class group	Predominant Land uses	Preferential species	Constant species	Dominant species
PCL	35	13	*37*	13	*37*	9	*26*	Upland grassland	66	0	14	Marginal 23 Uplands 12	Acid grass Heath	*Gali sax* *Desc fle* *Agro cap*	*Gali sax* *Agro cap* *Desc fle*	*Nard str* *Desc fle* *Gali sax*
PCM	38	12	*32*	14	*37*	12	*32*	Acid flushes	82	0	5	Marginal 17 Uplands 21	Flush Moorland grass	*Spha rec* *Poly com* *Aula pal*	*Anth odo* *Poly com* *Junc eff*	*Spha rec* *Nard str* *Poly com*
PCN	50	2	*4*	16	*32*	32	*64*	Moorland streamsides	60	0	8	Marginal 22 Uplands 28	Bog Streamside	*Poly com* *Junc eff* *Agro can*	*Junc eff* *Poly com* *Desc fle*	*Junc eff* *Spha spp* *Poly com*
PCO	110	66	*60*	37	*34*	7	*6*	Moorland grass	85	0	0	Marginal 43 Uplands 67	Moorland grass Heath	*Gali sax* *Fest ovi* *Vacc myr*	*Gali sax* *Fest ovi* *Nard str*	*Nard str* *Fest ovi* *Desc fle*
PCP	33	22	*67*	7	*21*	4	*12*	Sitka planted on to moorland	12	52	30	Marginal 12 Uplands 21	Woodland	*Plag und* *Pice sit* *Hypn cup*	*Plag und* *Hypn cup* *Desc fle*	*Pice sit* *Desc fle* *Vacc myr*
PCQ	30	14	*47*	9	*30*	7	*23*	Dry heath	67	0	10	Marginal 23 Uplands7	Heath Moorland grass	*Call vul* *Vacc myr* *Pter aqu*	*Call vul* *Vacc myr* *Agro cap*	*Call vul* *Vacc myr* *Desc fle*
PCR	27	17	*63*	7	*26*	3	*11*	Mossy moorland	96	0	0	Marginal 7 Uplands 20	Moorland grass	*Plag und* *Pleu sch* *Desc fle*	*Desc fle* *Fest ovi* *Poly com*	*Poly com* *Desc fle* *Junc squ*
PCS	20	2	*10*	8	*40*	10	*50*	Acid wet heath (*Juncus squarrosus*)	75	0	0	Marginal 12 Uplands 8	Bog Streamside	*Junc squ* *Call vul* *Poly com*	*Junc squ* *Poly com* *Call vul*	*Spha spp* *Junc squ* *Call vul*
PCT	23	7	*30*	10	*43*	6	*26*	Blanket bog	70	0	0	Marginals 8 Uplands 15	Bog	*Erio ang* *Erio vag* *Spha spp*	*Erio ang* *Erio vag* *Poly com*	*Call vul* *Erio vag* *Spha spp*
PCU	63	22	*35*	30	*48*	11	*17*	Wet heath/bog	36	0	16	Marginal 9 Uplands 54	Bog Woodland	*Erio vag* *Erio ang* *Call vul*	*Erio vag* *Call vul* *Erio ang*	*Call vul* *Erio vag* *Desc fle*
PCV	55	26	*47*	20	*36*	9	*16*	Northern bog	73	11	2	Marginals 31 Uplands 24	Wet Heath Bog	*Erio vag* *Call vul* *Erio ang*	*Call vul* *Erio vag* *Erio ang*	*Call vul* *Erio vag* *Vacc myr*

Appendix 2 Technical appendix to Chapter 5 – Historical characteristics of the upland mask

This Appendix includes:

- details of the work programme associated with characterising the upland mask (A2.1)
- commentary on available data (A2.2)
- Tables which provide further, detailed results from work on historical aspects of the upland landscape mask (A2.3), not given in Chapter 5.

A2.1 Detailed work programme

A2.1.1 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 km squares for the upland 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 upland landscape
     Quantification of management history data
3. Assessment of the effectiveness of current designations in protecting historic features within the upland 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.

A2.1.2 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.

A2.2 Assessment of archaeological data

Data sources

A2.2.1 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.

A2.2.2 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.

A2.2.3 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

A2.2.4 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 A2.1. The information collated divides into three main groups:

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

A2.2.5 Identifiers and location information is routinely given in archaeological databases and was readily collated.

A2.2.6 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 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 were therefore replaced by the single entry 'flint'.

A2.2.7 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 A2.3 (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'.)

A2.2.8 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

A2.2.9 Archaeological data were compiled for 165 archaeological sites in 32 sample squares drawn from 10 counties. A breakdown by county (Table A2.5) 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.

A2.2.10 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).

A2.2.11 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 of the archaeological resource.

A2.2.12 New sites (62) identified through ITE fieldwork, AP work and map analysis constitute 37.6% of the total number, representing an increase of 60.2% on the SMR/NMR entries (103). 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').

A2.2.13 It is also apparent from the compiled data that the mean density of monuments at 5.1 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 A2.7 makes clear, NMR figures for site numbers are consistently low in the upland landscape when compared to SMR entries (by a factor of between 1.5 and 3).

A2.2.14 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.

A2.3 Tables which provide further, detailed results from work on historical aspects of the upland mask (A2.3), not given in Chapter 5

Table A2.1 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 A2.2 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 A2.3 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 A2.4 Data source totals for the upland landscape

County	All sites SMR/ NMR	All sites New	Upland SMR/ NMR	Upland New
Beds	13	7	13	7
Berks	16	22	16	22
Bucks	14	17		
Cambs	4	4		
Cleveland	2	4		
Cornwall	213	36	47	12
Cumbria	53	32	3	
Derbyshire	5	8		
Devon	141	29	63	22
Dorset	44	46	36	31
Durham	6	7		
Essex	9	12		
E Sussex	12	18	3	6
Gloucester	50	15	20	5
Hants	51	46	46	40
Herts	2			
Humberside	28	14		
Isle of Wight	58	27		
Kent	36	16		
Lancs	18	15		
Lincoln	3	2	3	2
Norfolk	110	47	61	32
Northants	14			
Northumberland	16	19		
Nottingham	2	5	2	5
N Yorks	65	40	6	12
Oxford	9	2		
Salop	3	16	1	3
Somerset	16	5	6	2
Staffs	20	16	12	11
Suffolk	135	21	115	11
Surrey	14	32	14	32
Tyne & Wear	8	1		
Warwick	4	5	4	5
Wiltshire	29	6		
W Midlands		4		4
Worcester	1	1	1	1
W Sussex	28	8	11	4
York Dales	77	11		
Totals	*1329*	*616*	*483*	*269*
	1945		*752*	

Table A2.5 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 A2.6 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 A2.7 Number of sites and number of sites per square

Data source	Upland 89 squares Sites	km^{-2}
SMR only	83	2.6
NMR only	55	1.7
SMR/NMR	103	3.2
New survey	62	1.9
Combined sources	165	5.1

Table A2.8 Quantity of features – site types by period for the upland landscape (showing site types occurring more than once in the dataset)

RCHME class	Site type	Period	No
Agriculture and subsistence	Agricultural building	UN	2
	Farm	UN	5
	Field system	I-MD	2
		UN	8
	Sheep fold	UN	8
	Sheiling	J-PM	4
Domestic	House	J-PM	3
		UN	2
	Hut	A-PR	2
Garden & parks	Ha ha	UN	4
Industrial	Lime kiln	J-PM	10
	Mine	UN	9
	Quarry	J-PM	8
		UN	11
Recreation	Grouse butts	UN	2
Religious, ritual and funerary	Burial cairn	E-BA	4
	Chapel	UN	2
		UN	5
Unassigned	Boundary	UN	4
	Building	I-MD	2
	Earthwork	UN	3
	Enclosure	A-PR	2
		UN	9

Appendix 3 Technical appendix to Chapter 7 – Predicting changes in upland vegetation

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

A3.1 Introduction

A3.1.1 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.

A3.2 Phase I – allocation of functional types

A3.2.1 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.

A3.2.2 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.

A3.2.3 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.

A3.2.4 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.

A3.2.5 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.

A3.2.6 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.

A3.3 Phase II – effects of change scenarios on the abundance of functional types

A3.3.1 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).

A3.3.2 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.

A3.3.3 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.

A3.3.4 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.

A3.3.5 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.

A3.3.6 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 90–100).

A3.4 Phase III – computation of an 'index of vulnerability'

A3.4.1 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).

A3.4.2 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 in pages 90–100). 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.

A3.4.3 Finally, page 101 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

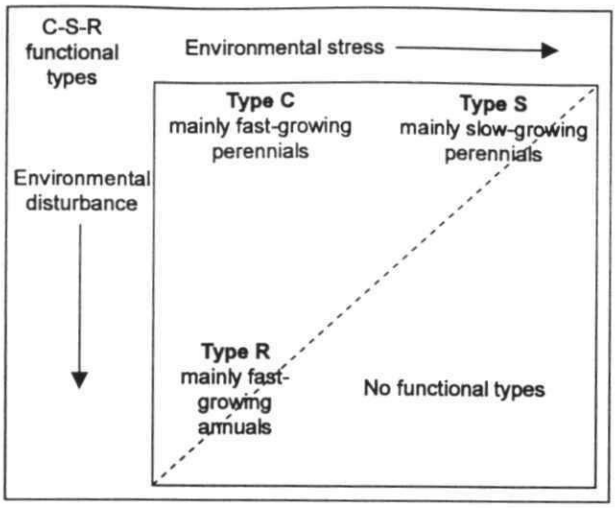


Figure B. The relationship between stress and disturbance factors and the C-S-R types

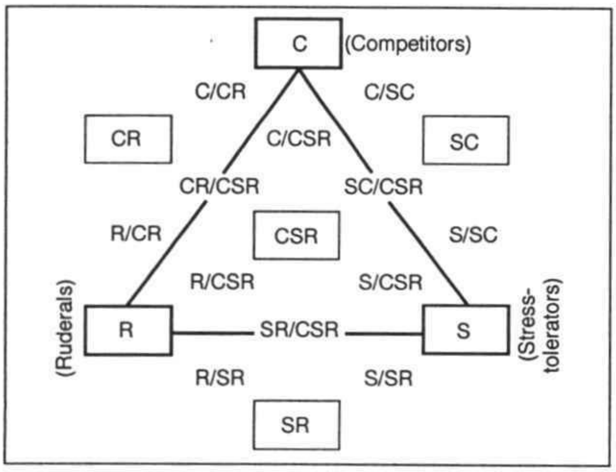


Figure C. The C-S-R triangle ordination showing the three principal functional types and intermediate positions

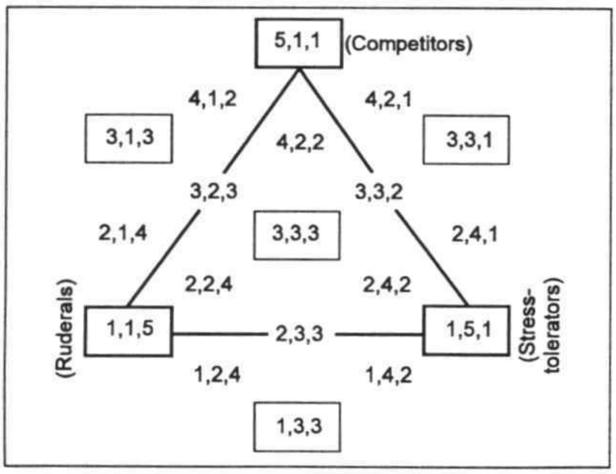


Figure D. C-S-R co-ordinates of functional types

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 upland landscape plot classes are not separated by TWINSPAN into natural groupings with respect to functional type and management regime. Accordingly, they will for the purposes of this interpretation be divided into three groupings that relate to habitat type:

- **woodland** (plot classes A, C, G and P)
- **grassland** (plot classes B, D, E, I, K, L, O, Q and R)
- **wetland** (plot classes F, H, J, M, M and S–V).

Grassland is further subdivided into relatively **productive** (plot classes B and D) with a high representation of functional type CSR and **unproductive** (plot classes E, I, K, L, O, Q and R) with high representation of type S. Unproductive includes both acidic variants, acidic grassland and heathland (plot classes I, K, L, O, Q and R), and calcareous ones (E).

1. **Woodland** (plot classes A, C, G and P) is a relatively natural grouping. It has its own range of management procedures with understorey shading by its woody dominants. 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 type 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 (neutral/calcareous woodlands – mainly ash) has the smallest representation of S, a type which, in the context of woodland, is often associated with shade tolerance and most species of type C. Plot class C (moist woodlands – mainly alder) have the greatest percentage of SR, and presumably most vernal species. Because the major check on growth of understorey species is shade, all woodland plot classes have a similar species composition in terms of functional types. However, there are probably inherent differences in the potential productivity of the soils. Woodlands on base-rich soils (plot classes A and C) are likely to be associated with greater levels of potential productivity than those on less acidic ones (G and P).

2. **Grassland** (plot classes B, D, E, I, K, L, O, Q and R), as indicated above, can be subdivided into groups on the basis of plant types. The more **productive** (plot classes B and D) have a high representation of type CSR and little of type S. In the remainder, 'unimproved' **unproductive** grassland (plot classes E, I, K, L, O, Q and R), type S is prevalent. Plot classes E (limestone grassland), I (acidic grassland – short fine turf) and K (damp acidic pasture) with a high representation of CSR are perhaps the only three closely grazed variants of unproductive grassland. The remainder (plot classes L, O, Q and R) have a high representation of type SC, a reflection of the presence of heather (*Calluna vulgaris*) and related subshrubs and of a lower intensity or absence of grazing.

3. **Wetland habitats** (plot classes F, H, J, M, N and S–V) are mostly unproductive with a predominance of types SC and S. The most extreme in this respect are plot classes M and R–V. The only relatively productive plot class is F (marshy streamsides) with a high percentage of types CR and CSR. The presence of type CR, and to a lesser extent type R, may relate to disturbance due to flooding. These types are also well represented in class H (enriched flushes). Type CR will include a number of species from near the water's edge, such as watercress (*Rorippa nasturtium-aquaticum*), which are able to regenerate from shoot fragments following damage associated with flooding. Plot class J (wet rushy pasture) also has a high representation of types CR and R. However, the class is somewhat intermediate between mire and grassland. It contains many CSR species, the type most characteristic of grazed habitats.

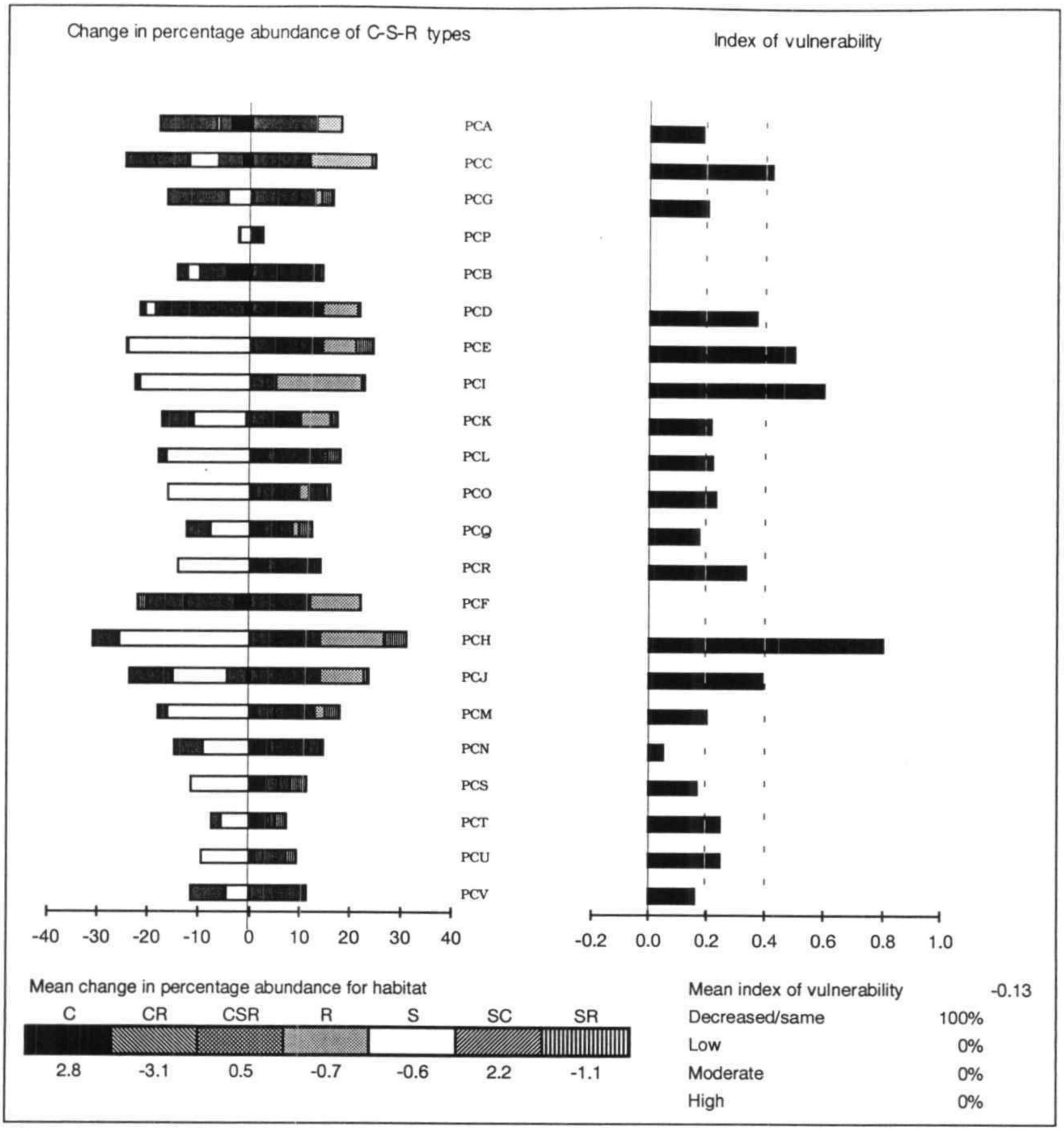
Key species

Heather (*Calluna vulgaris*)
Sheep's fescue (*Festuca ovina*)
Bilberry (*Vaccinium myrtillus*)
Common bent (*Agrostis capillaris*)

Important invaders

- **Derelict conditions**
  Birch (*Betula pendula, B. pubescens*) and other trees and shrubs
  Bracken (*Pteridium aquilinum*)
  Mat-grass (*Nardus stricta*) and other coarse grasses
- **Derelict eutrophicated conditions**
  Gorse (*Ulex europaeus*) – especially in areas which become burnt
  Bramble (*Rubus fruticosus*)
  Stinging nettle (*Urtica dioica*)
  Creeping thistle (*Cirsium arvense*) and other tall herbs
  False oat (*Arrhenatherum elatius*)
  Common couch (*Elytrigia repens*) and other coarse grasses
  In wet areas
  - soft rush (*Juncus effusus*)
  - tufted hair-grass (*Deschampsia cespitosa*)
  - great willowherb (*Epilobium hirsutum*)
  - reed canary-grass (*Phalaris arundinacea*).

Scenario 1 – [Disturbance decreased; eutrophication the same]

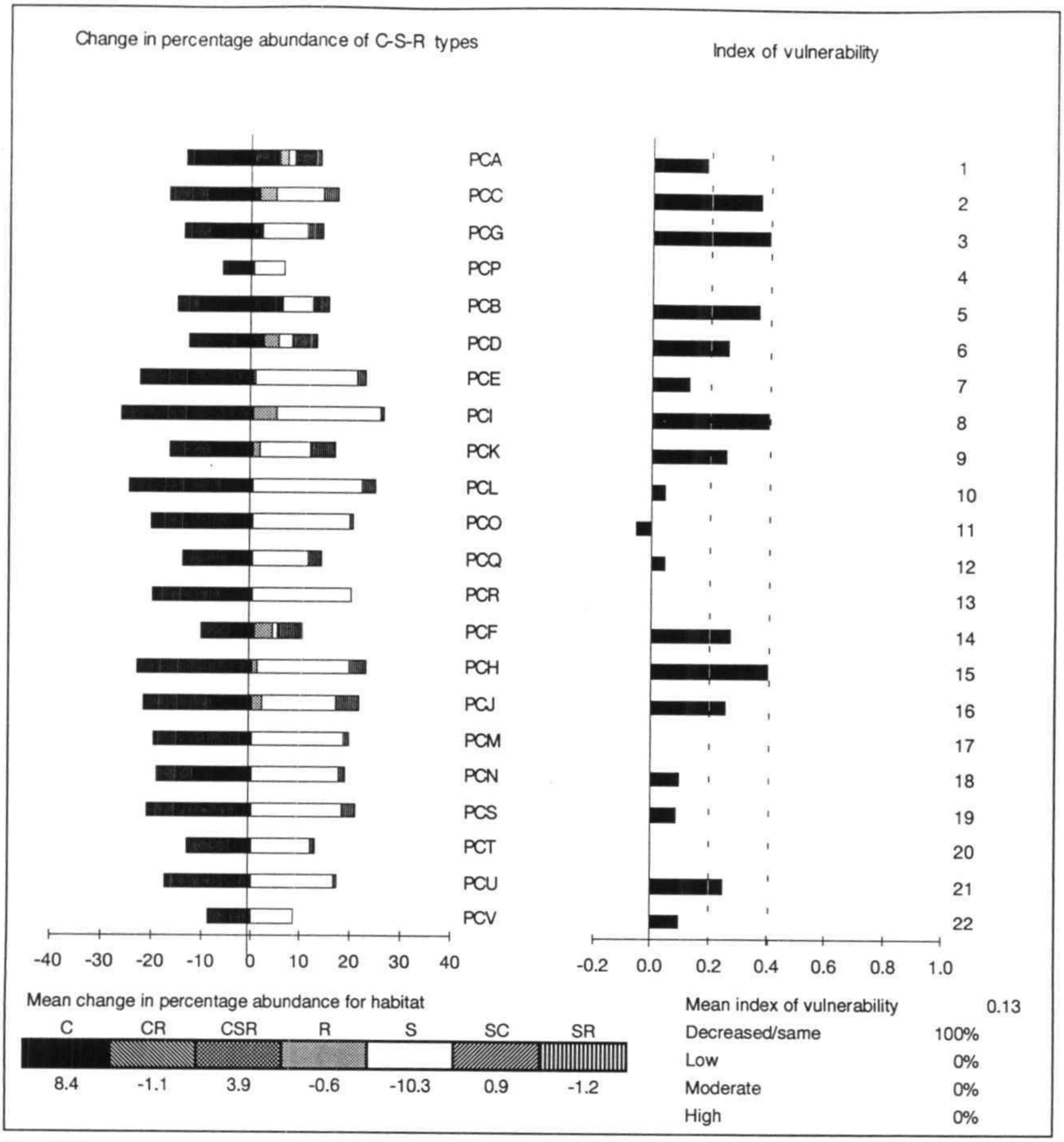


Possible causes of this scenario

- **Woodland** – *decreased disturbance* – no tree thinning [in heathy areas a reduced incidence of fires], less flooding
- **Grassland** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires, less flooding
- **Wetland habitats** – *decreased disturbance* – cessation/reduction of flooding, particularly severe floods where there is silt deposition or scouring by fast-flowing water, less recreational pressure, grazing or cutting

In **woodland** (plot classes A, C, G and P) only a small change is predicted. This to some extent 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. It is, however, unlikely that type C will be a beneficiary at the expense particularly of CR as predicted by TRISTAR. In **grassland** (plot classes B, D, E, I, K, L, O, Q and R), similar shifts in functional type are predicted. In the most eutrophic class (B) a denser taller sward would be expected and, consistent with this, there are increases in type C primarily at the expense of type CR. In the least productive grassland (plot classes O, Q and R), where growth rates are slow, smaller changes are expected, with SC the beneficiary at the expense of all other classes. 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. For **wetland** habitats (plot class F), which are eutrophic, a similar change to that for productive grassland is predicted, namely an increase in type C and to a lesser extent SC. For less productive habitats (eg plot classes S–V), SC is the main beneficiary, as in grassland. 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 negative or low, and short-term impacts on the strategic composition of the vegetation will be slight.

Scenario 2 – [Disturbance decreased; eutrophication increased]

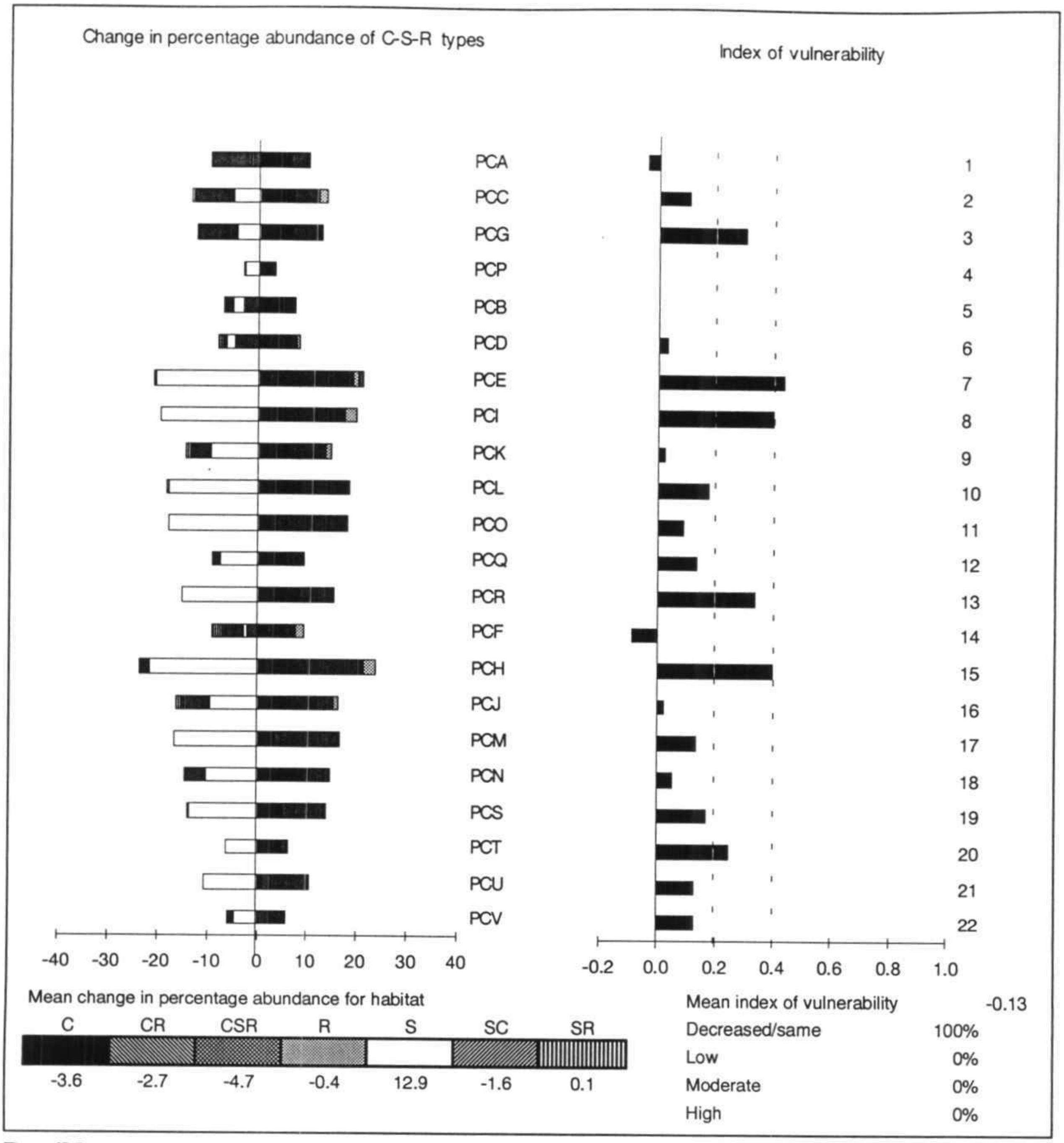


Possible causes of this scenario

- **Woodland** – *decreased disturbance* – no tree thinning [in heathy areas a reduced incidence of fires], less flooding; *increased eutrophication* – fertilizer runoff or atmospheric deposition, more flooding
- **Grassland** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires; *increased eutrophication* – fertilizer runoff or atmospheric deposition, more flooding
- **Wetland habitats** – *decreased disturbance* – cessation/reduction of flooding, particularly severe floods where there is silt deposition or scouring by fast-flowing water, less recreational pressure, grazing or cutting; *increased eutrophication* – fertilizer runoff or atmospheric deposition, more flooding

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). Taller, faster-growing vegetation should be produced and overall losses of types S and ruderals and an increased representation by type C are predicted. The reality for **woodland** (classes A, C, G and P) is likely to be somewhat different to that predicted by TRISTAR. 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 small losses within type SC are unlikely to happen. Instead, increased shade and litter production are likely. This would tend to suppress further the herb layer. Thus, in reality, types SR (vernals) and S seem most likely to increase in the longer term, provided that there are no barriers to their initial establishment. In **grassland** (classes B, D, E, I, K, L, O, Q and R), the predicted losses of types S and of ruderals, together with an increased representation by type C, is more realistic. However, the more eutrophic classes (classes B and D) will exhibit rapid change, while in the less productive grassland change will be slower, CSR and SC will tend to increase, and major losses will be of type S. For eutrophic **wetland** habitats (classes F, H, J, M, N and S–V), again an increase in type C is predicted mainly at the expense of other types. Even if natural processes (erosion and sedimentation) restrict the impact of type C, sites should be more strongly vegetated. As in less productive grassland, type SC and CSR rather than type C tend to increase in less productive mire (eg S–V). Eutrophication should encourage rapid recovery following disturbance. The values for index of vulnerability are mainly low, indicating that short-term impacts on the strategic composition of most plot classes will be slight. However, plot classes H, R and S have moderate indices.

Scenario 3 – [Disturbance same; eutrophication decreased]

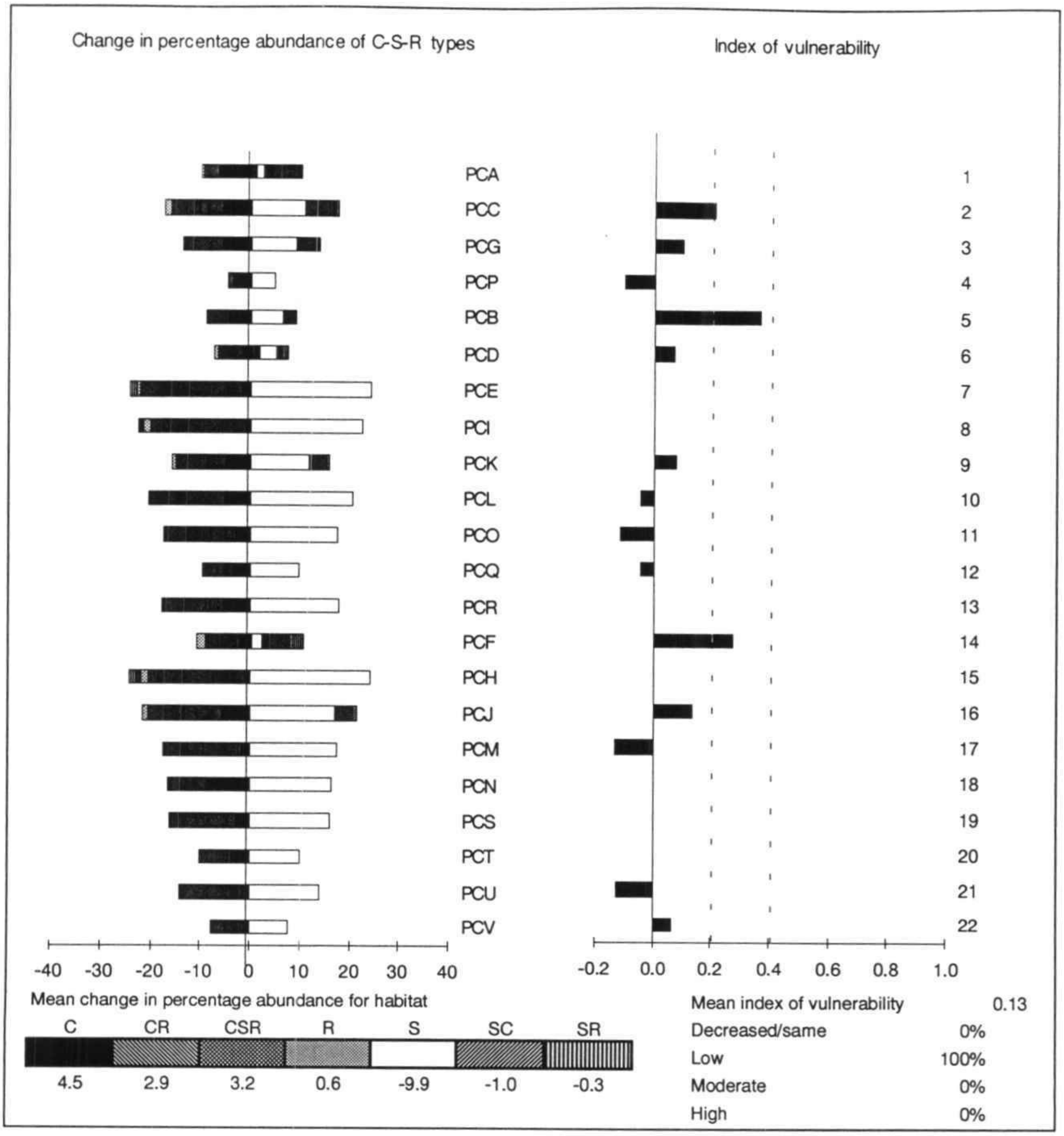


Possible causes of this scenario

- **Woodland** – *decreased eutrophication* – potentially a natural consequence of woodland ageing; the soil becomes progressively depleted of nutrients as the tree biomass increases. Also, reduced flooding, if this did not affect the level of disturbance, could reduce nutrient inputs into the system
- **Grassland** – *decreased eutrophication* – decreased usage of or pollution from fertilizers; reduced flooding, if this did not affect the level of disturbance, could reduce nutrient inputs into the system
- **Wetland habitats** – *decreased eutrophication* – decreased usage of or pollution from fertilizers, decreased deposition of nutrient-laden mud and silt

Increases in type S and decreasing C, CSR and ruderals (eg CR) are predicted. However, any increase in type S, which grows very slowly, will take a considerable period 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, sites in plot classes where type S is poorly represented (plot classes A and D) may fail to be colonised by type S. **Grassland** (plot classes B, D, E, I, K, L, O, Q and R) and **wetland** habitats (plot classes F, H, J, M, N and S–V) are expected to change in accordance with the general pattern predicted above. In less productive vegetation (plot classes E, and H–V), growth rates will already be slow and a major shift to class S is expected. However, the more eutrophic classes (B, D and F) start with a high nutrient status and will therefore not reach such low levels of productivity. For this reason, increases in type SC may be greater than in type S. Impacts on the **woodland** grouping (plot classes A, C, G and P) 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. As 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. Values for index of vulnerability are low; plot classes B, C and F, with moderate values, are exceptional, indicating that short-term impacts on the strategic composition of the vegetation will be slight for most plot classes.

Scenario 4 – [Disturbance the same; eutrophication increased]

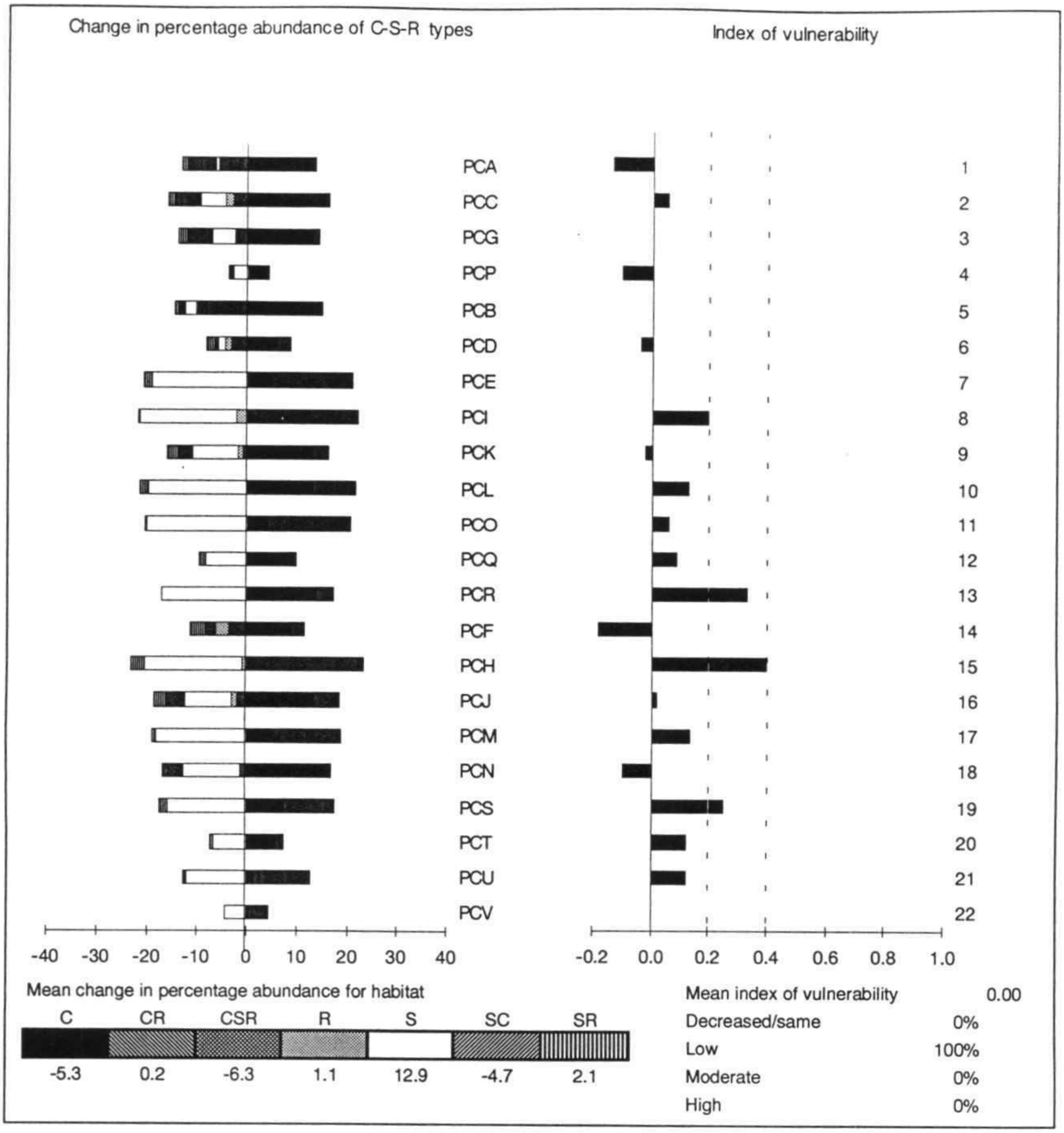


Possible causes of this scenario

- **Woodland** – *increased eutrophication* – fertilizer runoff or atmospheric deposition mainly from agricultural sources, fertilizer applications as a part of silvicultural practice, increased flooding (in absence of appreciable disturbance)
- **Grassland** – *increased eutrophication* – fertilizer runoff or atmospheric deposition, increased flooding (in absence of appreciable disturbance)
- **Wetland habitats** – *increased eutrophication* – increased flooding (in absence of appreciable disturbance), fertilizer runoff or atmospheric deposition

Increased eutrophication is one of the most important scenarios to consider with respect to changing land use. Within eutrophic **grassland** and **wetland habitats** (plot classes B, D and F), where many species are fast-growing, rapid changes are predicted, with a particular decrease in CSR and SC types and an increase in C and CR. In less productive **grassland** (plot classes E, I, K, L, O, Q and R) and **wetland** habitats (plot classes H, J, M, N and S–V), growth rates are slower and the predicted shift is more from class S and SC. In the **woodland** grouping (plot classes A, C, G and P), 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 vernals (type SR) and type S. Most values for index of vulnerability are low indicating that short-term impacts on the strategic composition of the vegetation will be small in many plot classes. However, plot class E has high vulnerability and plot classes G–I, R and T have moderate values.

Scenario 5 – [Disturbance increased; eutrophication decreased]



Possible causes of this scenario

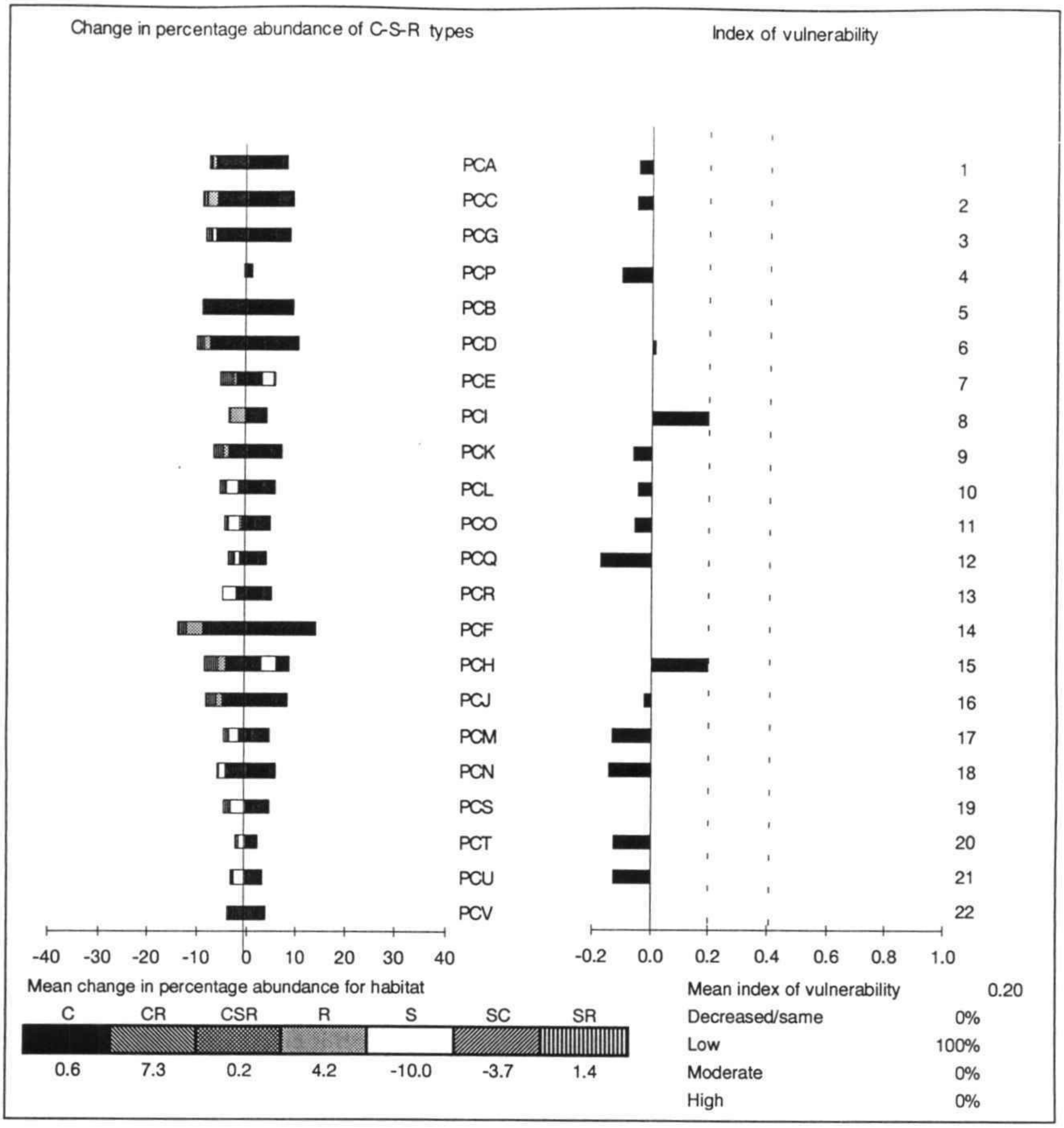
- **Woodland** – *increased disturbance* – tree thinning, incidence of fire (discouraged during forestry practice); *decreased eutrophication* – less fertilizer runoff or atmospheric deposition mainly from agricultural sources, less fertilizer added as a part of silvicultural practice or more leaching
- **Grassland** – *increased disturbance* – increased grazing or cutting, reduced incidence of fires, increased recreational pressure; *decreased eutrophication* – less fertilizer runoff or atmospheric deposition
- **Wetland habitats** – *increased disturbance* – increased grazing or cutting, increased recreational pressure; *decreased eutrophication* – less fertilizer runoff or atmospheric deposition

Flooding typically causes increased disturbance and increased eutrophication. It therefore cannot play a part in this scenario

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 more eutrophic **grassland** (plot classes B and D) and **wetland** habitats (plot class P). Damage to perennial species should allow the spread of types R or 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. TRISTAR does not distinguish these effects of low-level disturbance over long periods from more severe but punctuated episodes of disturbance. In less productive **grassland** (plot classes E, I, K, L, O, Q and R) and **wetland** habitats (plot classes H, J, M, N and S–V), opportunities for species with short life cycles are more restricted. Type SR, particularly low-growing bryophytes, would be expected to be the main beneficiary of disturbance but little change is predicted here for many of the plot classes. The main impact of decreased eutrophication should be an increase in type S. However, this type grows very slowly and many species of type S are poor colonists. Thus, changes will also be correspondingly slow and it is only in less productive habitats that major increases in type S are forecast. The changes affecting the **woodland** grouping (plot classes A, C, G and P) 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. 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. Moderate vulnerability is shown by plot classes B–D, F–K and U.

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 flooding; *increased eutrophication* – fertilizer runoff or atmospheric deposition mainly from agricultural sources, fertilizer applications as a part of silvicultural practice, increased flooding
- **Grassland** – *increased disturbance* – increased incidence of fires, more grazing, more recreational pressure, increased flooding; *increased eutrophication* – fertilizer runoff or atmospheric deposition, increased flooding
- **Wetland habitats** – *increased disturbance* – increased flooding, increased grazing or cutting, increased recreational pressure; *increased eutrophication* – increased flooding, fertilizer runoff or atmospheric deposition

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. In **woodland** (plot classes A, C, G and P), increases in types CR and R are predicted, particularly at the expense of types SC and S. However, floristic and strategic composition is strongly influenced by the dominants of the system, ie trees. For eutrophic **grassland** (plot classes B, D, E, I, K, L, O, Q and R) and **wetland** habitats (plot classes F, H, J, M, N and S–V), 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, for **acidic vegetation** (plot classes M, O and P), greatest losses of type S are predicted. In the **woodland** grouping (plot classes A, C, G and P), 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 classes C, E, H and I show high vulnerability.

Index of vulnerability

'Upland habitats' are a heterogeneous grouping of wetland, woodland and grassland vegetation. The individual classes differ in their representation of functional types. There are no plot classes with a predominance of ruderal types. Representation of type C is particularly high in some woodland (plot classes A and G) and wetland (plot classes K and N). Predictably, grassland plot classes (eg B and D) have most CSR; grazing is both a disturbance event (the removal of biomass) and induces stress (removal of nutrients). However, some wetland classes have high values (eg F) and may be grazed. Low productivity is associated with high values for type S and type S is well represented in most non-woodland plot classes. Habitats with woody species woodland (plot classes A, C, G and P) and moorland (grassland Q–R; wetland S–V) almost by definition have a high representation of type SC.

TRISTAR predicts considerable differences in responsiveness to changing land use. The impact to the various scenarios can be summarised as follows.

Low – moderate impacts

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

High impacts

(none)

Major differences occur within habitat groupings. Thus, wetland has both the highest average vulnerability(plot class H, enriched flushes 37%) and one of the lowest plot classes (N, moorland streamsides –3%). This illustrates that to a considerable extent it is the functional nature of the vegetation rather than its broad habitat type which determines susceptibility. Average vulnerability is greatest in those plot classes with a wide representation of classes. In the upland habitats, where most plot classes are unproductive, it is the more productive classes which exhibit this characteristic (plot classes H, I and E).