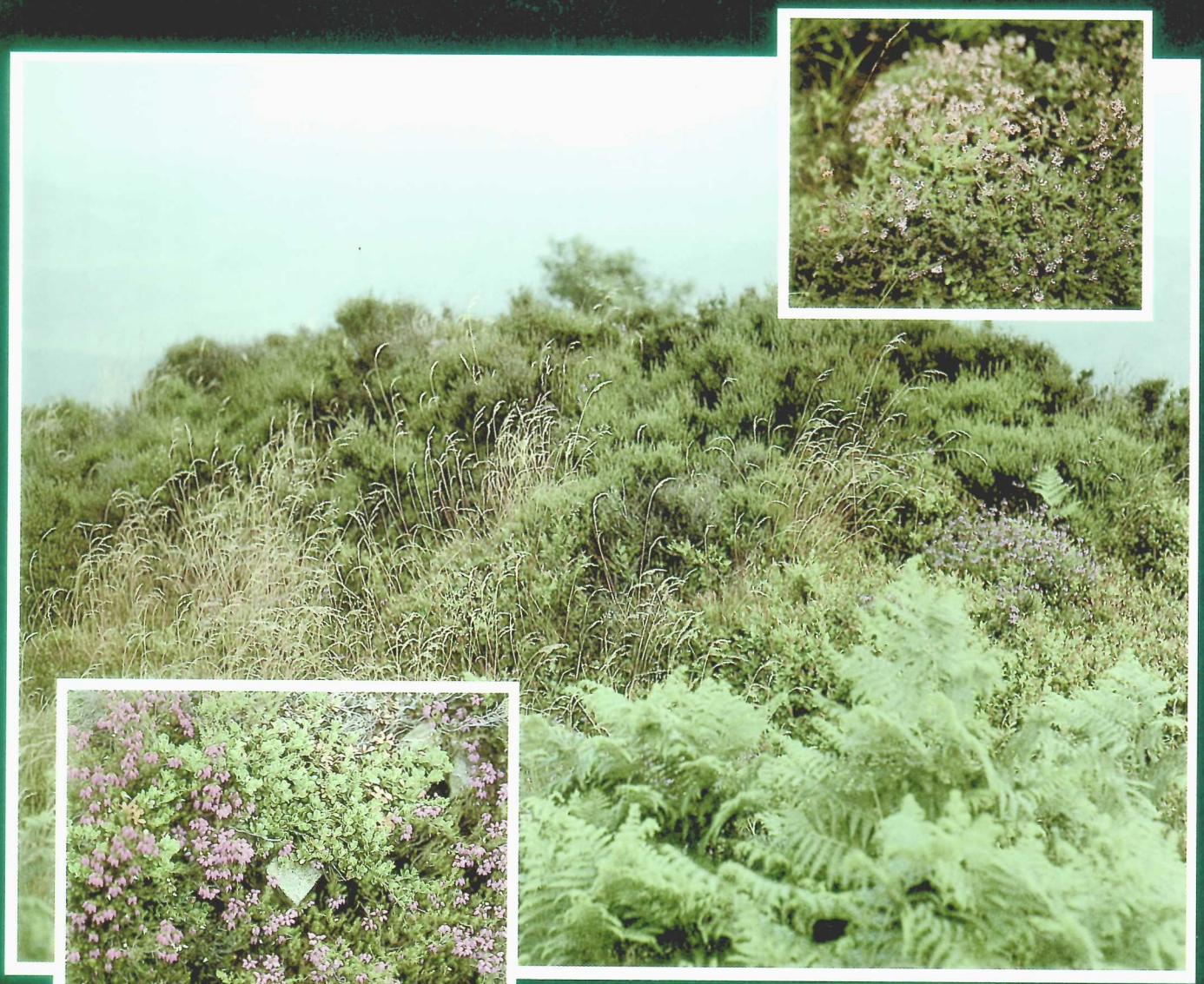
# HEATHER IN ENGLAND AND WALES



Institute of Terrestrial Ecology
Natural Environment Research Council

Natural Environment Research Council

Institute of Terrestrial Ecology

# Heather in England and Wales

ITE research publication no. 3

Edited by R G H Bunce



London: Her Majesty's Stationery Office

First published 1989
ISBN 0 11 701422 2

COVER ILLUSTRATIONS

Main picture: a mixture of some of the main species of heather moorland, ie heather (*Calluna vulgaris*), bell-heather (*Erica cinerea*), bracken (*Pteridium aquilinum*) and wavy hair-grass (*Deschampsia flexuosa*)

Inset (top) heather
(bot) bell-heather and bearberry (*Arctostaphylos uva-ursi*)

(All photographs by R G H Bunce)

The INSTITUTE OF TERRESTRIAL ECOLOGY (ITE) is one of 15 component and grant-aided research organizations within the NATURAL ENVIRONMENT RESEARCH COUNCIL. The Institute is part of the Terrestrial and Freshwater Sciences Directorate, and was established in 1973 by the merger of the research stations of the Nature Conservancy with the Institute of Tree Biology. It has been at the forefront of ecological research ever since. The six research stations of the Institute provide a ready access to sites and to environmental and ecological problems in any part of Britain. In addition to the broad environmental knowledge and experience expected of the modern ecologist, each station has a range of special expertise and facilities. Thus, the Institute is able to provide unparallelled opportunities for long-term, multidisciplinary studies of complex environmental and ecological problems.

ITE undertakes specialist ecological research on subjects ranging from micro-organisms to trees and mammals, from coastal habitats to uplands, from derelict land to air pollution. Understanding the ecology of different species of natural and man-made communities plays an increasingly important role in areas such as improving productivity in forestry, rehabilitating disturbed sites, monitoring the effects of pollution, managing and conserving wildlife, and controlling pests.

The Institute's research is financed by the UK Government through the science budget, and by private and public sector customers who commission or sponsor specific research programmes. ITE's expertise is also widely used by international organizations in overseas collaborative projects.

The results of ITE research are available to those responsible for the protection, management and wise use of our natural resources, being published in a wide range of scientific journals, and in an ITE series of publications. The Annual Report contains more general information.



R G H Bunce
Institute of Terrestrial Ecology
Merlewood Research Station
Grange-over-Sands
LA11 6JU
Tel: 05393 32264

# Contents

# Foreword

The results in the present document were obtained over a six-week period in August/September 1988, in response to the widespread concern over heather decline. The work was initiated by the Directorate of Rural Affairs of the Department of the Environment (DOE), and was carried out mainly by Hunting Technical Services Limited (HTS) and the Institute of Terrestrial Ecology (ITE). Hunting used remote satellite imagery as a rapid means of mapping heather, and ITE, in conjunction with Penny Anderson, provided a statement of the current status of heather. The results demonstrate how a short-term project can produce rapid results at a national level, and identify critical areas where further work is required.

A variety of other projects (eg the heather project of the Nature Conservancy Council and ITE's contract work with DOE) has already utilized these data.

# Acknowledgements

Anne Hawkins and Alison Thwaite (HTS) assisted with the processing of the satellite imagery and the production of the heather maps, and Kathy Troll (ITE Merlewood) was also involved in the field survey.

Gordon Miller (ITE Banchory Research Station, Kincardineshire) provided valuable advice and general background information. Mrs P A Ward provided major assistance in the conversion of the original project report into the present publication.

In addition, we acknowledge the help of the following individuals and organizations who were visited in order to obtain available ground data and to discuss the satellite imagery:

ITE Bangor Research Station, Gwynedd
Lake District National Park Special Planning Board, Kendal, Cumbria
Ministry of Agriculture, Fisheries and Food
Moorland Association
National Remote Sensing Centre, Farnborough, Hampshire
NCC Assistant Regional Officers
Nigel Webb, ITE Furzebrook Research Station, Wareham, Dorset
North York Moors National Park Authority, Helmsley, North Yorkshire
Northumberland National Park Authority, Hexham, Northumberland
Resource Planning Group, ADAS, Aberystwyth, Dyfed
Geoffrey Sinclair
Soil Survey of England and Wales, Aberystwyth, Dyfed
Yorkshire Dales National Park Authority, Leyburn, North Yorkshire

# Summary


The aim of the project was to define rapidly the distribution of the principal areas of heather in England and Wales, and to assess its current status, the historical changes that had occurred and the potential for its restoration. Detailed mapping may subsequently be undertaken to refine the general patterns that were identified.

Assessment of the area of heather in England and Wales depends upon the definition chosen. In this project, undertaken for the Department of the Environment, it was considered to be an area which had a detectable cover of dwarf ericaceous shrubs, most notably *Calluna vulgaris* (L.) Hull, but also other heaths of the genus *Erica*. Areas of heather were identified and mapped from recent satellite imagery (Landsat Thematic Mapper (TM)), and divided into three categories (ia, ib, ii):

i. Dominant – where the heather community covers more than 50% of the land. This category is further divided into:
   a. unmanaged, where there is little burning (called Dominant);
   b. managed with significant controlled burning (called Managed).

ii. Sub-dominant – where species other than heather dominate, but heather is still identifiable by satellite (ie >25% and <50%).

The total area of heather in the three categories in England was measured as 460 418 ha, with Wales having 124 733 ha. These figures are comparable (within 15%) with other published estimates of heather area, from the Hunting Technical Services (HTS) project on 'Monitoring landscape change' (MLC) and the ecological surveys carried out by the Institute of Terrestrial Ecology (ITE). The areas of heather were further divided by county and for National Parks and Environmentally Sensitive Areas (ESAs).

In estimating heather decline, methodological differences account for some apparent changes, and only major discrepancies can be considered valid. The decline in area mainly occurred between the late 1940s and 1960s. Subsequent decline appears to have been relatively small and is difficult to separate from differences in the methods of estimation. The lowland heaths have been reduced to a greater degree than in the uplands but, because of their small relative area, the decline is masked in the total figures. A reduction in the overall cover of heather would not be shown by the estimates of area because an area could have declined from 90% cover to 25%, yet still be included as heather. The widespread belief in the decline of heather could, therefore, still be consistent with the present figures, but further studies are required to assess the state of the heather and to determine whether there is evidence of dieback or a decline in vigour of the plants.

The accuracy of the identification of heather cover by TM was tested by a small-scale field survey and by comparison with the ITE national land cover data set. In general, the identification was accurate and only a few small isolated areas were identified where heather was not recorded by the interpretation of the satellite imagery. Such areas may be masked on the image by scrub cover or by topography such as cliffs. The current maps together with local mapping, eg by National Park Authorities, could form the basis for detailed maps of individual areas over a longer period of time.

The status of heather is described for major regions in England and Wales. The initial division is between heather moorland, present mainly in the north of England and Wales, and lowland heaths, which have a more southerly distribution and occur at a lower altitude. Other areas are found on Dartmoor and Exmoor and in the lowlands of Yorkshire, Cheshire, Shropshire and Lancashire. Both types of heather have diminished in recent decades and are currently under threat. In the heather moorlands, the major causes of loss are identified as overgrazing by sheep, a decline in management for grouse, accumulation of plant nutrients, unsympathetic management practices (including inappropriate burning), and afforestation. The lowland heaths have declined as a result of changes in management, through the conversion of land to agriculture, and because of eutrophication.

The main interests and value of heather as a cover type are identified as amenity (including landscape, tourism and sport) and wildlife conservation. The report identifies where current knowledge and information are lacking and identifies where research is needed to maintain heather cover.

The major requirements are:

- a better definition of heather areas and co-ordinated monitoring
- studies into the dynamics of heather moors and heaths
- an assessment of the consequences of different management practices.

Finally, incentives are required for management practices which favour heather.

# Introduction

R G H Bunce[1] and D Fowler[2]

*Institute of Terrestrial Ecology:*
*[1]Merlewood Research Station, Grange-over-Sands, Cumbria LA11 6JU. [2]Bush Estate, Penicuik, Midlothian EH26 0QB*

This report describes a study carried out by ITE in conjunction with HTS, for the Rural Affairs Directorate of the DOE, in August/September 1988.

Section 1 gives the objectives of the study, and presents the background to the significance of heather as a species, and the ways in which its cover has been reduced. Section 2 describes the methodology used, and presents the national statistics and regional breakdowns. Section 3 discusses the status of heather in the various regions in order to show how regional variations need to be taken into consideration when planning national measures to encourage the growth of heather. Section 4 draws some general conclusions on the implications of the study.

## 1.1 Objectives

The principal objectives of the study were:

i. the production of maps showing the distribution of the principal areas of heather in England and Wales;

ii. an assessment of the current status and historical changes in areas of heather, and of the dynamic information currently available, to provide an indication of the potential for restoring heather cover.

## 1.2 Background

As a species, heather occurs throughout Europe, although it is less common in Mediterranean countries. Because of its wide range, it is associated with different species and fulfils different ecological roles depending upon local conditions. Thus, in the north of its range in Norway and the uplands of Scotland, it is a dominant species in its own right occupying large areas, and would be unlikely to change even if man's interference was reduced. Further south, it is mainly present as a result of man's activities. The lowland heathlands of southern Britain and northern Europe are thus anthropomorphic, and heather would probably have been restricted to exposed locations on sea cliffs. It is not until the foothills of the Alps, the Massif Central, the Pyrenees and the Iberian Mountains that heather would have been part of the original natural vegetation cover. Heather in the lowlands of Europe is, therefore, under stress, because the conditions under which it originated have disappeared. Its status is complex in that, although heather often represents a degraded ecosystem, it is considered an environmentally important cover type mainly for amenity and wildlife conservation.

i. Amenity
The appreciation of purple heather moorland has been established since Victorian times. Landscapes dominated by heather are visually attractive, especially in late summer and early autumn when the plants are in flower. The scenic value of heather has led to large areas being protected by their designation as National Parks, Environmentally Sensitive Areas and Areas of Outstanding Natural Beauty. Grouse shooting is also an activity which depends upon heather cover.

ii. Wildlife conservation
Heather is not only ecologically interesting as a species, but it also has a wide range of associated habitat species, even within England and Wales, which poses a major problem in its definition. In the strictest sense, 'heather' is *Calluna vulgaris*, but for the purposes of this study the definition includes dwarf shrub species of *Erica*, but not of *Vaccinium*. Heather areas have been categorized in the current project to distinguish areas of pure heather moorland which support, for example, grouse, from boggy vegetation which contains a proportion of heather. The usual definition of heather moorland is the former category. Depending upon the strictness of definition, different areas of heather cover in Great Britain will be obtained. Thus, taking a conservative figure, there were approximately one million hectares of almost pure heather in Great Britain in 1978, with a further 1.3 million hectares containing varying amounts of heather (Bunce 1987).

There are other supporting reasons why it is important to maintain heather as a land cover type.

- The Nature Conservancy Council (NCC) has expressed concern about the loss of heather and the associated loss of habitat for wildlife. Species such as the merlin *(Falco columbarius)* are particularly at risk because their prey depend upon heather as a source of food and cover.
- The general concern over the loss of heather in a wider context arises from the fact that it indicates an increase in agricultural intensity and forestry in the uplands, and a resultant loss of habitats. Heather therefore acts as an indicator of change from semi-natural vegetation to more highly managed systems.
- A link is often made between the decline in heather moorland and grouse numbers. Although this is not

necessarily causal, and other factors, eg cyclical population movements, may be involved, the relationship between the structure of the heather and grouse is well documented (Watson & Miller 1976). The connection has particularly important economic consequences in the north of England.

– Heather is usually managed. Without burning and/or sheep grazing, it would quickly revert at lower altitudes to scrub.

There are five broad groups of factors which have been cited as the underlying causes of heather decline. These are presented in order of their likely importance.

*1. Moor/heath management*

i. Grazing which removes over 60% of annual growth can reduce competitive vigour, or even kill the plant altogether. Overgrazing resulting from increased sheep numbers is, therefore, most often cited as causing heather loss. The effects of such heavy grazing pressure have been studied both experimentally (eg Grant & Hunter 1966; Grant *et al.* 1978) and by field observation (Welch 1984). Besides excessive defoliation, herbivores can weaken heather in other ways. Trampling, especially by cattle, causes stem breakage and bruises leaf tissues, so rendering them liable to winter browning (Watson, Miller & Green 1966). Defaecation and urination can also raise the soil's nutrient status, giving a competitive advantage to faster-growing graminoids.

ii. Poor burning management can result in slow or even no regeneration. Aged heather cannot sprout from the base of burnt stems; regeneration from seeds is slow and uncompetitive with graminoids and bracken *(Pteridium aquilinum)*. On the other hand, however, frequent or severe burning can kill both heather plants and any buried seeds, again leaving gaps for competitors (Miller, Miles & Heal 1984).

iii. If there is no burning at all, heather becomes senescent and may eventually die of old age. This is most likely on well-drained, level ground at low altitude; on damp peaty slopes, heather regenerates by layering. However, loss by the erosion which may follow severe burning is avoided.

iv. In the lowland heaths, the decline of turf cutting is also considered to have reduced heather cover in some areas.

A combination of (i) and (ii) is particularly effective in eliminating heather wherever soil or climatic conditions make it vulnerable. In general, heather is most readily supplanted by other species on wet organic soils in western Britain and on brown forest soils anywhere.

*2. Habitat destruction*

i. Agricultural improvement has converted heather moor to improved grassland in marginal upland areas, eg Exmoor and the North York Moors.

ii. Afforestation on upland moors has converted heather moorland mainly to coniferous forestry.

iii. Drainage, both for agricultural purposes and grouse management, has caused decline locally.

*3. Ecological succession*

i. In lowland heaths, there has been widespread expansion of woodland scrub, partly because of changes in management mentioned under 1 (iv).

ii. The expansion of bracken has affected heather cover in some areas, partly because of natural succession, and maybe as a result of changes in soil chemistry.

iii. Insects may become significant pests on heather under certain conditions.

*4. Chemical inputs*

i. Increases in nitrogen inputs from intensive agriculture lead to conditions which favour grasses rather than heather.

ii. Nutrient build-up in the soil following the breakdown of soil minerals and organic matter is cited as a factor in the loss of heather because it is a species that has, in many cases, originated from nutrient depletion.

*5. Human use and development*

i. Erosion is caused by overburning or by track construction on soft material, usually morraines.

ii. Limited areas have been lost from quarrying, buildings and road construction.

iii. Footpath trampling has locally caused loss of heather, either by favouring grasses or by creating bare soil.

As stated above, these various factors have all been identified as causing a decline or loss of heather cover, and they are discussed in further detail in the regional assessments in Section 3. However, several other factors operate across the whole spectrum of sites, and these are discussed next.

The species composition of heathland vegetation is undoubtedly influenced by nutrient availability, with increases in nitrogen favouring the growth of grasses such as purple moor-grass *(Molinia caerulea)* relative to heather. Competition between these species has been studied in fertilizer experiments by Scheikh (1969), Berendse and Aerts (1984) and Roelofs (1986), among others. All show that the grasses profit from the increased N inputs at the expense of the heather, leading to a gradual increase in the proportion of grasses in heathlands (Heil & Diemont 1983).

In the Netherlands, a decline in heather has been recorded (Diemont & Heil 1984; Heil & Diemont 1983), with replacement by purple moor-grass and, to a lesser extent, wavy hair-grass *(Deschampsia flexuosa)* and sheep's fescue *(Festuca ovina)*. It is possible that such changes are caused by a marked increase in the amount of nitrogen deposited on the heathland in the form of gaseous ammonia from the intensive livestock farming (Heil 1984), although adequate data are not currently available for the UK.

Concentrations of ammonia have only recently been monitored, and the methods rely mainly on one- or two-week integrating methods using diffusion tubes. These instruments show the largest concentrations in a region between Cheshire and Dorset/Somerset, with annual average concentrations of about 8 ppbv ammonia. Norfolk, Suffolk and eastern Essex form the other 'high' zone, with annual average ammonia concentrations of 6–7 ppbv. The west and north of Scotland show the smallest concentrations in the UK at 1–2 ppbv, with the remaining areas of northern England, eastern and southern Scotland showing concentrations of 2–4 ppbv. The other inputs of nitrogen (N) from the atmosphere in rain as ammonium and nitrate show a more complicated pattern. No good spatial data are available for nitrogen deposition in the 1950s and 1960s, but there is evidence that areas of 'large' inputs ($>10$ kg N $ha^{-1}$ $yr^{-1}$) are probably a factor of two larger now. These values are smaller than those for the Netherlands, but of the same order.

Ammonia deposition on to moorland has been monitored at ITE Edinburgh Research Station. The process has been shown to be limited by atmospheric rather than surface properties, and large deposition rates generally apply. Annual inputs will be calculated in due course for the moorland areas from air concentration, windspeed and vegetation height data.

The studies in the Netherlands have stimulated interest in the UK. Work on the Pennines by the University of Manchester (Woodin, Press & Lee 1985) has linked *Sphagnum* decline to nitrate inputs from the atmosphere. The possible effect of inputs of N from the atmosphere on heather has not been examined, but forms part of an NCC-sponsored study begun in October 1988 at ITE Edinburgh. Related work at Imperial College and ITE Bangor is also just beginning. These studies will determine whether or not there is a link in the UK between nitrogen input and heather decline comparable to that in the Netherlands.

Much heather-dominated vegetation is in a successional stage and can suffer defoliation by members of the heathland community. The heather beetle can achieve pest status on heather moors. It is a member of the family Chrysomelidae (the leaf beetles), which is totally dependent upon heather for all stages of its life cycle. It is widespread in heathland throughout north-western Europe including the British Isles, but the intensity and frequency of outbreaks vary. In England and Wales, most damage occurs in the north, with major outbreaks occurring about every ten years on southern heaths (Webb 1986). Despite the beetle's requirement for a moist environment, the worst outbreaks generally follow two to three consecutive warm dry summers (Morison 1963).

Eggs are laid in damp heather litter of *Sphagnum* moss in March and April. If the conditions are suitable, hatching occurs in 3–4 weeks. The larvae feed on the heather shoots and can defoliate, and even kill, the host plant. Pupation occurs in litter under the plants, usually in early August. The adults appear in September and feed on heather until the first frosts, when they hibernate. In spring, the adults reappear and fly, occasionally in swarms, and can migrate between areas of heath (Cameron, McHardy & Bennett 1944; Birkett 1970; Webb 1986). Such defoliation has been recorded since about 1850, and has been linked with the invasion of Dutch heaths by grass species (Diemont & Heil 1984). Concerning control, Cameron *et al.* (1944) considered that insect predators could theoretically limit populations. Potential agents for biological control include a parasitic wasp (Golightly 1962) and a fungus (Brunsting 1982). Further investigations of these agents is needed before they could be used.

### 1.3 The approach

Maps showing the distribution of heather in England and Wales were produced at 1:250 000 scale using Landsat TM satellite imagery (1984), in conjunction with ITE ground survey data collected in 1984 and 1987, supplemented by new measurements in 1988. The satellite imagery was digitally processed by HTS to produce enhanced and geometrically corrected false

colour composite images in photographic format. A visual interpretation of these images identified the principal areas of heather in England and Wales.

Visual interpretation was chosen for this study because the basic requirement was for a distribution map of vegetation containing ericaceous species, which had to be produced quickly. The alternative to visual interpretation is the computer-aided classification of digital data. Whilst such techniques do have merit, they were not chosen because:

i. the 15 TM scenes required for complete coverage of England and Wales were acquired over a range of different dates, necessitating detailed analysis of each individual image in order to ensure precise discrimination of heather;

ii. an experienced interpreter can quickly take account of seasonal differences in vegetation and judge the extent of heather by referring to topography, geographical context, and the map data available;

iii. digital techniques would be less reliable in discriminating areas where heather species are sub-dominant.

Details of the methods used are described in Section 2.1.

Maps showing the three categories of heather were reproduced at 1:250 000 and 1:750 000 scales from the transparent overlays used for image interpretation. These maps were then analysed by ITE in order to assess their accuracy and to measure the area and distribution of the heather categories. These assessments are discussed in Section 2.1.5.

Accuracy assessment involved comparing the maps with ground data for a sample of one km grid squares throughout the country. The ITE 'Ecological consequences of land use change' (ECOLUC) data base was used to provide ground data, but additional field survey was necessary to collect sufficient data for assessing areas of heather cover.

Areas were calculated by computer digitization of the 1:250 000 scale maps, and heather cover information was tabulated by county. Further comparisons were also made with the ECOLUC data base. The results are presented in Section 2.2.

Assessments of heather status, historical changes and the potential for restoration were undertaken by ecologists with a considerable knowledge of heathland and moorland in each region of England and Wales. These assessments are presented in Section 3.

# Production of maps and estimates of area

P Bradbury[1], D C Howard[2], R G H Bunce[2] and G C Deane[1]

[1]*Hunting Technical Services Ltd, Thamesfield House, Boundary Way, Hemel Hempstead, Hertfordshire HP2 7SR.* [2]*ITE, Merlewood Research Station*

## 2.1 Methodology

### 2.1.1 *Production of hard-copy satellite imagery*

In order to undertake a visual interpretation of Landsat TM imagery, photographic hard-copy was produced in the consultants' own laboratories using a computer-based image processing system linked to a precision film-writer. Prior to film-writing, contrast enhancement of Landsat TM Bands 3 (red), 4 (near infra-red) and 5 (mid infra-red) was used to highlight areas of heather cover. The imagery was also rectified geometrically to fit the Ordnance Survey 1:250 000 scale base maps, and the 10 km grid was overlaid on to the imagery.

Colour prints were produced from the enhanced and rectified imagery, with Band 4 displayed in red, Band 5 in green and Band 3 in blue. Plates 1 and 2 show the hard-copy imagery of the Berwyn Mountains area in north-east Wales and upper Wharfedale and Nidderdale in North Yorkshire. Using the 4,5,3 Band combination, areas of lush vegetation growth appear orange, urban areas appear blue, woodland appears dark red, and heather moorland appears dark brown. Figure 1 shows the Landsat scenes which cover England and Wales, whilst Table 1 lists the dates of imagery used for this study. In some of the scenes, partial cloud cover necessitated the use of two dates of imagery to acquire all four quadrants of the scenes.

**Table 1. Landsat TM scenes used for this study**

| Path | Row | Quadrant | Date |
|---|---|---|---|
| 201 | 23 | 1–4 | 14/ 5/84 |
| 201 | 24 | 1–4 | 21/10/84 |
| 201 | 25 | 1,2 | 12/ 4/84 |
| 202 | 23 | 1–4 | 8/ 7/84 |
| 202 | 24 | 1,3 | 8/ 7/84 |
| 202 | 24 | 2,4 | 9/ 8/84 |
| 202 | 25 | 1,2 | 9/ 8/84 |
| 203 | 22 | 1–4 | 22/ 7/84 |
| 203 | 23 | 1–4 | 22/ 7/84 |
| 203 | 24 | 1–4 | 26/ 4/84 |
| 203 | 25 | 1–3 | 26/ 4/84 |
| 204 | 21 | 4 | 14/ 5/88 |
| 204 | 22 | 1–4 | 14/ 5/88 |
| 204 | 23 | 1,3 | 22/ 7/84 |
| 204 | 23 | 2,4 | 13/10/85 |
| 204 | 24 | 1–4 | 22/ 7/84 |
| 204 | 25 | 1–4 | 20/ 6/84 |

Hard-copy imagery was produced of all the scenes listed in Table 1, with the exception of scene 204/021 of northern Northumberland which was not available at the start of the study. Image interpretation of the small areas of heather occurring within this scene was undertaken from 35 mm slides produced at the National Remote Sensing Centre (NRSC) at Farnborough.

### 2.1.2 *Heather categorization*

Heather occurs throughout England and Wales over a variety of soil, climate and management conditions on lowland heathland and upland moorland in association with various plant species. Although *Calluna vulgaris* is the main species of heather, several *Erica* species are common, particularly in the south-west.

As this study is based upon the use of satellite imagery, heather categories have, by necessity, been restricted to those which are easily and consistently recognizable on that imagery. It is not possible to identify the different heather species from satellite imagery or to identify accurately other plant species which occur in mixture with heather. The following heather categories were chosen for the study, after an initial analysis of the imagery and discussions with ITE ecologists and experts at NRSC.

i. Dominant – where *Calluna vulgaris* and other dwarf shrubs of *Erica* represent more than 50% of the vegetation cover. The category is further divided into:
   a. unmanaged, where there is little burning (called Dominant) (Plate 3)
   b. managed with significant burning (called Managed) (Plate 4). In the recently burned patches, bare soil and small patches of bilberry *(Vaccinium myrtillus)* are commonly found.

ii. Sub-dominant (Plate 5) – where dwarf shrubs of *Erica* represent less than 50% of vegetation cover (called Sub-dominant). In some areas other species dominate but, occasionally, there may be bare rock or exposed peat.

Where heather occurs as the dominant vegetation type, it gives a fairly distinctive appearance on Landsat TM imagery of dark tones at all times of the year. Image analysis may sometimes result in a confusion between heather cover and coniferous woodland, deciduous woodland in winter, types of urban land use, shaded north-facing moorland slopes and certain moorland vegetation. However, use of the available map data and the analysis of image context avoid most of such identification errors.

The distinction has been made between heather-dominant cover with little managed burning and that with significant managed burning, based upon the

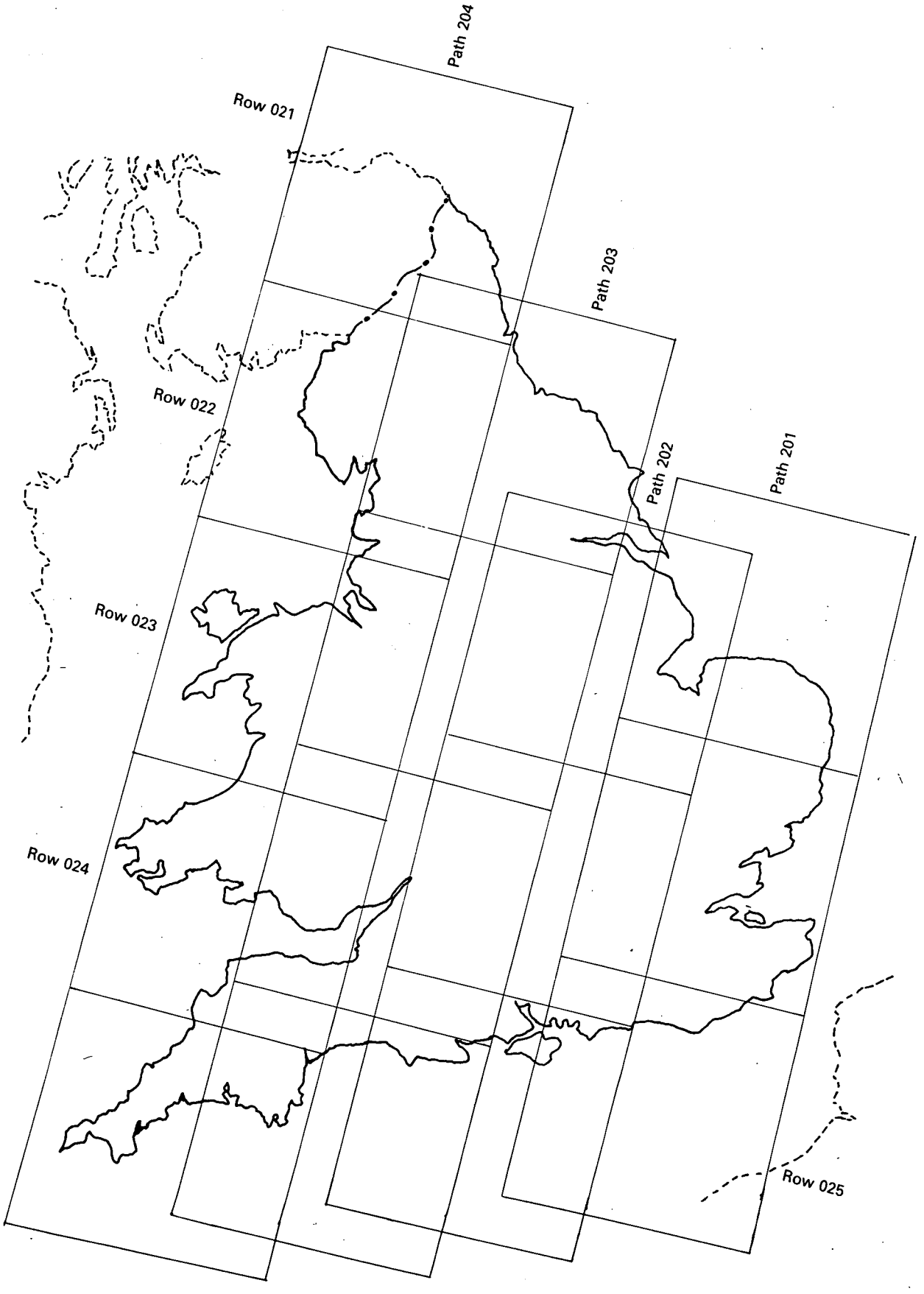



*FIGURE 1. The approximate location of Landsat TM (1984) images*

appearance on the imagery of a distinctive pattern of strips or blocks caused by burning in the managed areas. Such patterns normally indicate moorland managed for grouse shooting. Plates 1 and 2 show satellite images of the two classes of heather-dominant vegetation. The distinction between managed and unmanaged heathland that is based on the presence of strip burning is essentially applicable to upland areas in the north. When such criteria are applied to areas in the south, such as the New Forest and Dartmoor, they may produce false interpretations where patterns of heather management are different (ie mowing of heather, or cutting of gorse *(Ulex europaeus)* in the New Forest).

Where heather occurs in association with other vegetation species, it becomes difficult to recognize on the satellite imagery, particularly if the dominant vegetation species gives bright tones on the imagery which mask the appearance of the heather. Despite these difficulties, heather occurring as sub-dominant vegetation cover has been used as a category in this study based upon the combination of image colour and texture, the proximity to heather-dominant vegetation, and available ground data. Areas of sub-dominant heather vegetation have been identified on both Plates 1 and 2 of the satellite imagery.

In upland areas, heather occurs as a sub-dominant vegetation type in a variety of situations. On wet blanket bog, cotton-grass *(Eriophorum vaginatum)* often has heather as a sub-dominant vegetation type. On drier land, bilberry or bracken often represent the dominant vegetation, with heather sub-dominant. Mat-grass *(Nardus stricta)* is also commonly found in association with heather in upland areas. In lowland heaths, it may occur as a sub-dominant vegetation type, where gorse, bracken or grass species represent the dominant vegetation.

Given appropriate management, growth of heather within some of the areas where heather is sub-dominant can be encouraged. Where bracken and heather occur in association, for example, the bracken may be sprayed with herbicide or cut to encourage the growth of heather.

### 2.1.3 *Image interpretation and ground data collection*

The interpretation of satellite imagery was carried out in conjunction with an analysis of the available ground data and limited field work. The acquisition of ground information also enabled distinctions to be made between heather and vegetation types which gave a similar appearance on the imagery, as with cotton-grass and bilberry at certain times of the year

Image interpretation initially involved the analysis of the major features in the imagery to identify the main cover types, such as urban areas, woodland, farmland and topographic features. Areas of known heather cover were then identified based upon the interpreter's experience of the area or by using vegetation maps, if available. Localities which were unfamiliar to the interpreter, and for which few ground data were available, were subject to field inspection wherever possible.

Once adequate ground data had been collected for the date of imagery under study, a transparent overlay was placed over the imagery and the three categories of heather were mapped systematically. In many areas, particularly in lowland England, heather occurred near woodland, and there was a danger of misclassifying woodland as heather. In such situations, the woodland shown on the 1:250 000 scale OS base maps was used to distinguish these two often spectrally similar categories. It was assumed that the woodland areas mapped by OS are accurate, an assumption shown to be broadly correct when tested by the Forestry Commission (FC) in its 1982 census. However, small areas of heather do occur within some woodlands, and cannot be recognized on satellite images.

The following sources of ground data were consulted as part of this study.

i. Ordnance Survey 1:25 000 scale, 1:50 000 scale and 1:250 000 scale topographic maps, giving the location of woodland and urban land, and, in the case of the 1:25 000 scale maps, the location of moorland and heathland.

ii. The ITE ECOLUC data base, which provided detailed information on the cover of heather for a sample of one km grid squares throughout England and Wales.

iii. National Parks maps of moorlands and heathlands produced in the early 1980s as a requirement of Section 43 of the Wildlife and Countryside Act 1981. These maps were consulted for the Lake District, North York Moors and Yorkshire Dales National Parks.

iv. The Second Land Utilization Survey maps. Some information was obtained on vegetation cover of selected areas from surveys carried out by Sinclair in the late 1960s and early 1970s. Account was taken of possible changes to the vegetation since the time of survey.

v. ITE map information on heather cover for the county of Dorset.

vi. Small-scale maps of lowland heathland published by Webb (1986).

vii. Information on National Nature Reserves (NNRs) published by Ratcliffe (1977).

viii. MLC project information (Hunting Surveys & Consultants Ltd 1986).

In order to relate the heather categories to specific colours and textures on the imagery, field visits were made in the Lake District, north-west Lancashire, north and mid-Wales and the Yorkshire Dales. These visits involved approximately five days of field work, undertaken by the HTS image interpreter. In addition, randomly selected one km grid squares were mapped by ITE to assess the accuracy of the survey. Further details of these field assessments are given in Section 2.1.5.

Image interpretations were undertaken directly from the 1:250 000 scale hard-copy, with the exception of scene 204/021 of northern Northumberland which was interpreted from 35 mm slides of the imagery. In this instance, the interpretation was carried out by projecting the image on to the 1:250 000 scale overlay using a specially designed projection system.

### 2.1.4 *Map production*

The information from image interpretation was used to prepare five maps at 1:250 000 scale and one map at 1:750 000 scale covering England and Wales (excluding the Isles of Scilly and the Isle of Man).

The 1:250 000 scale maps were produced as black-and-white Dyeline maps, using traditional cartographic techniques. Heather categories were represented by shading, and the coastline, 800 foot contour and county boundaries were included.

The 1:750 000 scale map was produced using a Versatec plotter and digitized map data. The result was a colour digital map which showed the distribution of the three heather categories over England and Wales.

### 2.1.5 *Accuracy assessment*

In the two months available for the project it was not possible to perform detailed and rigorous accuracy tests, but some measure of the correlation between satellite images and cover types identifiable in the field was considered important. A rapid field survey was, therefore, done to assess the accuracy of the identification of heather moor and of the classification into dominant, sub-dominant or managed categories. A total of 34 one km squares were visited (Table 2), and the areas of heather were assessed by eye. Because travel time is a major component of ground truth survey, the squares were selected in pairs, by drawing random co-ordinates from areas of known heather.The randomly selected one km square was visited with a neighbouring square offset two km to the east. As a separate test to establish if areas of heather had been overlooked on the satellite image, a sample of the ITE land use survey data collected in 1984 was compared with the final maps.

**Table 2. Sites of ground survey for accuracy assessment**

| OS grid reference | Area | OS grid reference | Area |
|---|---|---|---|
| 318264 | Wales | 730580 | Northumbria |
| 373558 | Wales | 750580 | Northumbria |
| 320264 | Wales | 960120 | Northumbria |
| 375558 | Wales | 980120 | Northumbria |
| 291267 | Wales | 394493 | Pennines |
| 296512 | Wales | 396493 | Pennines |
| 293267 | Wales | 409445 | Pennines |
| 398512 | Wales | 411445 | Pennines |
| 281291 | Wales | 476501 | N. York Moors |
| 283291 | Wales | 478501 | N. York Moors |
| 281341 | Wales | 464508 | N. York Moors |
| 264332 | Wales | 466508 | N. York Moors |
| 266332 | Wales | 330490 | Cumbria |
| 292358 | Wales | 332490 | Cumbria |
| 294358 | Wales | 312487 | Cumbria |
| 323348 | Wales | 314487 | Cumbria |
| 325348 | Wales | | |
| 301329 | Wales | | |

Examination of these maps showed that a number of heathland sites in southern England have not been identified from the satellite images. Some of these sites that do not appear on the maps contain significant amounts of woodland and scrub (eg Kingsley, Shortheath and Silchester Commons in north Hampshire, and Snelsmore Common in Berkshire). However, other sites, such as Carrine Common in Cornwall, Broxhead in N. Hants, Horsell Common, near Woking, in Surrey, Chailey Common in east Sussex, contain areas of lowland heathland which are important with respect to landscape and wildlife conservation. Such sites are generally small in relation to the overall area of heathland, and would make only a small increase in the total. There are also some important areas of maritime heathland in the Scilly Islands that are not included in the maps.

Furthermore, in the Peak District, other inconsistencies have been found, notably over confusion between crowberry and bilberry with heather, which may have led to an overestimation of heather cover by the satellite maps on some moors.

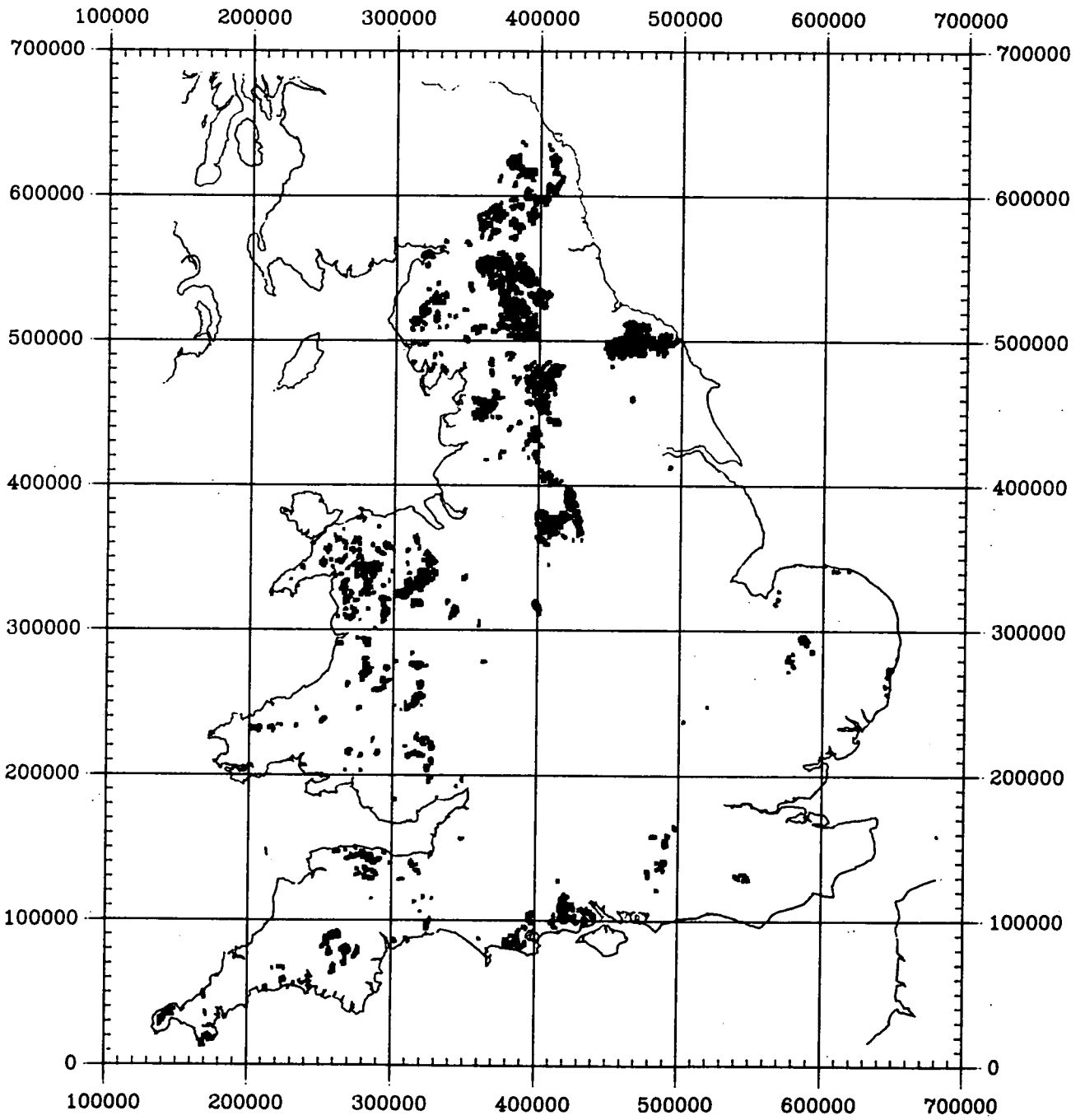



*FIGURE 2. Distribution of heather in England and Wales identified from Landsat TM (1984) imagery*

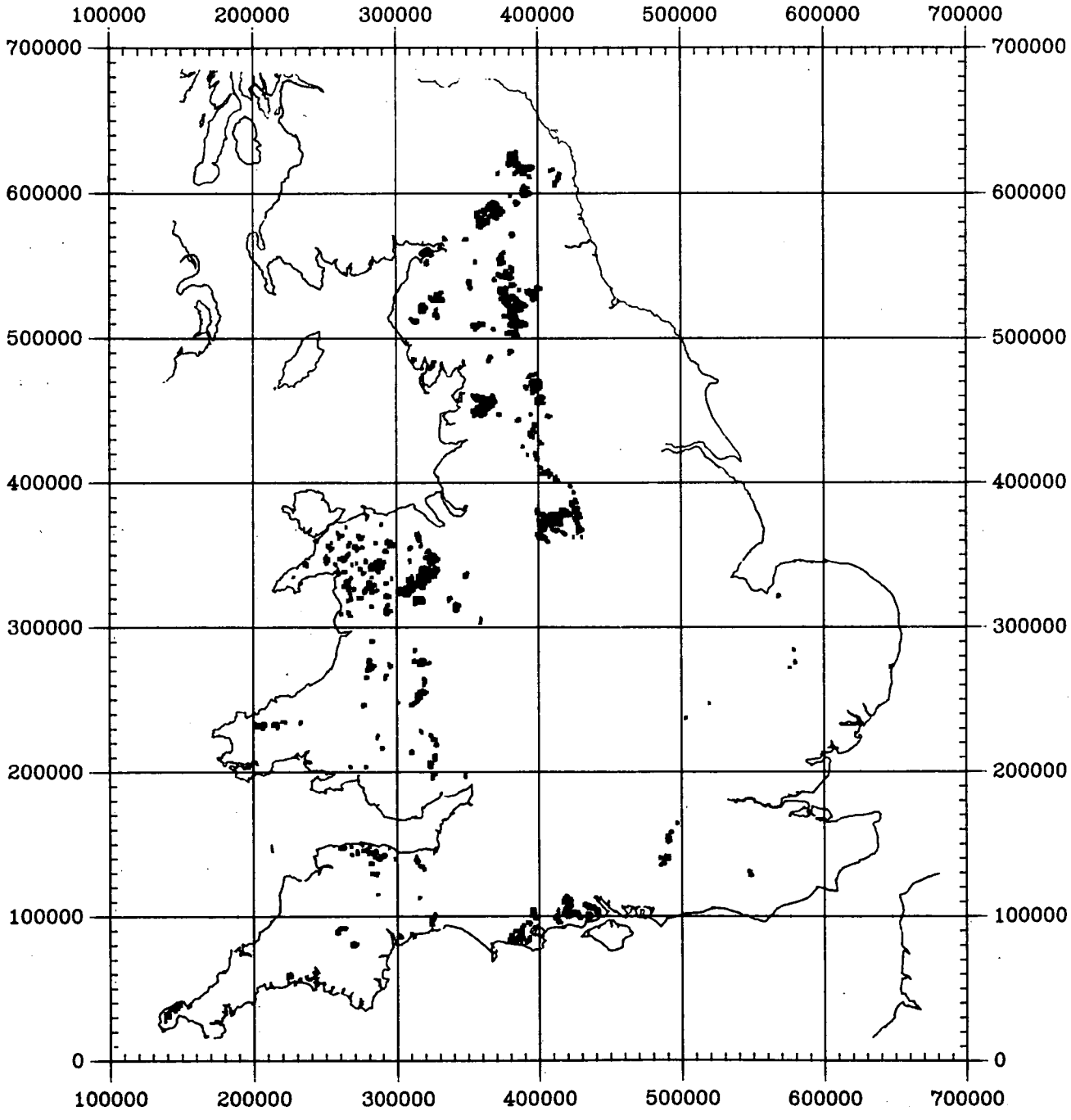



*FIGURE 3i. Distribution of Dominant heather (see Section 2.1.2)*

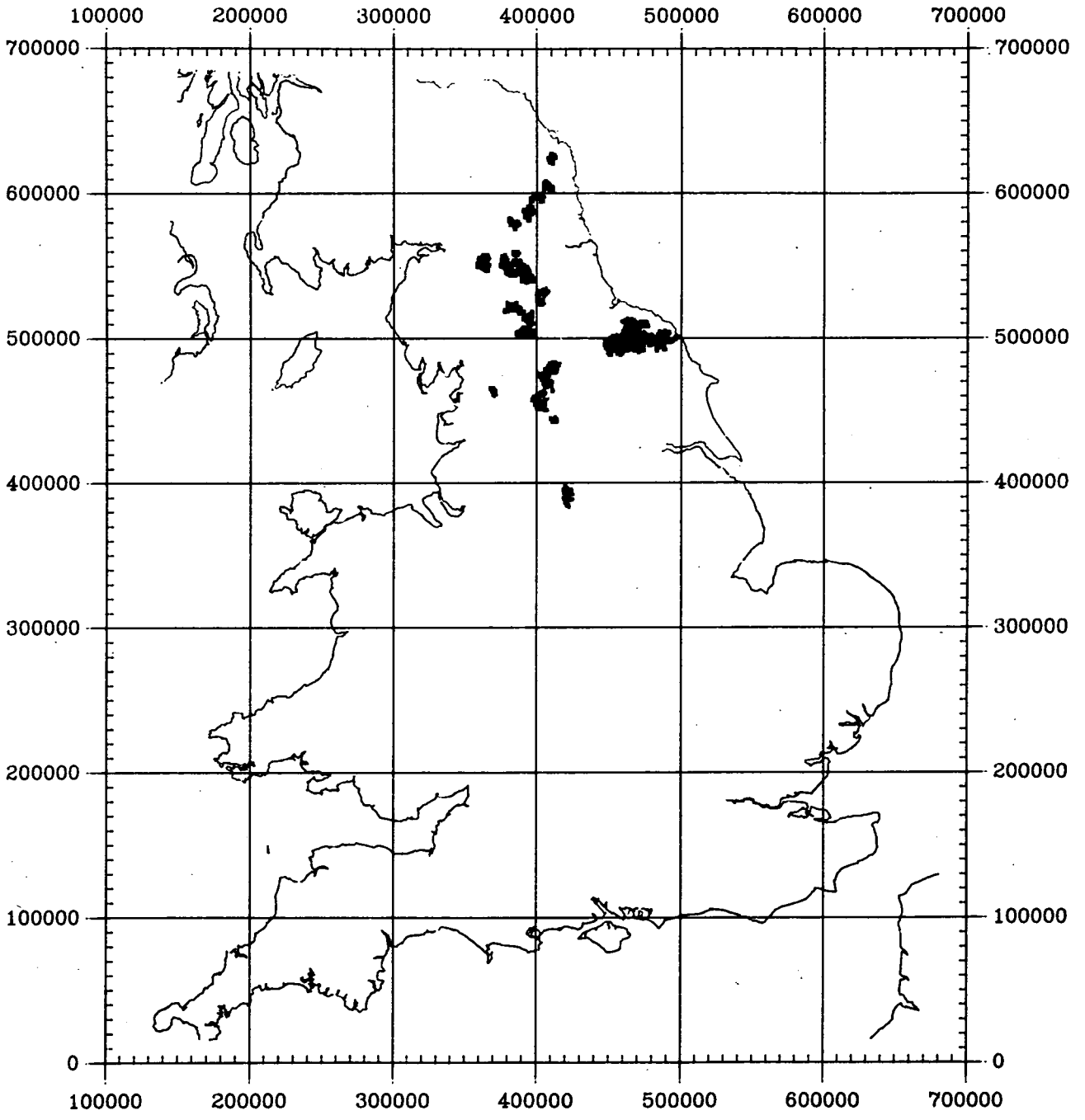



*FIGURE 3ii. Distribution of Managed heather (see Section 2.1.2)*

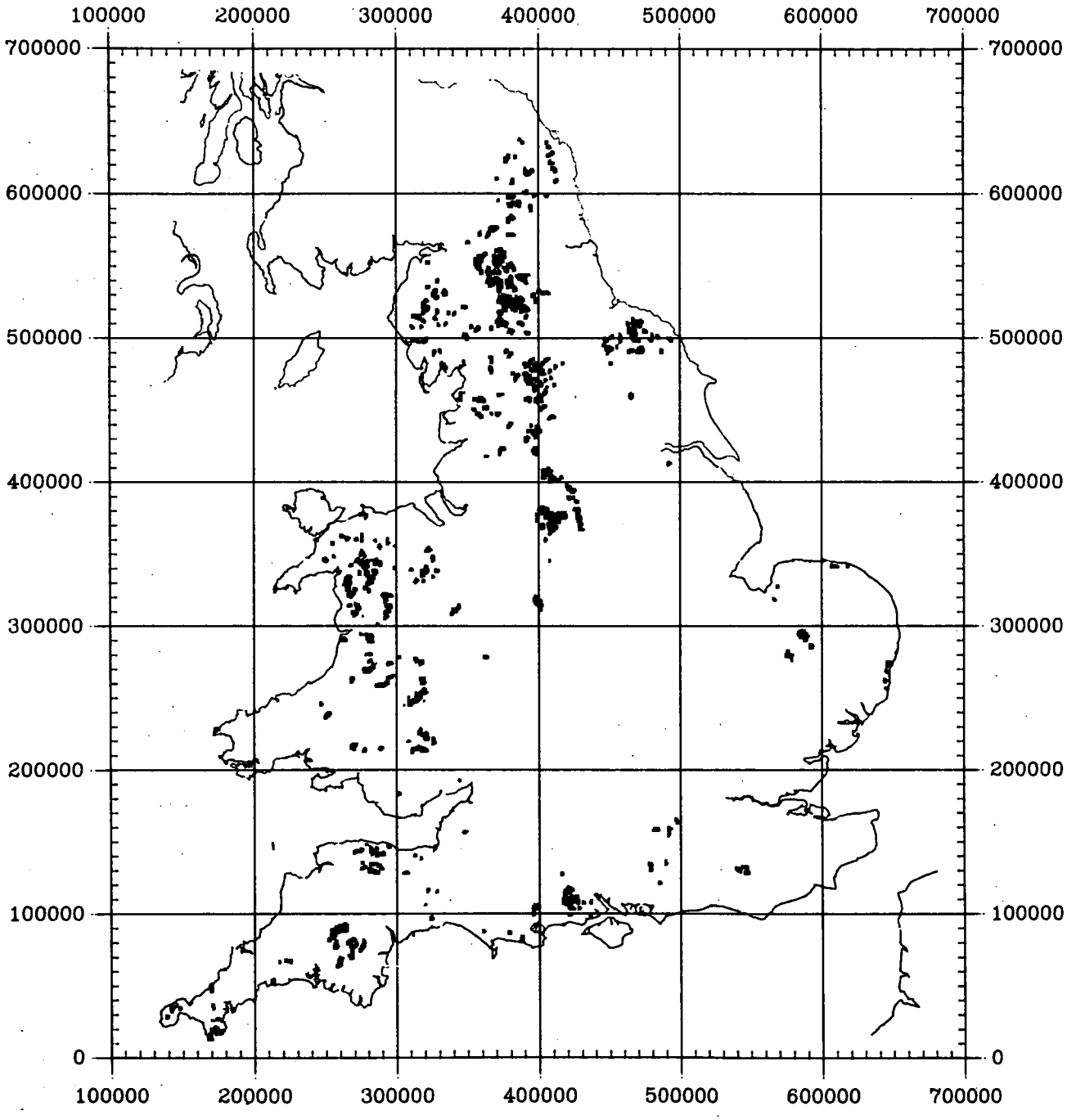



*FIGURE 3iii. Distribution of Sub-dominant heather (see Section 2.1.2)*

### 2.1.6 *Area measurements*

Areas were measured by digitizing the maps produced by HTS on a TDS LC digitizing tablet and cross-hair cursor. Heather boundaries were traced with the cursor and the information trapped as a stream of co-ordinates, which were then converted into raster format for rapid estimation of areas. The results showed the proportion of the three categories of heather in each square, and the information was amalgamated to produce totals for each county by incorporating the county information held on the ITE land use data base.

## 2.2 Results

### 2.2.1 *Heather distribution maps*

The six maps produced by HTS are available at ITE upon request, and are summarized in Figures 2 and 3.

### 2.2.2 *Accuracy assessment*

As already mentioned, the short period available for the study prevented a detailed analysis of accuracy. However, a number of checks were carried out.

i. Parcels identified from the satellite were compared with those on the ground. The different types of category in the squares were recorded by both satellite and field survey in 50 cases. In eight cases, the satellite recorded a category not seen on the ground, and in 11 cases the field survey recorded a category not seen on the satellite image. The field survey recorded the distribution of heather within one km squares, whereas the area on the heather maps is represented by 4 mm squares, so comparison by area is not meaningful. However, the parcel boundaries on the satellite-produced maps could be more accurate than those produced

**Table 3. The area (in hectares) of heather in England and Wales for counties where heather is found, mapped and measured from Landsat TM (1984) satellite imagery**

| County | Area | Sub-dominant | Dominant | Managed | Total | % total heather |
|---|---|---|---|---|---|---|
| Bedfordshire | 123 460 | | 426 | | 426 | 0.07 |
| Cheshire | 232 846 | | 726 | | 726 | 0.12 |
| Cornwall | 354 792 | 8 277 | 4 604 | | 12 881 | 2.20 |
| Cumbria | 681 012 | 29 386 | 22 048 | 10 042 | 61 476 | 10.51 |
| Derbyshire | 263 094 | 10 924 | 15 846 | 1 916 | 28 686 | 4.90 |
| Devon | 671 088 | 12 339 | 6 259 | | 18 598 | 3.18 |
| Dorset | 265 375 | 1 601 | 1 097 | | 2 698 | 0.46 |
| Durham | 243 592 | 11 789 | 19 344 | 18 197 | 49 330 | 8.43 |
| East Sussex | 179 512 | 1 997 | 438 | | 2 435 | 0.42 |
| Greater Manchester | 128 674 | 935 | 946 | | 1 881 | 0.32 |
| Hampshire | 377 698 | 6 979 | 20 633 | | 27 612 | 4.72 |
| Humberside | 351 212 | 137 | | | 137 | 0.02 |
| Lancashire | 306 346 | 4 830 | 11 517 | 1 296 | 17 643 | 3.02 |
| Norfolk | 536 776 | 4 275 | 548 | | 4 823 | 0.82 |
| North Yorkshire | 830 865 | 25 703 | 17 912 | 61 023 | 104 638 | 17.89 |
| Northumberland | 503 165 | 19 836 | 19 516 | 20 622 | 59 974 | 10.25 |
| Shropshire | 349 014 | 3 019 | 3 173 | | 6 192 | 1.06 |
| Somerset | 345 094 | 11 616 | 5 077 | | 16 693 | 2.85 |
| South Yorkshire | 156 049 | 2 095 | 1 562 | 2 352 | 6 009 | 1.03 |
| Staffordshire | 271 615 | 2 913 | 2 696 | | 5 609 | 0.96 |
| Suffolk | 379 663 | 4 907 | 1 162 | | 6 069 | 1.04 |
| Surrey | 167 924 | 5 179 | 2 165 | | 7 344 | 1.26 |
| West Sussex | 198 935 | 348 | | | 348 | 0.06 |
| West Yorkshire | 203 912 | 10 969 | 5 427 | 1 794 | 18 190 | 3.11 |
| England | 8 121 713 | 180 054 | 163 122 | 117 242 | 460 418 | 78.72 |
| Clwyd | 242 650 | 8 446 | 18 353 | | 26 799 | 4.58 |
| Dyfed | 576 577 | 12 472 | 13 325 | | 25 797 | 4.41 |
| Gwent | 137 599 | 349 | 1 105 | | 1 454 | 0.25 |
| Gwynedd | 368 708 | 18 998 | 20 474 | | 39 472 | 6.75 |
| Mid Glamorgan | 101 867 | 1 277 | 410 | | 1 687 | 0.29 |
| Powys | 507 471 | 8 700 | 19 137 | | 27 837 | 4.76 |
| West Glamorgan | 81 657 | 737 | 683 | | 1 420 | 0.24 |
| Wales | 2 016 529 | 50 979 | 73 487 | | 124 466 | 21.28 |
| Total | 10 138 242 | 231 033 | 236 609 | 117 242 | 584 884 | 100.00 |

**Table 4. The area (in hectares) of heather in National Parks in England and Wales, mapped and measured from Landsat TM (1984) satellite imagery**

| National Park | Area (ha) | Sub-dominant | Dominant | Managed | Total area | %NP |
|---|---|---|---|---|---|---|
| Dartmoor | 94 535 | 12 312 | 2 086 | | 14 398 | 15.23 |
| Exmoor | 68 635 | 10 189 | 2 525 | | 12 714 | 18.52 |
| Brecon Beacons | 134 679 | 951 | 3 958 | | 4 909 | 3.64 |
| Pembrokeshire Coast | 58 275 | 444 | 9 958 | | 10 402 | 17.85 |
| Snowdonia | 216 782 | 18 065 | 20 007 | | 38 072 | 17.56 |
| Peak District | 140 377 | 12 525 | 18 409 | 4 268 | 35 202 | 25.08 |
| Yorkshire Dales | 176 119 | 13 619 | 10 932 | 15 458 | 40 009 | 22.72 |
| North Yorks Moors | 143 226 | 6 574 | | 32 696 | 39 270 | 27.42 |
| Lake District | 224 293 | 15 822 | 9 494 | | 25 316 | 11.29 |
| Northumberland | 103 082 | 12 521 | 8 286 | 6 701 | 27 508 | 26.69 |
| Total | 1 360 004 | 103 022 | 85 655 | 59 123 | 247 800 | 18.22 |

by a field surveyor on the ground, because of the difficulty in drawing vegetation boundaries on maps without control points.

ii. Using squares drawn at random from the ITE land use data base, it was possible to compare the distribution of heather over a larger sample area.

iii. Two sets of detailed ground maps were examined and compared with the satellite maps for: (a) the Lake District National Park, and (b) lowland heaths in Dorset. Only small isolated areas of heather were missed by the satellite map. However, if further detailed searches were carried out, then other areas missed by this rapid survey would be identified.

### 2.2.3 *Regional distribution patterns*

The estimates of area (in hectares) by county, National Park and Environmentally Sensitive Area (ESA) are presented in Tables 3–6. The counties with lowland heaths, eg Dorset and Suffolk, are overwhelmed by the large areas of heather in the uplands, eg Cumbria and North Yorkshire, with 39% of the total in three counties alone. Overall figures for change can, therefore, be misleading, in that major local changes can be masked if very large areas elsewhere remain stable. Indeed, this may be a major source of confusion in the current debate about loss of heather because the very large upland areas are relatively remote, whereas smaller areas in marginal uplands are more easily observed. The census technique used to interpret the images has meant that very small areas have been identified, eg 137 ha in Humberside. A detailed comparison of the map of heather produced by the National Park staff in the Lake District showed very small differences, either on very steep slopes or in small areas with sub-dominant heather. England has a comparable amount of heather per unit area with Wales (6%).

Table 4 shows that, proportionally, the National Parks contain more heather than England and Wales overall (18% as opposed to $<4\%$), and, moreover, they contain together over 42% of the total heather cover in the two countries. The policies within National Parks can, therefore, have a major influence on heather maintenance. By contrast, the ESAs (Table 5) contain only 8% of the total heather and are thus relatively less important nationally. Within the national context, the northern Parks, with the exception of the Lake District, all contain over 20% of heather by area, and are thus important. The Yorkshire Dales and North York Moors contain the majority of managed moor, with implications for management in those Parks.

**Table 5. The area of heather (in hectares) in Environmentally Sensitive Areas (ESA) in England and Wales derived from Landsat TM (1984) satellite imagery**

| ESA | Area of heather | | | Total |
|---|---|---|---|---|
| | Sub-dominant | Dominant | Managed | |
| Cambrian Mountains | 6 962 | 7 170 | | 14 132 |
| Penrhyn Llyn | 27 | 113 | | 140 |
| Breckland | 4 136 | 926 | | 5 062 |
| South Downs | | | | |
| The Broads | | | | |
| Suffolk River Valleys | 2 097 | 236 | | 2 333 |
| West Penwith | 1 138 | 2 424 | | 3 562 |
| North Peak | 9 835 | 5 618 | 4 098 | 19 551 |
| Somerset Levels | | | | |
| Pennine Dales | | | | |
| Shropshire Borders | | | | |
| Test Valley | | | | |
| Total | 24 195 | 16 487 | 4 098 | 44 780 |

### 2.2.4 *Area measurements by one km square*

Whereas the total area covered (as presented in Tables 3–5) gives a measure of quantity, the heather can be mapped conveniently by recording its presence in one km squares. The number of squares containing heather

**Table 6. The number of one km squares containing heather in England and Wales for counties where heather is found, mapped and measured from Landsat TM (1984) satellite imagery**

| County | Area | Sub-dominant | Dominant | Managed | Total | % total heather |
|---|---|---|---|---|---|---|
| Bedfordshire | 123 460 | | 5 | | 5 | 0.06 |
| Cheshire | 232 846 | | 13 | | 13 | 0.16 |
| Cornwall | 354 792 | 104 | 58 | | 162 | 2.04 |
| Cumbria | 681 012 | 376 | 292 | 126 | 794 | 10.02 |
| Derbyshire | 263 094 | 140 | 211 | 24 | 375 | 4.73 |
| Devon | 671 088 | 172 | 80 | | 252 | 3.18 |
| Dorset | 265 375 | 19 | 15 | | 34 | 0.43 |
| Durham | 243 592 | 152 | 255 | 235 | 642 | 8.10 |
| East Sussex | 179 512 | 27 | 6 | | 33 | 0.42 |
| Greater Manchester | 128 674 | 11 | 11 | | 22 | 0.28 |
| Hampshire | 377 698 | 92 | 273 | | 365 | 4.60 |
| Humberside | 351 212 | 6 | | | 6 | 0.08 |
| Lancashire | 306 346 | 63 | 157 | 17 | 237 | 2.99 |
| Norfolk | 536 776 | 70 | 6 | | 76 | 0.96 |
| North Yorkshire | 830 865 | 332 | 228 | 890 | 1 450 | 18.29 |
| Northumberland | 503 165 | 268 | 249 | 271 | 788 | 9.94 |
| Shropshire | 349 014 | 51 | 71 | | 122 | 1.54 |
| Somerset | 345 094 | 149 | 66 | | 215 | 2.71 |
| South Yorkshire | 156 049 | 30 | 22 | 30 | 82 | 1.03 |
| Staffordshire | 271 615 | 42 | 34 | | 76 | 0.96 |
| Suffolk | 379 663 | 60 | 14 | | 74 | 0.93 |
| Surrey | 167 924 | 66 | 31 | | 97 | 1.22 |
| West Sussex | 198 935 | 5 | | | 5 | 0.06 |
| West Yorkshire | 203 912 | 140 | 74 | 24 | 238 | 3.00 |
| England | 8 121 713 | 2 375 | 2 171 | 1 617 | 6 163 | 77.75 |
| Clwyd | 242 650 | 124 | 263 | | 387 | 4.88 |
| Dyfed | 576 577 | 165 | 162 | | 327 | 4.13 |
| Gwent | 137 599 | 4 | 13 | | 17 | 0.21 |
| Gwynedd | 368 708 | 304 | 332 | | 636 | 8.02 |
| Mid Glamorgan | 101 867 | 16 | 5 | | 21 | 0.26 |
| Powys | 507 471 | 117 | 240 | | 357 | 4.50 |
| West Glamorgan | 81 657 | 10 | 9 | | 19 | 0.24 |
| Wales | 2 016 529 | 740 | 1 024 | | 1 764 | 22.25 |
| Total | 10 138 242 | 3 115 | 3 195 | 1 617 | 7 927 | 100.00 |

**Table 7. Comparison of heather areas (in hectares) mapped and measured from Landsat TM satellite imagery with MLC estimates for 1947, 1969 and 1980. MLC estimates are from aerial photography interpretation. The ITE 1984 survey was from a stratified random sample. Methodological differences may account for apparent increases between MLC and the other independent surveys**

| DOE Region | Total Area | MLC 1947 | MLC 1969 | MLC 1980 | TM 1984 | ITE 1984 survey |
|---|---|---|---|---|---|---|
| North | 1 541 500 | 167 300 | 162 100 | 155 500 | 170 780 | 208 989 |
| North West | 735 400 | 19 600 | 18 800 | 18 000 | 20 250 | 31 082 |
| Yorkshire & Humberside | 1 542 500 | 218 500 | 136 300 | 151 200 | 128 974 | 137 810 |
| West Midlands | 1 299 800 | 3 000 | 1 300 | 1 300 | 11 801 | 16 049 |
| East Midlands | 1 563 900 | 21 600 | 21 200 | 21 100 | 28 686 | 19 310 |
| East Anglia | 1 262 200 | 3 000 | | | 10 892 | 5 913 |
| South West | 2 389 300 | 45 400 | 35 200 | 32 400 | 50 870 | 41 153 |
| South East | 2 730 500 | 23 000 | 12 800 | 13 700 | 38 165 | 39 864 |
| England | 13 065 100 | 501 400 | 387 700 | 393 200 | 460 418 | 500 170 |
| Wales | 2 082 300 | 130 000 | 124 500 | 116 600 | 124 466 | 104 253 |
| Total | 15 147 400 | 631 400 | 512 200 | 509 800 | 584 884 | 604 423 |

were compared with the figure for area obtained by digitizing, and the results are shown in Table 6. These data are comparable with Table 3 and are now held in a data base, so that they can be compared with other data held on a one km square framework. They can be incorporated into models examining the outcome of different scenarios on the countryside. Although the figures are higher in total (25%), the areal extent suggests that the areas recorded within the one km squares are adequately presented at this level to indicate the main areas of heather in the country.

### 2.2.5 *Estimate of change in heather cover from the MLC data set*

Table 7 compares data for 1947, 1969 and 1980 from the MLC project with the current data set. Data are also presented from the ITE 1984 land use survey. The ITE field survey data refer to areas with more than 25% cover of heather. The information was collected during a field survey of a random sample of one km squares, and the sample was stratified between 32 land classes. Regional estimates were produced by calculating the product of the mean coverage per square for each land class and the area of that land class within the region, and then summing the land class estimates. Table 8 compares the MLC data for 1980 with the new areal estimates by county.

Table 3 shows that the principal decline occurred between 1947 and 1969, mainly within Yorkshire and Humberside, with subsequent recovery possibly following burning. However, the differences between 1980 and 1984 are likely to be methodological, in that the MLC data were drawn from a sample whereas the TM survey in 1984 was a census, albeit with potential

**Table 8. The area (in hectares) of heather in England and Wales for counties where heather is found, derived from MLC interpretation of aerial photography (1980) and the new satellite Landsat TM satellite imagery (1984) estimates. Methodological differences may account for apparent increases between MLC and the other independent survey.**

| County | Area | 1980 | 1984 | 1984–80 |
|---|---|---|---|---|
| Bedfordshire | 123 460 | | 426 | |
| Cheshire | 232 846 | | 726 | |
| Cornwall | 354 792 | 8 610 | 12 881 | 1.50 |
| Cumbria | 681 012 | 30 370 | 61 476 | 2.02 |
| Derbyshire | 263 094 | 21 140 | 28 686 | 1.36 |
| Devon | 671 088 | 11 220 | 18 598 | 1.66 |
| Dorset | 265 375 | 6 690 | 2 698 | 0.40 |
| Durham | 243 592 | 27 840 | 49 330 | 1.77 |
| East Sussex | 179 512 | 3 930 | 2 435 | 0.62 |
| Greater Manchester | 128 674 | 7 790 | 1 881 | 0.24 |
| Hampshire | 377 698 | 4 650 | 27 612 | 5.94 |
| Humberside | 351 212 | | 137 | |
| Lancashire | 306 346 | 8 600 | 17 643 | 2.05 |
| Norfolk | 536 776 | | 4 823 | |
| North Yorkshire | 830 865 | 138 990 | 104 638 | 0.75 |
| Northumberland | 503 165 | 72 780 | 59 974 | 0.82 |
| Shropshire | 349 014 | | 6 192 | |
| Somerset | 345 094 | 2 590 | 16 693 | 6.45 |
| South Yorkshire | 156 049 | 8 090 | 6 009 | 0.74 |
| Staffordshire | 271 615 | | 5 609 | |
| Suffolk | 379 663 | | 6 069 | |
| Surrey | 167 924 | 5 080 | 7 344 | 1.45 |
| West Sussex | 198 935 | | 348 | |
| West Yorkshire | 203 912 | 4 130 | 18 190 | 4.40 |
| England | 8 121 713 | 362 500 | 460 418 | 1.27 |
| Clwyd | 242 650 | 30 550 | 26 799 | 0.88 |
| Dyfed | 576 577 | 6 730 | 25 797 | 3.83 |
| Gwent | 137 599 | | 1 454 | |
| Gwynedd | 368 708 | 30 750 | 39 472 | 1.28 |
| Mid Glamorgan | 101 867 | 1 170 | 1 687 | 1.44 |
| Powys | 507 471 | 37 090 | 27 837 | 0.75 |
| West Glamorgan | 81 657 | 1 330 | 1 420 | 1.07 |
| Wales | 2 016 529 | 107 620 | 124 466 | 1.16 |
| Total | 10 138 242 | 470 120 | 584 884 | 1.24 |

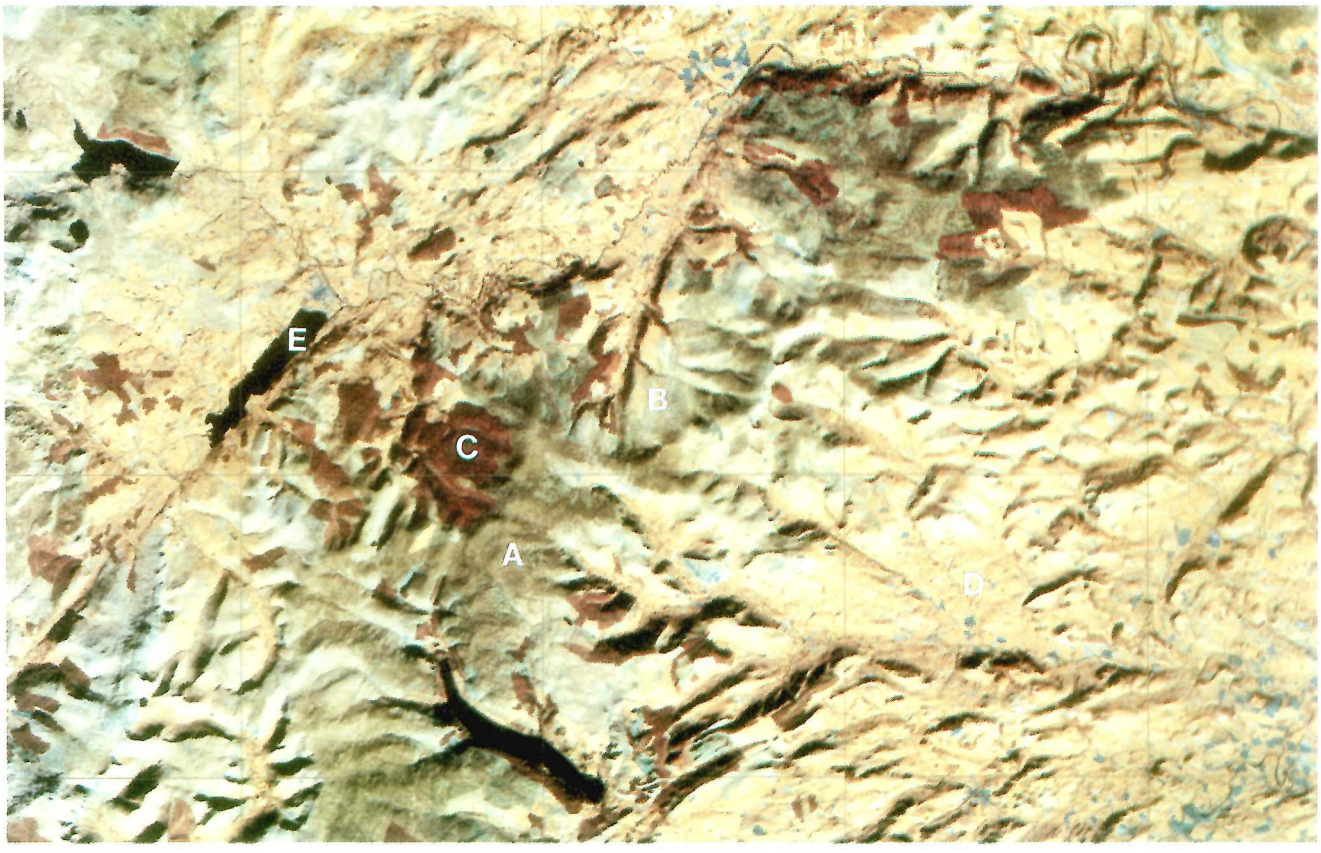



*PLATE 1. Landsat TM (1984) image of the Berwyn Mountains in north-east Wales (provided by HTS)*

*A Heather-dominant vegetation with little managed burning*
*B Heather sub-dominant vegetation*
*C Coniferous woodland*
*D Agricultural grassland*
*E Lake Bala*

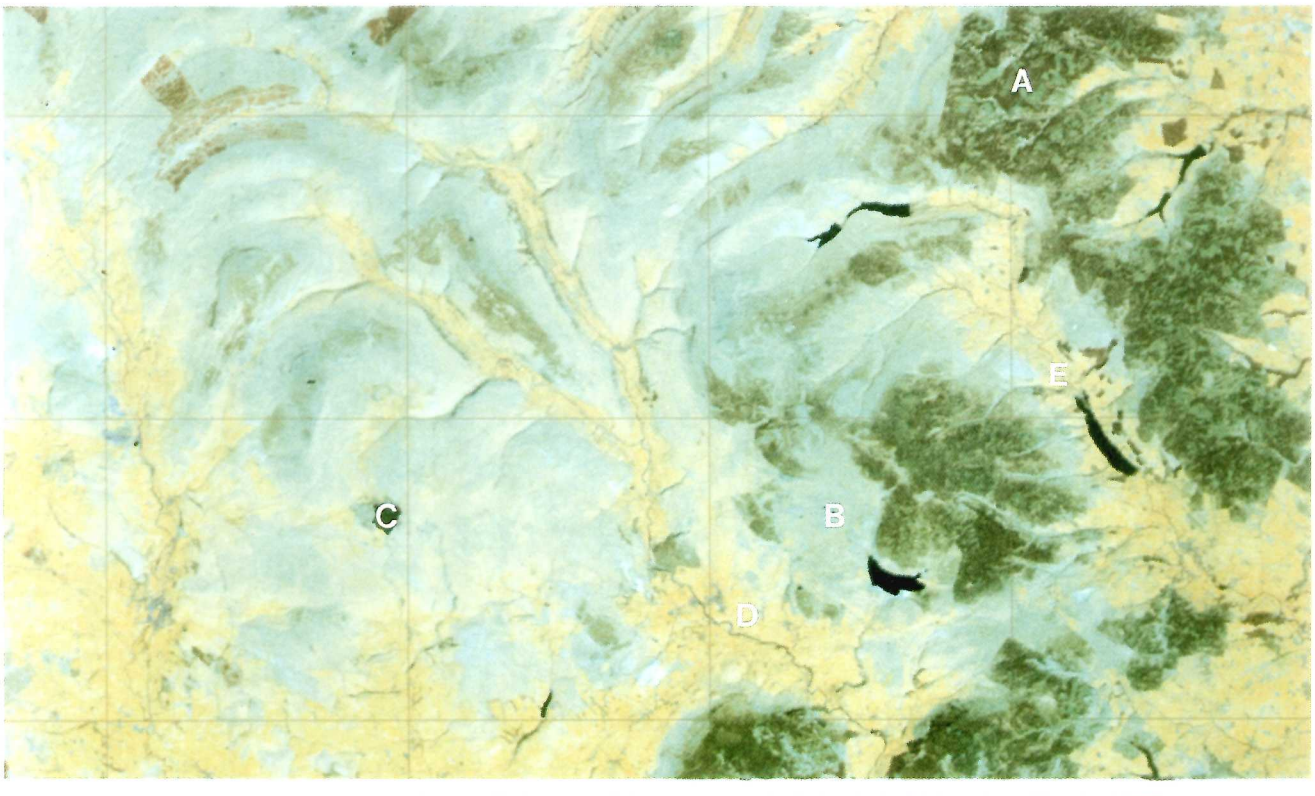



*PLATE 2. Landsat TM (1984) image of Wharfedale and Nidderdale in the Yorkshire Dales (provided by HTS)*

*A Heather-dominant vegetation with significant managed burning*
*B Upland grassland*
*C Malham Tarn*
*D Wharfedale*
*E Nidderdale*

*PLATE 3.* Heather-dominant vegetation

*PLATE 4.* Heather-dominant vegetation with managed burning showing vigorous regeneration – this picture was taken in the Picos de Europa where management by burning is practised

*PLATE 5.* Heather sub-dominant vegetation with crowberry (*Empetrum nigrum*) as an important species

*PLATE 6.* Lowland heath (Woodbury Common, Devon)

*PLATE 7.* Causes of decline in heather

i. Expansion of bracken (*Pteridium aquilinum*)

ii. Death

iii. Heavy grazing pressure, as in the Peak District, with replacement by crowberry

*PLATE 8.* Many other species are associated with heather moorland in varied habitats

i. Spotted orchid (*Dactylorhiza maculata*) on flushed peats

ii. Marsh thistle (*Cirsium palustre*) on mineral flushes

iii. Larva of Lasiocampid moth, which lives on heather plants

*PLATE 9.* The effect of fencing grass moorland on Cwm Idwal National Nature Reserve in north Wales

inconsistencies because of problems of interpretation. Taken in conjunction with Table 6, it will be seen that the census detects many small areas missed by the sampling procedure. Thus, in East Anglia the area of heather within the MLC sample was estimated to have declined to zero, but elsewhere in the region areas of heather remained that were detected by the satellite in 1984. The latter agree with the known distribution of heather shown in Figure 4. As with the previous Tables, the figures are dominated by the northern regions, with the decline in the lowlands being large in proportion to the local areas, but small overall. The figures from the TM survey are closer to the ITE 1984 survey than those from the MLC.

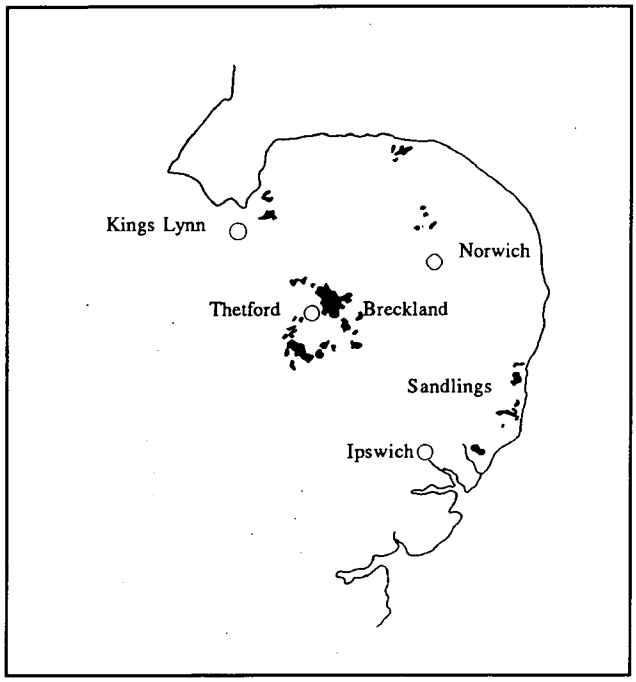



*FIGURE 4. East Anglian heaths*

Great reliance should not be placed on detailed analysis of these comparisons because the errors attached to the estimates are not comparable, being on the one hand due to interpretation within the census and on the other due to spatial variation in the sampling strata. The decline should, therefore, be judged primarily from the three MLC data sets, which are strictly comparable: the principal decline of about 16% was between 1947 and 1969, mainly in England, with the subsequent MLC and ITE figures confirming in general the overall extent of the heather coverage, and therefore the extent of the decline. Finally, the decline was slightly more marked in England than in Wales when expressed as a percentage, but much greater in hectarage (87 500 and 13 400 respectively).

Turning now to Table 6, many of the same strictures apply, with many counties having small areas missed by the MLC sample – in some counties, the final column of the difference between the two measures reflects the efficiency of the sample, rather than actual change. Otherwise, the Table is useful for examining individual counties and comparing them with the MLC report (Hunting Surveys & Consultants Ltd 1986).

The MLC data were estimates of areas from the interpretation of aerial photographs and were presented by standard DOE regions. Several categories may include heather either as a dominant or subdominant cover, and the major ones are:

| | |
|---|---|
| upland heath | – heather, ling and bilberry |
| upland grass moor | – including blanket bog |
| lowland heath | – heather and grass |

# Regional assessments

## 3.1 Central and southern England

S B Chapman
*ITE, Furzebrook Research Station, Wareham, Dorset BH20 5AS*

### 3.1.1 *Introduction*

Heathland is a dynamic system undergoing continual change, and is subject to gains, and losses, of species, individuals, and of both organic and inorganic materials. Any assessment or discussion of heathland must, therefore, consider the main structural and functional relationships that exist within the system.

The origin and meaning of the term 'heathland' have been discussed by Graebner (1901), Rübel (1914), Gimingham (1972), Specht (1979) and Noirfalise and Vanesse (1976). The word 'heath' is derived from the Germanic word 'heide', which means an uncultivated stretch of land. There are many words used to describe such dwarf shrub vegetation in other parts of the world (ie lande, bruyere, chaparral, maquis or fynbos). The vegetation of such areas is generally evergreen, contains members of one of the 'heather' plant families, and occurs on soils that are low in plant nutrients.

Within north-west Europe, the term 'heatherland' generally describes areas of vegetation containing a significant proportion of some member of the Ericaceae, of which *Calluna vulgaris* is the most important species. The requirements for dominance by heather were summarized by Beijerinck (1940) as a soil containing low levels of plant nutrients with a pH between 3.5 and 6.7, an oceanic climate, protection from low temperatures by snow cover during the winter months, and sufficient light.

The origin of heathland vegetation has been the subject of discussion since the earliest days of ecology. Whilst it is known from contemporary accounts that heathlands occupied large areas at the end of the 18th century, information from earlier times is both less abundant and less precise. Evidence from pollen analysis shows that an expansion of heathland took place as a result of the deforestation that accompanied man's change from a nomadic hunter-gatherer to an agriculturalist, with heathland becoming an important landscape feature in southern Britain by the late Bronze Age.

As early as 1892, Kranse concluded that the Lüneburg heathlands in Germany were the result of deforestation, and the subsequent grazing by cattle and sheep. However, Graebner (1925) suggested that heathlands represented climax vegetation upon podzolized soils under the conditions of an Atlantic climate. Whilst not excluding the role of man, he suggested that the natural regeneration of woodland on podzolized soils would be precluded. These ideas were responsible for the initial non-intervention management policy on the Lüneburg heathland nature reserve. Subsequent events have shown that such a policy can result in widespread recolonization by birch (*Betula* spp.) and pine (*Pinus* spp.), especially in the absence of grazing.

The maintenance of heathland is, therefore, dependent upon some factor which prevents the establishment of trees and arrests natural succession to scrub and woodland. Such succession may be checked by exposure, as on some coastal sites in Cornwall, but grazing, combined with burning, was probably the most important factor on most heathland sites. Heathlands were also used extensively by local inhabitants to cut peat and turf, or to gather wood, heather and gorse as fuel, and, when combined with grazing and burning, these activities prevented the establishment of trees and scrub, and maintained a low nutrient status in the soil. As traditional uses declined and enclosure proceeded, the area of heathland was reduced, sites became fragmented, and the use of heathland, by commoners, ceased in many areas. The advent of myxomatosis, and the subsequent reduction in numbers of rabbits removed any residual grazing, and, in the absence of any form of management, many heathland areas in lowland Britain have now developed into birch woodland. The management of lowland heathland has been reviewed by Webb (1986), and the management regimes in the New Forest, the last remaining major area of heathland still managed as common land in southern Britain, have been documented by Tubbs (1986).

Whilst relatively little is known about the practice of turbary, or the cutting of turf, from heathland in lowland Britain, it is thought to have been an important factor in the formation and maintenance of many areas of lowland heath. Some aspects of the history of turbary are given in papers included in the proceedings of a symposium edited by Gailey and Fenton (1970), and the practice of sod cutting on heathlands in the Netherlands is described by Gimingham and de Smidt (1983). Turf and peat cutting on lowland heathland has now almost ceased, and, as a result, the rate at which shrub and tree species have invaded some areas has increased. Only small areas of relict heathland now remain in previously traditional heathland areas, with consequent effects on their plants and animals (Webb 1985, 1989).

### 3.1.2 *Variation within lowland heaths*

The small number of plant species associated with dry

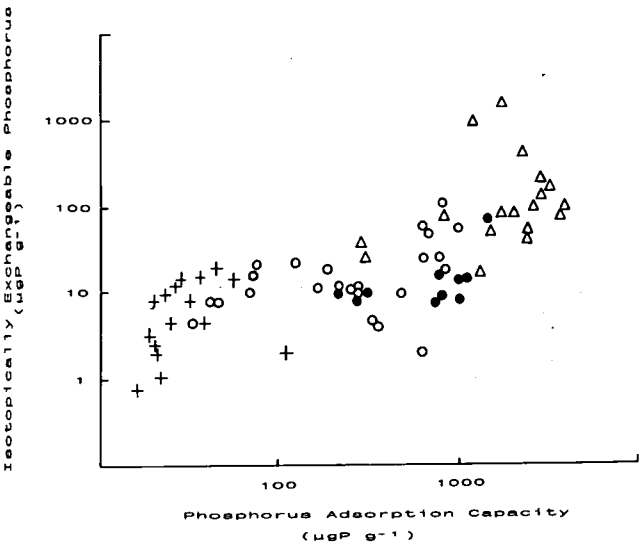
heathland shows distinct patterns of distribution which result in a series of well-marked types of heath throughout Britain and Europe. Differences in soil moisture produce a further range of variation from dry heathland, through humid and wet heathland, to a series of peatland and open water communities. Much of the local variation in drier heathland vegetation can be attributed to seral changes that result from burning, or other management practices.

Heathlands in lowland Britain occur on soils derived from a range of geological deposits. The principal areas are on the Tertiary deposits of the London and Hampshire basins, on a number of the cretaceous deposits in south-eastern England, in Breckland, the east Suffolk Sandlings, the east Devon commons, the Lizard and Land's End peninsulas. Other areas such as Dartmoor, Exmoor and the Shropshire hills provide heathlands that are intermediate in character between lowland and upland areas. These areas contain an almost continuous range of heathland vegetation, in a succession from open heather to woodlands that contain only relict areas of heathland.

Studies of production and nutrient budgets (Gimingham, Chapman & Webb 1979) have often assumed heathlands are uniform across the country. However, Chapman and Clarke (1980) have examined some of the relationships between soil, climate and production, and have shown that lowland heathlands in southern England differ markedly in the major environmental parameters from those in the uplands. Studies of land use and the management of heathland in the Netherlands (Gimingham & de Smidt 1983; Heil & Diemont 1983; Heil 1984) suggest that losses of phosphorus by leaching may not be so great on some Dutch heathlands as in Dorset.

A range of soils from heathlands in southern England have been examined (Chapman, Rose & Basanta 1989) in relation to their phosphorus adsorption characteristics, ie the ability of the soil to retain phosphorus. The soils fall into three groups. The first group, derived from Tertiary sands, shows adsorption maxima of less than 100 μg P $g^{-1}$ soil. The second group shows adsorption maxima which can rise to levels in the order of 4000 μg P $g^{-1}$ soil. The third group comprises those heathland soils which show values between these two extremes.

There is a clear relationship between phosphorus adsorption capacity and the rates of change in the vegetation on individual sites (Figure 5). In the absence of grazing or alternative management, succession to shrub and woodland is slower on open heathland where the phosphorus adsorption maximum is less than about 70 μg P $g^{-1}$ soil, but invasion by gorse is likely where the adsorption maximum is between 70 and 700 μg P $g^{-1}$ soil. Where the adsorption maximum exceeds 700 mg P $g^{-1}$ soil, succession to birch wood is most likely if grazing or positive management techniques are not maintained. Sites that have remained as heather, despite being on soils with phosphorus adsorption levels in excess of 300 mg P $g^{-1}$ soil, are all found in areas that are still actively grazed or managed, eg Dartmoor, Exmoor and the New Forest. Whilst climate might control or retard the development of woodland on Dartmoor or Exmoor, it is unlikely that some sites in the New Forest would remain as open heathland if grazing or management were discontinued.




† *Ungrazed* Calluna *heathland*
△ *Grazed* Calluna *heathland*
○ *Ungrazed heathland sites subject to invasion by gorse*
● *Ungrazed heathland sites subject to invasion by birch, and other species*

*FIGURE 5. The relationship between the vegetational state of heathland sites in southern England, phosphorus adsorption capacity and level of isotopically exchangeable phosphorus in the soil*

### 3.1.3 *Current threats and status*

Heathlands in north-west Europe have become so reduced, and in many areas fragmented, that what now remains is a series of small and isolated remnants of a formerly extensive landscape. Heathlands in lowland Britain are largely the result of particular forms of land use on suitable soils. Changes in land use, on both the immediate site and the surrounding area, have led to marked changes in both the structure and composition of the vegetation, and associated fauna, on many British heathlands. The survival of representative areas

of heathland in some parts of lowland Britain is now a serious and urgent problem.

Whilst the need to control succession exists in the management of most heathlands, the requirements of individual sites must be considered. On some sites the loss of traditional forms of land use will require drastic alternatives if heathland is to be retained. The use of herbicides for the control of birch and bracken has been investigated by Marrs (1987), but methods of reducing the nutrient capital contained in heathland sites must be considered if their long-term future is to be assured. Mowing and the removal of the cut heather as bales, as practised in the New Forest, may be more effective than burning to remove nutrients. Turbary, or sod cutting, as practised by Diemont (1982) and Diemont and Heil (1984) on heathland areas in the Netherlands may be even more effective in reducing nutrient levels. However, the exposure of deeper soil material may accelerate or promote unwanted changes in the vegetation.

The major areas of heathland that remain in lowland Britain (excluding East Anglia) occur in Dorset, in parts of Ashdown Forest, the New Forest and on the Lizard and Cornish coast. Other major areas of heathland, such as those found on parts of Dartmoor, Exmoor, the Long Mynd and the Stipperstones, are transitional between upland and lowland in character, but occur in what is generally termed 'lowland Britain'.

### i. Dorset heathlands

The previous extent, subsequent losses, and current fragmentation of heathland in Dorset have been described by Moore (1962), and Webb and Haskins (1980). The remaining heathlands were surveyed, in 1978 and 1987, by staff at ITE Furzebrook, using a 4 hectare recording grid. The resulting data were used to produce computer-drawn maps (Figures 6–8), and to estimate the areas of different heathland vegetation types (Table 9). The areas of types of vegetation associated with heathlands are important in that they

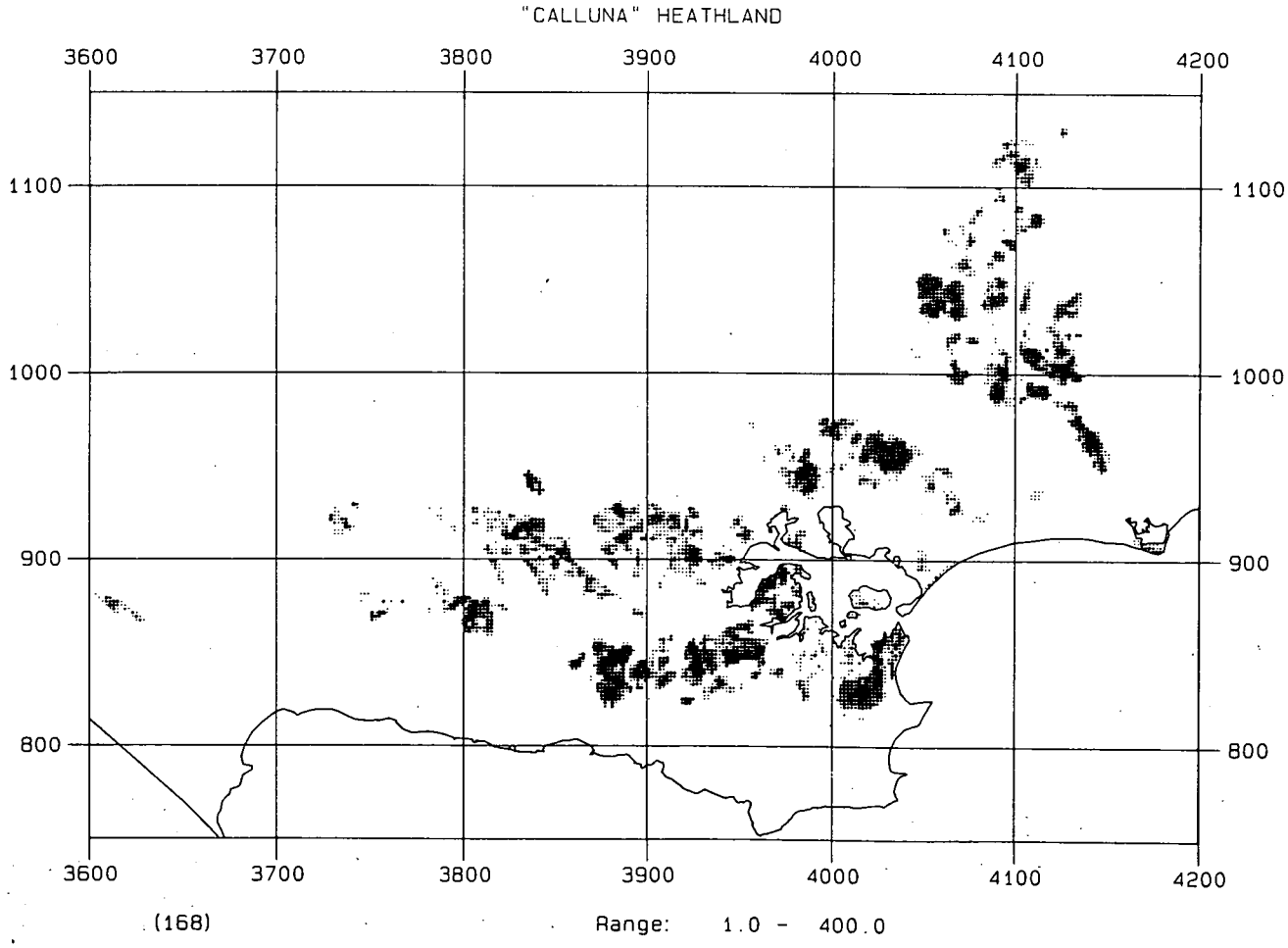



*FIGURE 6. Distribution of heathland (ie open* Calluna *heath and associated vegetation types) in Dorset, 1987. Size of circles is proportional to area in each 4 ha square*

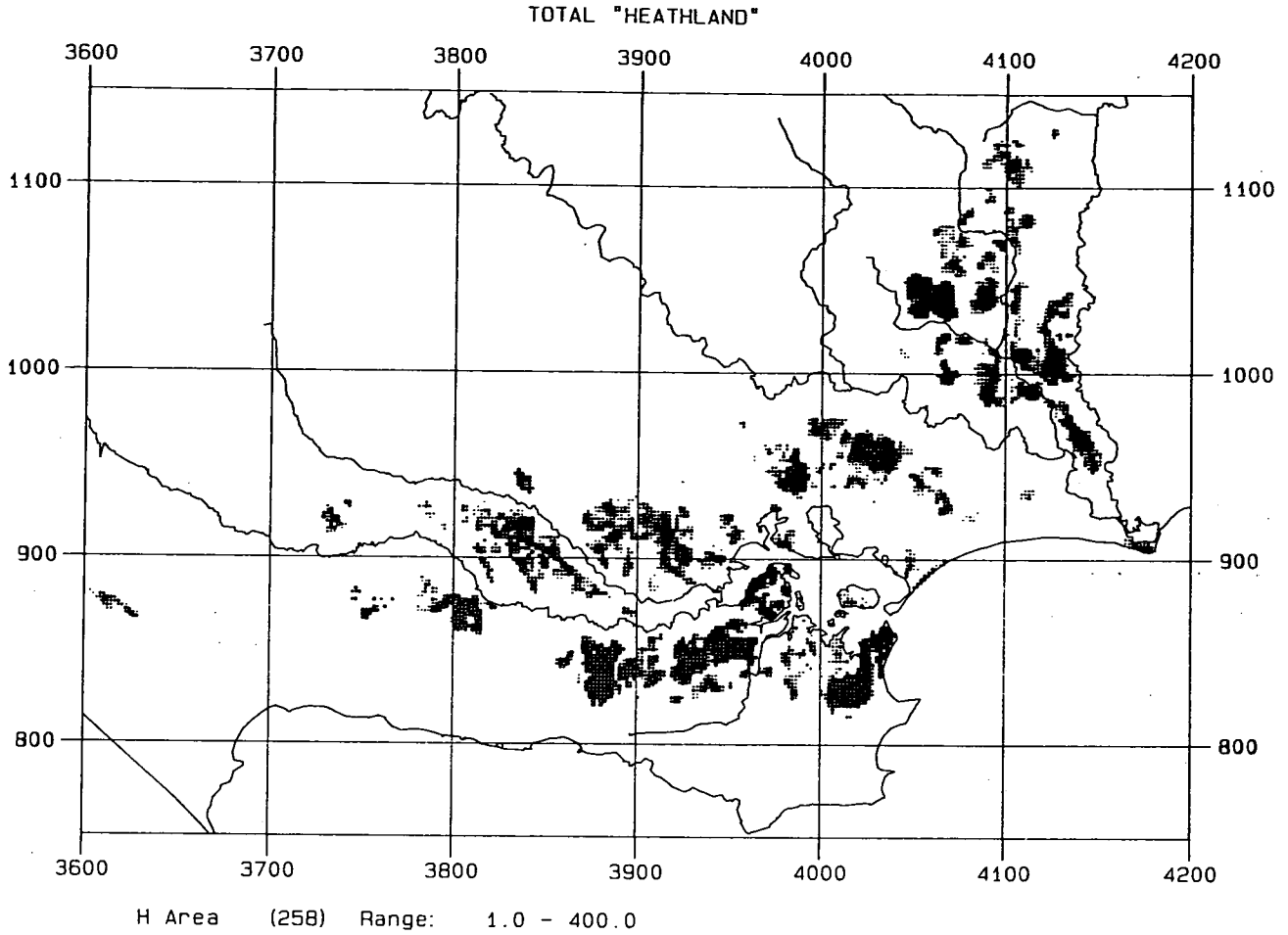



*FIGURE 7. Distribution of* Calluna *heathland (ie wet, humid and dry heathland) in Dorset, 1987. Size of circles is proportional to area in each 4 ha square*

are part of a complex of vegetation types that make up the 'heathland' system in the wider sense. The survey data obtained in 1978 have been discussed by Chapman, Clarke and Webb (1989) in relation to the need to define survey criteria, and to assess heathland for conservation, and possible restoration. The heathlands in Dorset contain a number of notable species of plants and animals not found in the same abundance elsewhere in Britain.

ii. Other heathland sites in lowland Britain

The main area of heathland in south-eastern England is found in Ashdown Forest. However, grazing by commoners' animals is now absent or minimal, and invasion by scrub species has reduced the area of open heathland. Some smaller areas of heathland remain, but they are similarly threatened by successional change. Some areas are maintained as heathland by virtue of their management as National Nature Reserves (NNRs) (Chailey Warren), or their use as golf courses (Crowborough Common).

**Table 9. Changes in the area of heathland vegetation in Dorset between 1978 and 1987 (source: Chapman, Clarke & Webb 1989)**

| Vegetation type | 1978 Area (ha) | 1987 Area (ha) | Change (ha) | Change (%) |
|---|---|---|---|---|
| Dry heath + acid grassland | 2597 | 2087 | −510 | −20 |
| Humid heath | 1476 | 1628 | +152 | +9 |
| Wet heath | 844 | 825 | −19 | −2 |
| Peatland | 590 | 601 | +11 | +2 |
| Heathland scrub | 1037 | 1213 | +176 | +15 |
| Heathland carr | 198 | 215 | +17 | +8 |
| Bare ground | 618 | 328 | −290 | −47 |
| Tracks/firebreaks/etc | 304 | 334 | +30 | +9 |
| Pools/streams/ditches | 236 | 244 | +8 | +3 |
| Totals | 7900 | 7475 | −425 | −5 |

Heathland in Surrey and Greater London has also been greatly reduced, and important sites such as Thursley Common and the Devil's Punchbowl are threatened by invasion of birch, pine, and bracken. Areas such as Frensham Common remain as open heathland, but, in the absence of sufficient grazing, will require continuing management. Heathland conditions can only survive on

many smaller sites with considerable management, and in many cases such management may well be in the form of landscape architecture rather than wildlife conservation.

Apart from the New Forest, the heathlands remaining in Hampshire are mostly in the north-east of the county. These heathlands are different in Surrey. This area includes a number of important heathland sites, some of which are military training areas (Woolmer Forest), and others which are controlled and managed by the National Trust (Ludshot Common). However, like the nearby sites in Surrey, there are problems with successional change, due mainly to cessation of grazing and fragmentation.

With the exception of Dartmoor and Exmoor, the remaining heathland sites in Somerset and Devon are scattered and generally limited in area. However, problems with birch invasion, although present, are generally less than in south-east England. The main area of heathland in Cornwall is found on the Lizard, where the particular soil conditions associated with the Serpentine result in a type of heathland dominated by *Erica vagans* (Cornish heath). The remaining heathlands in Cornwall are generally small and scattered, or associated with coastal areas.

Lowland heathland within the rest of lowland Britain is scattered, and mostly small in area, with the consequent problems of management and long-term survival.

Small local areas of heathland are to be found in Worcestershire, Shropshire, Yorkshire and Lincolnshire. As with some of the smaller sites elsewhere in southern Britain, several of these areas are of particular importance because of the habitat provided for certain demanding species of plants and animals.

### 3.1.4 *Research needs*

The major problems concerning lowland heathlands relate to changing land use, fragmentation, and the successional change to scrub and woodland. Future research needs can be listed under three headings.

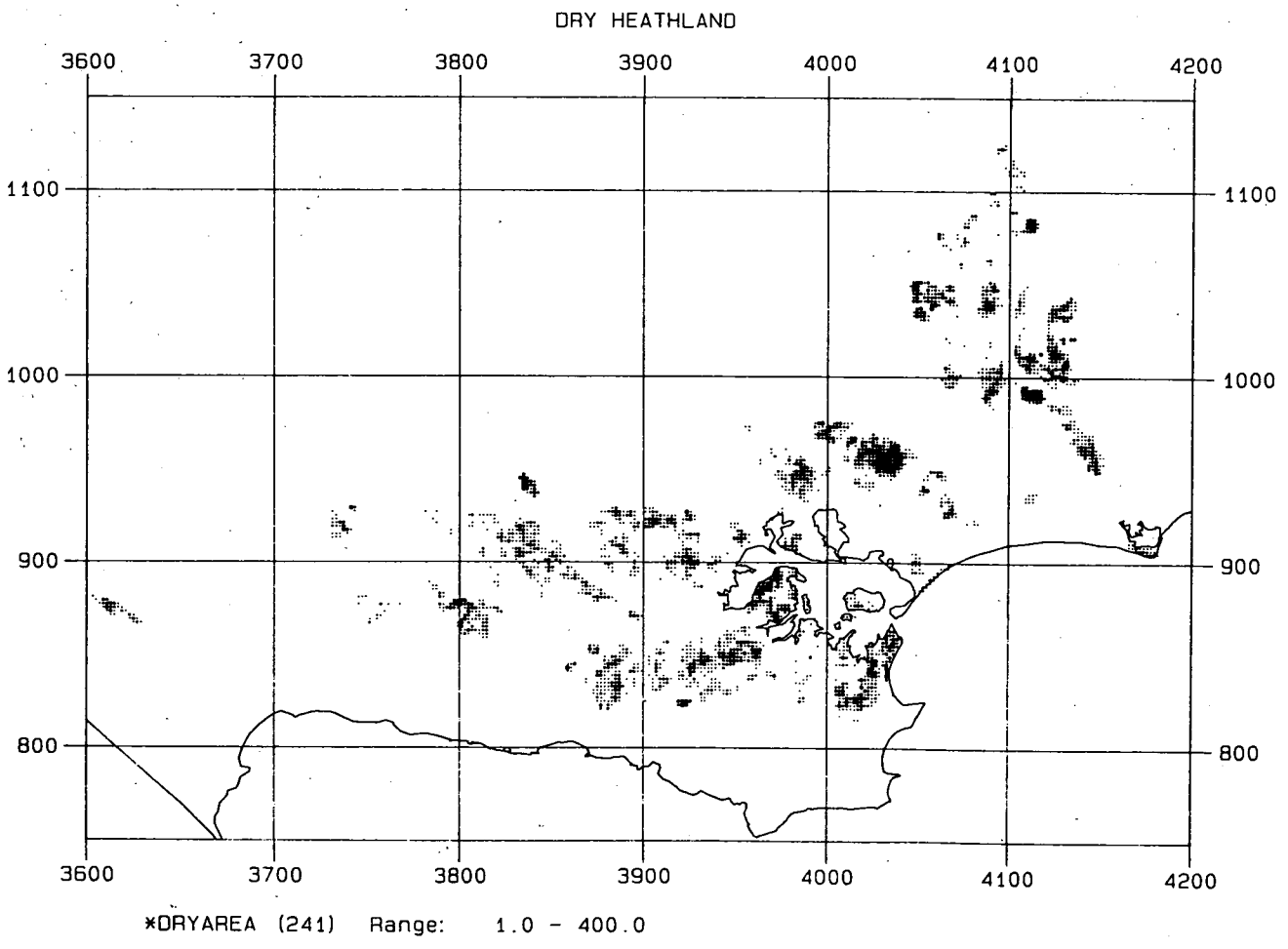



*FIGURE 8. Distribution of dry heathland in Dorset, 1987. Size of circles is proportional to area in each 4 ha square*

1. MONITORING

i. Resurvey Dorset heathlands at suitable intervals to extend existing data base. Such intervals must depend upon rates of change, but an interval of ten years is suggested.

ii. Extend the methodology developed with the Dorset heath survey to other heathland areas in lowland Britain.

iii. Examine data from the Dorset heath survey in relation to remote sensing techniques, with a view to interpretation from such techniques.

iv. Undertake case studies of rates of change from selected sites by comparisons with previous surveys and aerial photographs.

2. SUCCESSIONAL STUDIES

i. Develop existing nutrient and other models (Chapman, Rose & Clarke 1989) in relation to techniques for the future management of heathlands.

ii. Further examine nutrient losses and soil factors in relation to the rates of vegetation change, as described by Chapman, Rose and Basanta (1989).

iii. Further assess nutrient inputs to a selected range of heathlands (size, shape and area), including inputs from atmospheric deposition. Such work should be related to studies elsewhere in Europe.

iv. Further define the relationships between area, shape, fragmentation, dispersal and colonization of heathland areas by plant and animal species in relation to adjacent land use (Webb 1989).

3. MANAGEMENT AND RESTORATION

i. Establish sets of experiments to test the possible use of turbary, or related techniques, in the management and restoration of lowland heathland.

ii. Examine the timing, duration and intensity of grazing in the management of lowland heaths.

iii. Examine soil and seed bank in relation to the restoration of heathland, the recovery of heathland areas from woodland, and the re-establishment of heath on abandoned reclamation sites.

## 3.2 East Anglia

R H Marrs
*ITE, Monks Wood Experimental Station, Abbots Ripton, Huntingdon PE17 2LS*

### 3.2.1 *Introduction*

In East Anglia, the term 'heath' is often widened from its strict definition to include semi-natural grasslands. In this introduction, the wider definition is used, but thereafter the emphasis will be on heather-dominated areas. There are three main blocks of heathland in East Anglia (Figure 4):

i. the Breckland heaths around Thetford

ii. the Sandlings heaths along the Suffolk coast

iii. the north Norfolk heaths

More information is available on the Breckland heaths than the others, mainly because of the classic long-term (>50 years) scientific studies of the late Dr A S Watt of the Cambridge Botany School.

In Breckland, the present heathland vegetation reflects a complex interaction between soil type and past land use. The geology and soils are complicated by a great variety of superficial deposits of varying thicknesses, left after successive glaciations. Generally, most of the heathland soils in Breckland are very sandy and infertile. The heaths have been present presumably since forest clearance in Neolithic times (*c* 4000 BC) (Godwin 1944), and have been grazed by sheep since Roman times (Crompton & Sheail 1975; Sheail 1979). In the Middle Ages, rabbits (*Oryctolagus cuniculus*) were introduced to Breckland, and extensive rabbit warrens were established. Moreover, a 'shifting cultivation' form of agriculture was practised, where heathland areas called breaks (hence the name Breck) were ploughed and sown with cereal rye in prosperous times, followed by a reversion to heath and sheep grazing either when the soil fertility declined or the crop became unprofitable.

The vegetation found on the Breck heaths ranges from various semi-natural grasslands (grass heaths) to heathlands. The grass heaths themselves show a wide range of variation, ranging from species-rich calcareous grasslands to acidic ones dominated by species of bent-grass (*Agrostis* spp.) and fescue (*Festuca* spp.), and on some very infertile soils the vegetation is dominated by lichens (Webb 1986). These different communities often reflect the depth of superficial deposits overlaying calcareous substrata. At one site, Lakenheath Warren, at least five different grass and heather communities persist in close proximity. Intimate mosaics of plant communities reflecting the soil differences also occur as a result of the differential sorting of soil particles by solifluction after glaciation. Soil polygons have been formed on level ground, but on slopes stone stripes occur. On these striped areas, grassland tends to be found on the coarser materials and heather on the finer ones (Duffey 1976).

The Sandlings and north Norfolk heaths have also

**Table 10. Rare plants of Breckland**

| | | |
|---|---|---|
| Group 1<br>Ungrazed turf species | Heath sedge<br>Sickle medick<br>Purple-stem cat's-tail | *Carex ericetorum*<br>*Medicago sativa* ssp. falcata<br>*Phleum phleoides* |
| Group 2<br>Perennial species | Spanish catchfly<br>Spiked speedwell<br>Grape hyacinth<br>Field southernwood | *Silene otites*<br>*Veronica spicata* spp. *spicata*<br>*Muscari neglectum*<br>*Artemisia campestris* |
| Group 3<br>Poor competitors | Dense silky-bent<br>Mossy stonecrop<br>Wall bedstraw<br>Glabrous rupture-wort<br>Bur medick<br>Sand catchfly<br>Breckland speedwell<br>Fingered speedwell<br>Perennial knawel<br>Breckland thyme | *Apera interrupta*<br>*Crassula tillaea*<br>*Galium parisiense*<br>*Herniaria glabra*<br>*Medicago minima*<br>*Silene conica*<br>*Veronica praecox*<br>*V. tripyllos*<br>*Scleranthus perennis* ssp. *prostratus*<br>*Thymus serpyllum* |

developed on sandy soils, and in the past were grazed mainly by sheep and, to a lesser extent, by other stock. Some sites were also used as rabbit warrens.

The East Anglian heaths have several features in common.

- They have all developed on infertile soils, and the heathlands occur on extremely infertile sandy soils with a low pH.
- They were all formerly managed as sheep walks or rabbit warrens, or as commons with various management rights. These rights varied from place to place, but included the right to graze stock, cut bracken and heather for thatch or bedding, and cut scrub or turves for fuel.

### 3.2.2 *Variation within East Anglian heaths*

There are two particular reasons why the East Anglian heaths are important.

i. Rare species interest. Partly because of the diversity of habitats, Breckland, in particular, has many rare plant species (Table 10), and several others, eg creeping ladies' tresses *(Goodyera repens)* and ground pine *(Ajuga chamaepitys)*, which occur at the edge of their range (Webb 1986). Several coastal species, eg sand sedge *(Carex arenaria)*, sand cat's-tail *(Phleum arenaria)* and wild pansy *(Viola tricolor* ssp. *curtsii)*, are found on inland sites. Moreover, some sites are important for rare reptiles and birds. Syderstone Common in north Northfolk has natterjack toads *(Bufo calamita)*, and Breckland heaths are the main British centre for the stone curlew *(Burhinus oedicnemus)*. Nightjars *(Caprimulgus europaeus)* and woodlarks *(Lullula arborea) are* also found on many East Anglian heaths.

ii. Similarity to Continental heaths. East Anglia in general, and Breckland in particular, has a more Continental climate than the rest of Britain. The rainfall is low (*c* 560 mm $yr^{-1}$), summers tend to be warm, and the winters cold with severe frosts, especially in the spring. Thus, heathlands in East Anglia tend to be more like heathlands in Holland and Germany, than those elsewhere in Britain.

The similarity with the Dutch heaths is confirmed by studies on heather dynamics. In Holland it has been shown that the regeneration cycle of heather (Watt 1947), used in Britain as a model for the description of heathland processes, may not be applicable. The general model of Watt implied that a given patch of even-aged heathland will develop naturally into an uneven-aged patch by the natural death of individual bushes followed by a recruitment of new plants. On the Dutch heaths, this process does not occur; rather, the cycle is interrupted by catastrophes, such as extreme climatic events (hot summers or cold winters) or outbreaks of heather beetle. Thus, many large areas of heathland have been killed at one time, and in some instances almost the whole site has been affected. When these catastrophic events occur, regeneration depends on seed, and there is an opportunity for other species to invade and change the course of succession away from heathland. Dutch conservationists are very worried about these events because they allow grasses such as wavy hair-grass and purple moor-grass to invade.

Marrs (1986, 1988) has described similar catastrophic events at one site, Cavenham Heath, in Breckland,

where the hot summers of 1976 and 1977 followed by a heather beetle outbreak in 1978–79 affected almost half the heather; the remainder has been affected by severe winters since that time. Marrs (1988) has summarized our knowledge of the differences between heather dynamics on British and Continental heaths into a simple decision-making model (Figure 9) for heathland managers, but the general usefulness of this model needs to be evaluated. If the East Anglian heaths are similar to the Dutch heaths, then it is reasonable to suppose that they may have similar problems. In Holland, there is a great deal of evidence to suggest that loss of heathland through successional change to grasslands of wavy hair-grass and purple moor-grass is driven by high inputs of nitrogen in polluted rain (Heil & Diemont 1983). Purple moor-grass is increasing on some East Anglian heaths, and it is possible that high nutrient inputs are one of the causes. Unfortunately, we have no information of the amounts of nutrients added to heathland sites in dry and wet deposition or from fertilizers, which are used in large amounts on adjacent agricultural land.

### 3.2.3 *Current threats and status*

There has been a great reduction in absolute heath in all heathland areas. In Breckland, 60 000 ha of sheep walk and rabbit warrens have been reduced to <10 000 ha, divided between 19 sites of varying size (Ratcliffe 1977), and in the Sandlings 23 370 ha have been reduced to 5412 ha (Armstrong 1975). The largest site in Breckland (4740 ha) is the Stanford Practical Training Area (PTA) (Ministry of Defence), which is mainly grass heath; one site, Lakenheath Warren, is <500 ha and two groups of sites (Berner's/Horn/Wether heaths and Bridgam/Brettenham heaths) are <300 ha. All other sites are <200 ha, and some are <50 ha. In the Sandlings, the heathland is split into 42 small sites, with half being <25, and only two 'extensive' blocks (Minsmere/Westleton/Dunwich heaths (380 ha) and Sutton/Hollesley heaths (510 ha)). Few data are available for the north Norfolk heaths, but Ratcliffe (1977) cites Royden Common as the largest at 160 ha.

In addition to these losses in absolute area, losses also occur through succession to late-successional communities, as bracken, gorse, birch and Scots pine *(Pinus sylvestris)* invade. Although a general feature of all British heaths, the losses have been documented in detail for four sites in East Anglia (Marrs, Hicks & Fuller 1986). At three of the four sites, scrub invasion was the major problem, with a 10% loss at Cavenham Heath, a 30% loss at Knettishall Heath, and a 50% loss at Lakenheath Warren between 1946 and 1984. Bracken was also increasing at three sites, but it was not as serious a problem as scrub on the sites investigated. Given the similarity with Dutch heaths, nitrogen input represents a potential threat, as suggested above.

The reasons for these successional losses are clear.

- Lack of grazing. The sites have not been grazed by stock for many years, and the grazing pressure has been further reduced by the decline in rabbit

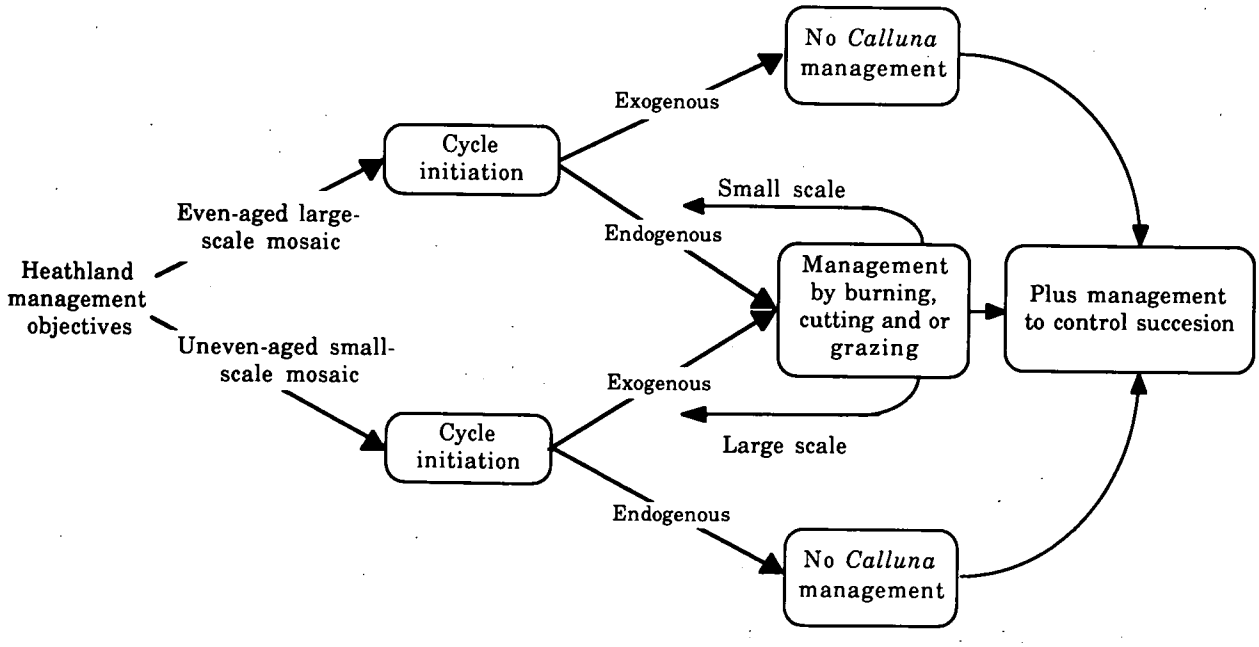



*FIGURE 9. A decision tree showing four potential scenarios for managing lowland heath, depending on the scale of the vegetation mosaic required on the site and the type of initiation of the* Calluna *regeneration cycle (source: Marrs 1988)*

numbers following the introduction of myxomatosis.

– Lack of vegetation management. Bracken, scrub and turves are no longer removed from the heaths.

These changes in management have allowed succession from early-successional communities (heathlands and grass heaths) to late-successional ones (bracken and woodland). These successional effects are exacerbated by the small size of the heathlands, and hence their large perimeter/area ratio and their fragmented distribution.

### 3.2.4 *Research needs*

The major problem in East Anglian heaths is that of successional change brought about by the invasion of bracken and scrub. The basic knowledge for solving the problem exists (Marrs & Lowday 1989), and techniques are available for both the management of existing heathland and the restoration of areas where succession has already begun. The major emphasis of heathland conservation in East Anglia must now be given to implementing these management strategies. This implementation has already occurred to some extent with the recent introduction of both large-scale bracken clearance and sheep grazing at several sites in Breckland, and the very successful community-based Sandlings Project, which has restored and is currently managing many of the Sandling heaths (Fitzgerald, Martin & Auld 1985). Moreover, the designation of Breckland as an ESA implies a major initiative in the near future in the restoration and management of heathland in Breckland. Currently, it is hoped to increase the areas of heath which are grazed, and also to introduce a cereal cropping programme, designed to reduce soil fertility on arable land, in the hope of accelerating heathland reversion. With all of these initiatives, however, properly designed monitoring schemes are important. It is essential to have at the outset (i) management objectives with stated criteria for success, (ii) monitoring programmes designed to assess whether the criteria are being attained, and (iii) programmes of remedial action, should problems arise.

There are five areas where further research on East Anglian heaths is needed.

i. Detailed monitoring of management currently being done by conservation agencies, and that proposed for the ESA.

ii. Reappraisal of existing data related to vegetation change over the last 50 years. Two data sets at least are available: the species lists published by Watt, and the heather survey results of Marrs for other sites. Species change could be determined by resurveying these sites.

iii. Assessment of the amount of nutrients being added in wet and dry deposition, fertilizer drift, and gaseous inputs. These amounts could be related to the levels found to be causing adverse vegetation change in Holland. If problems are detected, then vegetation management techniques must be developed to prevent further damage.

iv. Assessment of the scale of 'Continental'-type heathland dynamics. If heathlands are to be managed effectively, some evidence for massive mortality is required. However, the catastrophic death of large areas has only been documented in detail for one site, and long-term surveys of heather status are required to evaluate the scale of the problem. A modelling approach based on both the age structure of heather populations on different heaths, and physiological assessments of tolerance to drought, heat, frost and herbivore attack would be useful.

v. Synthesis of all available information into 'user-friendly' management models, such as an expert system, that will enable heathland managers to develop low-cost, effective management policies.

## 3.3 **Northern England** (Pennines northward)

P Anderson
*52 Lower Lane, Chinley, Stockport, Cheshire SK12 6BD*

### 3.3.1 *Introduction*

Extensive tracts of flowering heather are widely recognized as an attractive sight in the hills in the north of England. Heather moorland, too, often has strong literary and cultural associations with areas such as Ilkley Moor.

This landscape significance was reflected in the Wildlife and Countryside Act 1981, which required a map to be prepared by all National Park Authorities of heath and moor which it was considered important to conserve. The expanded requirements for this map (Wildlife and Countryside (Amendment) Act 1985, Section 3) continue to include heather moorland.

The wildlife living on heather is also distinctive. The Royal Society for the Protection of Birds (RSPB) (1984) lists ten bird species in the UK which depend on moorland habitats for breeding. Of these, hen harrier, merlin, red grouse (*Lagopus lagopus scoticus)* and black grouse (*Lyrurus tetrix),* golden plover (*Pluvialis apricaria),* dunlin (*Calidris alpina),* ring ouzel (*Turdus*

*torquatus)* and twite (*Acanthis flavirostris)* are characteristic of heather communities in upland England. Some of these (hen harrier, merlin, red grouse and golden plover) are regarded as internationally important because their British populations form a significant proportion of European or world totals. Widdybank Fell has exceptional populations of golden plover, while the moors in the Northumberland National Park support many birds of prey.

The expanses of heather-dominated moorland, mixed heather and other ericaceous shrubs, and heather/cotton-grass blanket bog are exceptional, and compare with western Norway and, to a lesser extent, with western France and Spain. The management policies for sport practised on moorland in Britian are unusual in an international context, in that both grouse and sheep are implicated. Red deer (*Cervus elaphus)* are also involved, but mainly in Scotland. The abundance of oceanic heathland species (eg dwarf furze (*Ulex gallii*)) adds to the significance of moorland in a national and international ecological context.

Many of the Sites of Special Scientific Interest (SSSIs) in the English uplands were selected by the NCC specifically for their upland birds, notably breeding merlin, hen harrier, and waders. Some are also scheduled for their floristic and invertebrate composition. The richest areas botanically are the small flushes within the heather moor, and the steeper banks which have not generally been frequently burnt. Regular burning leads to a dominance of heather at the expense of various lichens and mosses, as well as a loss of the intimate mixture of dwarf shrubs (Pearsall 1968).

All commercial grouse moors include extensive tracts of heather. Young heather shoots are the staple diet of grouse, and moors have been regularly burnt for decades to regenerate heather. The characteristic pattern of burning long narrow strips (20–30 m wide) with the intention of maintaining a heather growth cycle of 8–12 years, as advocated by Watson and Miller (1976), is widely practised.

Although heather is of limited grazing value, it provides winter browse, and young plants are also grazed in July–October. Sheep numbers have increased, and grazing pressure determines the nature of the vegetation (Anderson & Yalden 1981; Ball *et al.* 1982). Sheep select the more palatable and preferred fine-leaved moorland grasses (bents, fescues and wavy hair-grass) in the spring, but, as the nutritional value of grass declines over the growing season, the gap between the digestibilities of heather and grasses narrows. Young heather is then taken in late summer and autumn. In winter, where snow falls are heavy, sheep graze on the exposed older heather when its nutritive value is no poorer than that of the surviving grasses (Grant *et al.* 1976; Hunter 1962; Miller *et al.* 1984). A diet composed only of heather in mid-summer is just adequate to maintain the weight of a non-lactating sheep, but would be inadequate for sustenance in other seasons (Scottish Agricultural Colleges 1988). There is thus an apparent contradiction in that sheep grazing causes heather loss and conversion to graminaceous cover.

### 3.3.2 *Variation in northern heather moorlands*

Vegetation in which heather is a major component is not evenly distributed throughout northern England. Extensive and smaller fragmented heather moorlands occur in the Peak District, in the southern Pennines. In the central Pennines, heather moorlands are scarce, except in the Forest of Bowland. The northern part of the Yorkshire Dales National Park supports a significant cover of heather, as do some of the adjacent Durham moors. Extensive cover is apparent in Northumberland (10% of total) and Cumbria (11% of total). There are less well-known scattered areas elsewhere. Heather also occurs extensively in the northern Pennines. North Yorkshire, however, which includes the North York Moors, holds the largest area (18%).

In the east, heather-dominant vegetation tends to occur on dry hills, where the soils are peaty podzols. Heather often forms pure stands, excluding most other species. However, after burning, temporary flushes of wavy hair-grass or purple moor-grass may occur. Bell-heather (*Erica cinerea)* and some other moorland species such as bilberry may occur in patches amongst the heather, especially on more rocky slopes. Beds of bracken are a feature of the lower edges of such moors, or occupy the sometimes grassy valleys below the moorland.

On peaty gleys or deeper peats in the west and north, the heather is usually co-dominant either with cotton-grass (mostly *Eriophorum vaginatum* but also *E. angustifolium)* or with purple moor-grass.

In the Peak District and in the Forest of Bowland, dry heather-dominated moorland is characteristic on the more level, lower moorlands. Mixtures of ericaceous shrubs, patches of bracken and heather/grass mixtures fringe some valleys. However, there is now little cotton-grass/heather moorland. In contrast, heather is usually mixed with cotton-grass on the blanket peats in the North Yorkshire Dales. The drier heather moors here are limited to gritstone rocks.

In the Durham and Northumberland moors, there is a

similar distinction between the drier heather-dominated sandstone areas as opposed to the cotton-grass/heather of the plateau blanket bogs. The North York Moors, however, have mainly dry pure stands of heather growing on podzolized soils, with extensive bracken on the lower slopes. In the Lake District, the rocky granitic fells of Shap and Buttermere contrast with the rounded slopes and blanket bogs of the Skiddaw slates.

Heather is also a constituent of other types of vegetation found in the uplands. It shares the humid heath with cross-leaved heath (*Erica tetralix)* (Gimingham 1972), and the sedges and grasses of base-rich flushes. Elsewhere on cliffs and gills, it occupies rocky ledges with sub-montane species, grasses and ferns. It grows, uniquely, on limestone pavement in the Yorkshire Dales and in south Cumbria, where it is rooted in leached soils in the crevices adjacent to limestone species, and it is a characteristic colonizer of roadside banks and abandoned quarries, especially in the sandstone areas of the Pennines.

### 3.3.3 *Current threats and status*

It is generally believed that there have been substantial losses of heather-dominant and sub-dominant communities this century in all upland areas. For individual areas, the extent and rate of loss tend to be anecdotal rather than quantitative. Pearsall and Pennington (1973), for example, describe the loss of heather in parts of the Lake District. Other studies provide more quantitative information. Parry (1977) studied the moorlands in the upland National Parks and concluded that, on the whole, the core remained as moorland, whilst the fringes alternated between being improved agricultural grassland and reversions to rough, acid grassland or ericaceous shrub vegetation, reflecting fluctuations in economic pressures or incentives. Ball *et al.* (1982) consider such changes to affect only some 11% of the total moorland area (including land other than that covered by heather), but, in the Lake District at least, some of the supposed core area of moorland in the south-east of the Park has recently been reclaimed for agriculture.

In the Peak District, Anderson and Yalden (1981) have documented a 33% loss of heather-dominant moorland, and an average 53% loss of heather sub-dominant vegetation between 1913 and 1979 (1.5% annual loss if a consistent rate of loss is assumed of the 6563 ha). In the North York Moors, a one per cent annual loss has been calculated (North York Moors National Park Committee 1982), which ITE (1978) has converted to a total of nearly 1000 ha of heather moorland being enclosed and improved between 1951 and 1974.

In Cumbria, NCC (1987) has recorded a 65% loss of heather moorland and a 12% loss of heather-dominated blanket bog to unimproved grassland between 1940 and 1970 from a limited number of sample areas. However, this estimate shows a discrepancy with the extent of heather as recorded in the current study, and it may be that definitions of heather cover were different between the surveys.

Afforestation has directly caused loss of heather, eg on Skiddaw and the Shap fells. In the Northumberland National Park, much of Kielder Forest is reputed to have once been grouse moor. The absence of actively managed grouse moors in this Park and in the Lake District, where they were known to have been more widespread in the past, also points to substantial losses of heather. Conversion of more accessible heather moor to improved grasslands has occurred widely (Parry 1977), but quantitative data are unavailable except for the MLC report, NCC (1987) and Anderson and Yalden (1981).

In contrast with the lowlands, the upland heaths are likely to have changed as a result of a more gradual process of overgrazing, or changes in sheep management. The sequence of the conversion of heather moor to grass heath, to acid grassland or to a blanket bog dominated by cotton-grass are well known (Hudson 1986; Anderson & Yalden 1981; Miller *et al.* 1984). Losses can result from winter feeding in heather (both across the centre of moors where new tracks have increased accessibility, but more especially round moorland edges on the grass/heather interface); from limited burning, whereby sheep concentrate on and suppress too small an area of regrowth; from grazing on old heather with no burning when brittle stems are broken down and grasses replace the heather; or from too frequent burning combined with heavy grazing. The decline in traditional shepherding, increasing stocking levels, and the use of the moor in winter as well as summer may well be causes for the decline in heather in many upland parts of northern England. For example, one estate of 5000 ha in Durham has lost 800 ha over the last 20 years as a result of winter feeding across the moor.

Ball *et al.* (1982) found that stock numbers were broadly stable in the upland parishes they studied, with local exceptions. A few parishes showed rising stock numbers since the 1950s. However, not all the study areas were heather moorland, and these findings contrast with the Peak District's moorland parishes where Anderson and Yalden (1981) noted a three-fold increase in sheep numbers between 1930–34 and 1974–76. Not all these sheep occur on heather moor-

land, but the nature of the general trend is corroborated by Hudson (1984), who found increases of stocking rates on 39% of heather moors (representing 311 $km^2$) and all-winter use on 84% in a survey of 63 grouse moors in the north of England.

Detailed clipping and grazing experiments by the Hill Farming Research Organisation (HFRO) (now part of the Macaulay Land Use Research Institute (MLURI)) have demonstrated that heather can tolerate consumption of up to 40% of its current year's growth without damage to its reproductive capacity, but 80% utilization is damaging whatever the season (Grant *et al.* 1978, 1982; Milne, Bagley & Grant 1979).

MacEwen and Sinclair (1983) blame EEC agricultural policies for encouraging a shortage of labour, a decline in traditional shepherding, changes in stock and land management, and the amalgamation of small farms in the uplands. The hill livestock compensatory allowances (HLCA) encourage increases in stock rather than better management or productivity per ewe. Increasing stock levels to compensate for declining income affects heather through grazing intensity. Furthermore, annual burning, which results in a repeated loss of nutrients, does little in a free-range grazing system because of the interaction between sheep and heather. Grazing on common land can have a major influence because of the lack of control over grazing pressure.

Where heather persists in the sward, or its seed remains dormant in the soil, heather cover can be restored, but further detailed study is required to establish the proportion of heather moor that can be restored by different means. In many areas, it is too late to reclaim heather moor without a substantial programme of reintroducing heather seed with appropriate cultivation to provide a suitable seed bed.

Recent policy changes may well be restricting further afforestation. In general, however, loss of heather from overgrazing and poor burning management is probably the main current problem. Fires which are too hot can burn thin peaty soils, as in the Forest of Bowland and Skiddaw, leading to erosion. Moorland fires resulting from public access can cause extensive damage in years of drought. Both Anderson (1986) and Maltby (1980) have demonstrated the deleterious impact on wildlife and landscape, and the threat of moorland erosion which can result from severe summer fires (Phillips, Yalden & Tallis 1981). If public access increases, and heather moorland, or blanket bog, dries out in the summer, several more areas could be at risk.

Recent work at HFRO has sought to develop a moorland management system whereby sheep grazing and grouse production are fully integrated. Furthermore, the Ministry of Agriculture, Fisheries and Food (MAFF) is attempting to promote moorland management practices which are compatible with the retention of heather moorland. The intensity of management of the grouse has reduced, due to the decline in labour on the moors, both of agricultural workers and of game keepers. Hudson (1986) correlates the decrease in grouse in all the major moorland areas of upland England with the reduction of game keepers. With the decline in burning, or where sheep farming predominates, increased grazing pressure causes a reduction and loss of heather.

However, on many grouse moors, the buoyancy of the field sports market has led to a change in emphasis, from a family interest to commercial promotion of grouse shooting. This change has resulted in better financial returns which many owners are reinvesting in moorland management. More keepers are being employed, better burning programmes are undertaken, bracken is controlled, sheep stocks are limited and their management is improved. The position is not stable, and a change in economics or social habits could be sufficient to tilt the balance away from grouse management and towards sheep farming. If this change occurs with the current system of agricultural support policies, the heather moors could be reduced even further. Currently, good grouse moor management is the dominant factor which provides the heather landscapes and wildlife habitats, although some species of wildlife considered as vermin, eg stoats (*Mustela erminea)* and weasels (*M. nivalis)*, are killed. Moreover, protected species, particularly harriers, are illegally controlled from time to time. Apart from neglect, the alternative is for management specifically for amenity and wildlife.

General open access for recreational use both on commons (as proposed by the Common Land Forum) and on open moorland (as sought by the Ramblers Association and others) is regarded by some authorities as a major threat to the quality of the wildlife on some heather moorlands. The Moorland Association represents owners who are fearful of increased disturbance to grouse moor productivity and management. It supports increased access to the moor, but would promote a rationalized, improved path and track network rather than the freedom to wander at will.

There is concern that open access, coupled with the promotion of tourism, could affect waders in Durham and birds of prey in the Forest of Bowland. In support of this concern, Anderson (1989) has shown that off-path use can be as high as 40% where access is available.

Yalden and Yalden (1988) recorded 32% off-path use on blanket bog, with one dog per 25 people and 8% of the dogs running wild. Hudson (1983) emphasizes how damaging such dogs can be on a grouse moor.

On the other hand, neither Picozzi (1971) nor Hudson (1983) found any effect on grouse nesting close to well-used paths, but Myrberget (1983) noted how nest fidelity increased during disturbance in the closely related willow grouse (*Lagopus lagopus)* as incubation proceeds, and Watson (1982) found a substantial decline in nesting success of ptarmigan (*L. mutus)* and red grouse from an area around the ski slopes on the Cairngorm as a result of increased predation following the development of tourism.

Many ground-nesting birds are vulnerable to disturbance, and, although grouse tend to sit tight almost until trodden on, curlew (*Numenius arquata)*, golden plover, and dunlin have all been shown to be highly disturbed by human presence (Van der Zande 1984; Yalden & Yalden 1988).

Footpath trampling is rarely regarded as a general threat to moorland, but paths over 50 m wide are developing in parts of the Yorkshire Dales across former heather moorland (the Three Peaks area), the Pennine Way is particularly wide, and bare ground is prevalent in parts of the Peak District (Bayfield 1985). Other land uses, eg quarrying, may also take small areas. Erosion is important in the Peak District, affecting some 11–13% of moorland, and in the North York Moors large areas are eroding as a result of intensive fires.

Although there are few quantitative data showing extension of bracken cover, its spread is still regarded as an important issue in areas like the North York Moors and Northumberland. Control programmes are being initiated in both areas.

Moorland gripping (a type of drainage, now in decline) was frequently undertaken in an attempt to increase the quantity of heather. Its success was often limited to the edge of the grips (Stewart & Lance 1983), and, instead, it threatened grouse productivity by draining wet areas that provide insects (especially craneflies) on which grouse chicks depend for survival (Hudson & Renton 1988).

Currently, some grouse moor owners are restoring small areas of heather moor by spraying bracken, improving sheep management, or reducing grazing pressures. In contrast, the management of moors primarily for sheep can result in the loss of heather, and a change in the whole moorland ecosystem. The current management situation is described by Hooper and Whitby (1988), who present a wide range of data summaries. On the other hand, where SSSIs have been designated, and where NCC has entered into negotiations or a management agreement with the owners or tenants, stock levels have not increased and management has improved. Some National Park Authorities have also entered into management agreements (both voluntarily and as a result of Farm Grant Notifications) to prevent moorland cultivation and agricultural improvement, and have adopted policies to protect moorlands. Whilst national wildlife agencies own relatively little heather moorland in England and Wales, they are major advocates of appropriate management to further their objectives. Currently, they are mostly dependent on land owners managing their land within the economic framework for grouse or sheep.

The Water Authorities own more moorland in some areas than any other public authority, and some, too, are instigating heather restoration programmes and seeking to reinstate grouse moor management. The Peak Park Joint Planning Board is attempting integrated management of heather moorlands for wildlife, landscape and farming. The Lake District Special Planning Board owns several moorland areas, and is seeking to secure a balanced management programme for them. A project officer is being sought, for example, to work closely with the NCC and other organizations in managing Board-owned and adjacent SSSI land. The Yorkshire Dales Authority not only owns no moorland, but has a policy which prevents its purchase of land. In the North York Moors, in contrast, ownership of a major moorland estate, much of which is an SSSI, has involved developing special management prescriptions. The National Trust also owns large areas of moorland, much of which lies in the Lake District and Peak District.

Various agencies have established research and monitoring projects to investigate aspects of moorland ecology, dynamics and management. The Countryside Commission has initiated a study of landscape change in the National Parks. The Peak District's moorland restoration project has evolved into a moorland management project, and is monitoring changes in moorland management, as well as various restoration studies. The project is now hoping to work closely with the Dark Peak ESA. In the North York Moors, research and restoration projects were initiated after the fires of 1976, and a programme of restoration continues. Bracken control is now a major theme, with grants being provided to restore heather moorland. The grants form part of an agreed management package, which incorporates moorland management for wildlife and better grazing control.

The Lake District Special Planning Board, the RSPB and NCC have been surveying and monitoring moorland birds in order to identify the most valuable areas for protection. The NCC is also establishing studies on the ecological status of several specific estates in the Forest of Bowland to quantify the changes and develop a suitable management regime, and has also nearly completed a review of its moorland SSSIs.

The North of England Grouse Research Project continues to study grouse-related problems. Dr Yalden (Department of Zoology, University of Manchester) is completing a study of the effects of disturbance on golden plover in the Peak District, funded by the NCC, and the North York Moors National Park Authority and York University are collaborating on a study of invertebrates on different types of heather communities, and on cut or burnt heather.

Experiments in moorland management, whereby grazing levels are manipulated and heather reintroduced, are being undertaken on Earl Peel's land at Hall Moor in the Yorkshire Dales; the Joseph Nickerson Foundation is sponsoring work on economic aspects of the use and management of heather moorland (eg at the University of Newcastle-upon-Tyne), as well as practical heather restoration and management. Other management experiments are being initiated in the Northumberland National Park on Ministry of Defence (MOD) land, where grazing levels and heather reinstatement are being manipulated, and the efficacy of using heather cutting instead of, or in combination with, burning is being investigated in the North York Moors.

### 3.3.4 *Research needs*

In policy terms, the main need is for a review of the agricultural support system and of how it could be modified to produce appropriate incentives for grazing management in the uplands to encourage heather.

Various suggestions have been made for improving the upland agricultural support system, eg by modifying the timing of HCLA payments. Alternatives include productivity or percentage of lambs weaned payments to encourage better management, or some means of controlling stocking rates. The Dark Peak ESA is developing a system which could be applied to other moorlands. Prescriptions would also need to vary geographically, even in a small area where conditions and breeds of sheep vary. Sufficient levels of incentive payments would be needed to involve the agricultural community. A holistic approach is required whereby vegetation growth, the extent and composition of vegetation types, the current management regime and sheep requirements are incorporated into a computer model of the type being tested by HFRO. However, greater emphasis on the needs of wildlife and landscape is required within the model, as well as the setting of a wider range of objectives.

There is also a need for better training for the improvement of moorland management, both through burning and shepherding. Better technical information needs to be provided, together with an advisory procedure for conveying that information to farmers and landowners to ensure that up-to-date management procedures are used.

The above discussion relates to management requirements, but the technical aspects are equally important and are summarized below.

i. Determination of the circumstances in which heather-dominant vegetation is most at risk. These areas are likely to be mainly in England and Wales, on wet western soils or on fertile mineral soils, on land carrying large stocks of herbivores, around the edge of moorland blocks, and where there are heather/grass mosaics. This aspect would also involve an investigation of the importance of retaining labour on the moors.

ii. Further details of actual loss of heather.

iii. Review of published information on the relationships between herbivore stocking rates and the rate and direction of successional change on heather moorland. Such a review is currently being undertaken by MAFF as part of the Peak District moorland management project. It will take account mainly of work by MLURI, ITE and NCC.

iv. Identification of possible management techniques to correct and reverse successional changes leading to a loss of heather. This would not only involve control of grazing pressure but also ways of re-establishing heather in areas from which it has been eliminated.

v. Surveys of the size and composition of seed banks in different vegetation types thought to have been dominated by heather at earlier successional stages. The micro-distribution of heather seeds in the soil within vegetation types and the pattern of aggregation also need investigation.

vi. Experimental studies of possible methods to promote regeneration from the seed bank. These studies would include soil cultivation and chemical treatments to reduce the competition from existing vegetation and to stimulate the germination of heather seeds.

vii. A detailed assessment of the socio-economic factors relating to heather moorland, including the influence of common land, access, and economic factors following up the work of Hooper and Whitby (1988).

viii. Monitoring of key species such as moorland birds on a representative series of samples.

## 3.4 Wales

G L Radford
*ITE, Bangor Research Station, Penrhos Road, Bangor, Gwynedd LL57 2LQ*

### 3.4.1 Introduction

Heather grows widely in Wales and has been reported from all but 19 of the 282 ten km squares containing land, ie 93% (Ellis 1983). Within that range, it occurs in several contrasting habitats, from the coast to the uplands. The major habitats represented in sites surveyed during the *Nature conservation review* (Ratcliffe 1977) are:

| | |
|---|---|
| coastal heath | – mainly sub-maritime |
| lowland heath | – the central type, and wetter variants |
| lowland mire | – valley and raised mires |
| upland heath | – dry and wet variants |
| upland mire | – mainly blanket bog, western and eastern variants |

Heath occurs frequently around the Welsh coastline, often dominated by *Calluna* or bell-heather, and mixed with dwarf furze. Away from the coast but still at low altitudes, heather is most abundant on wetland habitats, notably on the drier parts of valley and basin mires, but also in some raised mires. Predominantly, however, heather occurs in upland heaths and mires, in 'moorland' habitat above the level of field enclosure, which tends to stop at 250 m OD.

Despite its widespread occurrence in Wales, there are relatively few areas, even on the uplands, where heather occurs extensively as the dominant plant. These areas are primarily in the northern half of the country, and are centred on the major peat deposits. Place names based on 'grug', the Welsh name for heather, provide evidence of its former, more extensive occurrence as the dominant vegetation.

Vegetation dominated by heather, particularly in upland heaths, is at risk because it can be replaced relatively easily by agriculturally more productive acidic grassland. A combination of severe burning and sheep grazing has resulted in the disappearance of much heathland and in the removal of heather and other dwarf shrubs from extensive areas of blanket bog. Consequently, heather persists unchecked in those situations where access is difficult for grazing, typically in local craggy areas such as the northern Rhinogs, Tryfan and other parts of Snowdonia, and Cader Idris.

Successful management for extensive tracts of heather on more even ground is typified on the remaining Welsh grouse moors, where small areas are lightly burnt in rotation giving a patchwork of different-aged stands. Light burning can also be effective on blanket bog, but, although it can achieve good heather regeneration, it can have an adverse effect on the cover of bog moss, and can put at risk the more sensitive flowering plants such as lesser twayblade *(Listera cordata)* and marsh andromeda *(Andromeda polifolia)*.

The major stronghold for upland heather is in the Berwyn Mountains, which support one of the largest remaining areas of heather-dominated heath and blanket bog in Wales, and the least fragmented of these habitats in north Wales. The blanket bog is also considered to be one of the few actively growing examples in Wales. (The Berwyns have been the subject of special study by agencies with conflicting land use interests in the area: NCC, FC and the Welsh Office Agricultural Department (Lofthouse 1980)).

Another large area of heather-dominated heath occurs on the Denbigh Moors, where management for grouse has ensured a healthy cover. Large grouse moors also occur near Ruabon, and, less extensively, on the Rhinogs. Grouse numbers dwindle towards the south, where the upland heaths, often on relatively shallow peat, have been under greater agricultural pressure from sheep grazing. Heaths in the Glamorgans, for example, occur only in small fragmented stands, although these are fairly frequent and some are regularly managed. Examples of several variants of heath vegetation occur on the Preseli Hills in western Dyfed, including a markedly oceanic type with heather, bell-heather and dwarf furze.

The most extensive areas of heather moorland are: the Berwyns, Denbigh Moors, Clwydian Range, Ruabon and Llantisilio Mountains, parts of Snowdonia, and the Rhinogs. An estimated 32 000 ha of upland dry heather moorland remain in Wales (NCC unpublished figure).

Although heather/cotton-grass blanket mire is a widespread upland habitat in Wales, there are relatively few examples that are both extensive and largely intact.

Among the major sites are the Migneint, the Berwyns and Duallt in north Wales, and Plynlimon, Radnor Forest and Cwm Ystwyth in mid-Wales. Futher south, the blanket bog is often fragmented, heavily disturbed or less well developed at the lower altitudes. Heather-dominated blanket bog is not currently well represented in the Glamorgans, for example, although opportunities exist for its rehabilitation on those areas where it remains.

### 3.4.2 *Variation within Welsh heather moorlands*

Two major field surveys have been carried out in Wales since the original work for the *Nature conservation review* (Ratcliffe 1977). They are the Welsh lowland wetland survey (unpublished NCC report) and the upland vegetation mapping programme, both of which are described in internal reports by the NCC. Species records from sample quadrats were collected as part of the wetland survey, so that there is much useful detail on the structure and composition of lowland communities containing heather. The upland mapping scheme is based on unsampled vegetation units, following those of Ratcliffe and Birks (1980). Categories with a significant component of heather include:

dwarf shrub heaths
  sub-montane heather moorlands

blanket bogs
  purple moor-grass/heather mire
  heather/cotton-grass mire

### 3.4.3 *Current threats and status*

The major threats to heather are habitat destruction, largely by major agricultural improvement activities, and habitat deterioration, mainly through attempts at drainage or because of unsympathetic management, usually in the form of severe grazing and burning. Those areas where it remains extensive or well developed are protected by the difficulty of the terrain, eg on the Rhinogs and in parts of Snowdonia, by sympathetic management as a natural resource, eg the grouse moors of Denbigh and Ruabon, or by statute or management as nature reserves, eg some of the coastal and lowland heaths on Anglesey.

Coastal heaths are threatened by a tendency to extend improvement as near as possible to the cliff edge, and many heath remnants are at risk. Examples are evident on Anglesey, the Lleyn peninsula and the Pembrokeshire coast.

Lowland mires, which are often a stronghold of heather in an otherwise agriculturally improved landscape, have long been under threat from unsympathetic use, usually through a combination of burning, trampling and grazing. More recently, the threat has become one of direct habitat destruction by subsidized and efficient drainage operations.

The threats to upland moorland habitats supporting heather come mainly from overgrazing and uncontrolled burning. Grazing and severe burning open up the heather canopy, allowing the invasion of grasses, such as bent-grasses and fescues, or of bracken. In those areas which escape severe burning, but where burning is largely uncontrolled, the heather plants grow straggly and again allow the invasion of grasses, such as purple moor-grass, or the stronger development of bilberry, an associated species in upland heaths.

Many Welsh examples of blanket bog are subject to severe gullying and erosion through the effects of grazing and burning. As a result, the dwarf shrub cover is removed and the mire's surface gradually dries out, so that the cover of bog moss (*Sphagnum* spp.) is also lost. It is rare to find undisturbed heather/cotton-grass blanket bog in which the surface is intact, the bog moss content high, and the bog itself still extending. Drainage of some blanket bogs tends to favour the residual heather at the expense of cotton-grass, but the growth of the planted conifers soon cancels its brief advantage.

Studies of ecological succession in plots from which grazing has been excluded, for example in Cwm Idwal and at Cothi Towy, have demonstrated the great potential for recolonization of acidic grassland by scrub, including heather. A reduction in grazing pressure in the uplands, particularly if coupled with controlled burning, would help to restore heather as a dominant species in suitable habitats, but the process is not rapid, and it demands long-term commitment to a management regime not conducive to agricultural production.

### 3.4.4 *Research needs*

TRIALS ON RECOLONIZATION

i. The history of some recently destroyed lowland heathland habitats is relatively well known. The sites provide useful localities for trials on the recolonization of agriculturally improved land. One such area, near Rhoshirwaun on the Lleyn peninsula, was once an extensive heath, almost all of which has now been 'improved'. However, remnants of the original habitat remain within the area on extensive earth banks and on roadside verges. There is an opportunity to undertake trials

of recolonization by altering the grassland management, including grazing pressure (and also to investigate the practicality and relative performance of planting/reseeding as a means of habitat restoration).

ii. Small-scale exclusion plots have demonstrated the potential for recolonization by heather. Similar, larger-scale trials should be started to define the effects of altered management in areas of different densities or sources of recolonizing heather, allowing for the isolation of effects from any differences in previous grazing pressure or burning pattern. Experiences at Moor House NNR would be of direct relevance (Marrs 1988; Rawes 1975). (Attention is also needed to prevent further erosion on areas of blanket bog.)

DIGEST OF HABITAT SURVEY DATA

The raw material for an inventory of much of the heather habitat in Wales is available, but requires substantial analysis. Example figures from the upland survey include the estimates of upland dry heather moorland given above, and provisional areas for heather-dominated blanket bog in Clwyd, Brecon and Gwent of 7434, 1485 and 234 ha, respectively. Summary data on lowland wetland data are available within the NCC, but preparation of continuous summary figures for upland habitats by region within Wales would be most useful in anticipation of the current survey being completed. Understandably, the NCC priority is to complete the field work and site reports/maps as quickly as possible.

# Discussion

R G H Bunce and D C Howard

*ITE, Merlewood Research Station*

'Gold under bracken, silver under gorse, famine under heather' is a traditional saying of Welsh hill farmers (Condry 1966), and highlights the nutrient-poor soil conditions which heather requires for its growth. In many instances, the initial cause of the soil infertility was bad land management in the past. The distribution of heather and the ericaceous species associated with it, therefore, reflects history as well as ecology.

Heather is capable of growing throughout Great Britain, avoiding rich, fertile soils or those on chalk or limestone. To promote or maintain heather, it is necessary to manage the land so that nutrients are continually being removed and not allowed to accumulate – hence, controlled burning, grazing or turf cutting.

The areas of heather found within National Parks and Environmentally Sensitive Areas show the value placed on heather when determining boundaries. Only the Brecon Beacons has less than 10% of its area under heather, whilst nearly a third of the North York Moors is covered. The ESAs were designated with more specific features in mind, so it is less surprising that many contain no measurable areas of heather. It would be undesirable to concentrate on heather, to the exclusion of other habitats and species associations.

Heather areas are also included within many Areas of Outstanding Natural Beauty, such as Cannock Chase, the Forest of Bowland and the Clwydian Range. The existence of designated areas does not in itself protect features, and may even lead to their destruction, as in the Lüneberg heath. Having created a designation, it is essential to support it by encouraging land owners to follow sympathetic management practices. The resurgence of interest in grouse shooting may offer a financial incentive, but this must still be supported by advice and possibly grant schemes.

To be able to offer accurate and detailed advice, research must be continued into subjects such as the dynamics of heather moorlands and the influences of management practices. Heather and its decline is a subject which has caught the imagination of many people, and there are many hypotheses about the causes of change which must be investigated thoroughly. If policies are phrased to encourage heather, it will be necessary to monitor heather areas. This monitoring can be done using satellite imagery and aerial photography, as demonstrated here and in the MLC project (Hunting Surveys & Consultants Ltd 1986).

However, monitoring should not rely solely on remote sensing, for a measure of the quality of the habitat is essential, especially for some of the rarer flora and fauna. Changes in the status of heather may be identifiable earlier from ground survey, where features such as age, height, and neighbouring invasive species can be readily detected. For example, if fragmentation occurs at a local level, the increased rate of invasion by bracken due to perimeter/area ratio effects could be detected sooner.

Monitoring should also be planned for the longer term, and not rely on *ad hoc* sampling. The comparison between the MLC results and those presented here illustrates the problems of differing approaches. It is generally accepted that heather has declined since 1947: evidence has been reported in Section 3, and the general trend of heath loss can be seen in the MLC data set. However, the estimates of heather cover presented in Tables 6 and 7 show an increase between 1980 and 1984. A number of points must be taken into account. First, the estimates are collected in very different ways: the aerial photography used in the MLC project is based on a sample of points scattered throughout England and Wales, whilst the estimate for 1984 is based on complete coverage by satellite image. Certain counties such as Bedfordshire, Cheshire and Humberside have no heather recorded within them in the MLC because the areas involved are relatively small. Second, the definition of heather used in the studies is different, and, like trying to measure a piece of string, the result depends upon where you start and finish.

The data presented in Table 8 illustrate a number of significant points.

- Contemporary estimates produced by three different techniques (satellite imagery, aerial photography and field survey) are within 15%, despite differences in coverage and definition.
- Major losses in lowland heaths can be seen in areas such as East Anglia, and much of what remains is becoming fragmented.
- Losses of lowland heath are masked if national estimates are presented, because heather moorland covers a much larger area.
- The heather moorland in the north of England shows proportionately less change and the changes may be due to differences in definition.
- Measurements of cover cannot show changes in status of heather.
- Rates of heather loss cannot be used to predict future losses unless and until the relationships between management and land cover are known.

– The long life cycle of heather will act as a buffer to change, but catastrophic losses may occur as a result of changes in management in the past.

Detailed local information for the designation of any new areas would also be invaluable. If Table 3 were used to assess the status of heather, the division between heather moors and lowland heaths would be completely overlooked, and efforts would be concentrated on either preserving those areas which contain the largest proportion of the heather (the northern counties) or those areas with the least (the lowlands).

Finally, there is a wealth of information both in this country and abroad which should be collated and presented in a palatable form for land managers. Good communication of the management prescriptions and advice is essential, if the ideas are to be made to work.

# Bibliography and references


ANDERSON, P. 1986. *Accidental moorland fires in the Peak District: a study of their incidence and ecological implications.* (Peak District Moorland Restoration Project.) Bakewell: Peak Park Joint Planning Board.

ANDERSON, P. 1989. *Moorland recreation and wildlife, a review of the available information.* (Moorland Management Project.) Bakewell: Peak Park Joint Planning Board.

ANDERSON, P. & YALDEN D. W. 1981. Increased sheep numbers and the loss of heather moorland in the Peak District, England. *Biol. Conserv.*, **20,** 195–213.

ARMSTRONG, P. H. 1975. *The changing landscape.* Lavenham: Dalton.

BALL, D. F., DALE, J., SHEAIL, J. & HEAL, O. W. 1982. *Vegetation changes in upland landscapes.* Cambridge: Institute of Terrestrial Ecology.

BAYFIELD, N. G. 1985. Effects of extended use on footpaths in mountain areas of Britain. In: *The ecological impacts of outdoor recreation on mountain areas in Europe and North America,* edited by N.G. Bayfield & G.C. Barrow, 100–111. (RERG report no. 9.) Wye: Recreation Ecology Research Group.

BEIJERINCK, W. 1940. *Calluna:* a monograph on the Scotch heather. *Vehr. Akad. Wet. Amst. (3rd Sect.),* **38,** 1–180.

BERENDSE, F. & AERTS, R. 1984. Competition between *Erica tetralix* L. and *Molinia caerulea* (L.) Moench as affected by the availability of nutrients. *Oecologia,* **5,** 1–13.

BIRKETT, N. L. 1970. Insects. In: *The natural history of the Lake District,* edited by G. A. K. Hervey & J.A.G. Barnes, 117–137. London: Warne.

BRUNSTING, A. M. H. 1982. The influence of the dynamics of a population of herbivorous beetles on the development of vegetations in a heathland system. *Proc. 5th int. Symp. on Insect – Plant Relationships,* 215–223. Wageningen: Pudoc.

BUNCE, R. G. H. 1987. The extent of upland areas in Great Britain. In: *Agriculture and conservation in the hills and uplands,* edited by M. Bell & R. G. H. Bunce, 19–21. (ITE symposium no. 23.) Grange-over-Sands: Institute of Terrestrial Ecology.

CAMERON, A. E., McHARDY, J. W. & BENNETT, T. T. 1944. *The heather beetle* (Lochmaea suturalis): *its biology and control.* Petworth: British Field Sports Society.

CHAPMAN, S. B. & CLARKE, R. T. 1980. Some relationships between soil, climate, standing crop and organic matter accumulation within a range of Calluna heathlands in Britain. *Bull. Ecol.,* **11,** 221–232.

CHAPMAN, S. B., CLARKE, R. & WEBB, N. R. 1989. The survey and assessment of heathland in Dorset for conservation. *Biol. Conserv.,* **4,** 137–152.

CHAPMAN, S. B., ROSE, R. J. & BASANTA, M. 1989. Phosphorus adsorption by soils from heathlands in southern England in relation to successional change. *J. appl. Ecol.* In press.

CHAPMAN, S. B., ROSE, R. J. & CLARKE, R. T. 1989. A model of the phosphorus dynamics of *Calluna* heathland. *J. Ecol.* In press.

CONDRY, W. M. 1966. *The Snowdonia National Park.* London: Collins.

CROMPTON, G. & SHEAIL, J. 1975. The historical ecology of Lakenheath Warren in Suffolk, England: a case study. *Biol. Conserv.,* **8,** 299–313.

DIEMONT, W. H. 1982. Heathland management: accumulation and removal of organic matter. *Annu. Rep. Research Institute for Nature Management,* 24–26.

DIEMONT, W. H. & HEIL, G. W. 1984. Some long-term observations on cyclical and seral processes in Dutch heathlands. *Biol. Conserv.,* **30,** 283–290.

DUFFEY, E. 1976. Breckland. In: *Nature in Norfolk: a heritage in trust,* 62–77. Norwich: Jarrold for Norfolk Naturalists Trust.

ELLIS, R. G. 1983. *Flowering plants of Wales.* Cardiff: National Museum of Wales.

FITZGERALD, C., MARTIN, D. & AULD, M. 1985. *The Sandlings project.* Ipswich: Sandlings Group.

GAILEY, A. & FENTON, A. 1970. *The spade in northern and Atlantic Europe.* Belfast: Queen's University of Belfast, Institute of Irish Studies.

GIMINGHAM, C. H. 1972. *Ecology of heathlands.* London: Chapman & Hall.

GIMINGHAM, C. H. & SMIDT, J. T. de. 1983. Heaths as natural and semi-natural vegetation. In: *Man's impact upon vegetation,* edited by W. Holzner, M. J. A. Werger & I. Ikusima, 185–199. The Hague: Junk.

GIMINGHAM, C. H., CHAPMAN, S. B. & WEBB, N. R. 1979. European heathlands. In: *Heathlands and related shrublands,* edited by R. L. Specht, 365–413. (Ecosystems of the World 9A.) Amsterdam: Elsevier.

GODWIN, H. 1944. Age and origin of the Breckland heaths of East Anglia. *Nature, Lond.,* **154,** 6.

GOLIGHTLY, W.H. 1962. Biological control of *Lochmaea suturalis* (Thompson) (Col: Chrysomelidae). *Entomologist's mon. Mag.,* **98,** 196.

GRAEBNER, P. 1901. *Die Vegetation der Erde. V. Die Heide Norddeutschlands,* edited by A. Engler & O. Drude. 1st ed. Leipzig: Englemann.

GRAEBNER, P. 1925. *Die Vegetation der Erde. V. Die Heide Norddeutschlands,* edited by A. Engler & O. Drude. 2nd ed. Leipzig: Englemann.

GRANT, S. A. & HUNTER, R. F. 1966. The effect of frequency and season of clipping on the morphology, productivity and chemical composition of *Calluna vulgaris* (L.) Hull. *New Phytol.,* **65,** 125–133.

GRANT, S. A., LAMB, W. I. C., KERR, C. D. & BOLTON, G. R. 1976. The utilization of blanket bog vegetation by grazing sheep. *J. appl. Ecol.,* **13,** 857–869.

GRANT, S. A., BARTHRAM, G. T., LAMB, W. I. C. & MILNE, J. A. 1978. Effects of season and level of grazing on the utilization of heather by sheep. 1. Responses of the sward. *J. Br. Grassld Soc.,* **33,** 289–300.

GRANT, S. A., MILNE, J. A., BARTHRAM, G. T. & SOUTER, W. G. 1982. Effects of season and level of grazing on the utilization of heather by sheep. 3. Longer term response and sward recovery. *Grass forage Sci.,* **37,** 11–320.

HEIL, G. W. 1984. *Nutrients and the species composition of heathland.* Ph.D. thesis, University of Utrecht.

HEIL, G. W. & DIEMONT, W. M. 1983. Raised nutrient levels change heathland into grassland. *Vegetatio,* **53,** 113–120.

HOOPER, S. & WHITBY, M. 1988. *Heather moorland management: an economic assessment.* Newcastle-upon-Tyne: University of Newcastle, Dept of Agricultural Economics and Food Marketing.

HUDSON, P. 1983. Red grouse production and management in relation to tourism. In: *Moorlands: wildlife conservation, amenity and recreation,* edited by K. Hearn, 45–54. (RERG report no. 8.) Wye: Recreation Ecology Research Group.

HUDSON, P. 1984. Some effects of sheep management on heather moorlands in northern England. In: *Agriculture and the environment,* edited by D. Jenkins, 143–149. (ITE symposium no. 13.) Cambridge: Institute of Terrestrial Ecology.

HUDSON, P. 1986. *Red grouse, the biology and management of a wild gamebird.* (North of England Grouse Research Project.) Fordingbridge: Game Conservancy Trust.

HUDSON, P. & RENTON, J. 1988. What influences changes in grouse numbers. *Annu. Rev. Game Conserv. 1987,* 41–49.

HUNTER, R. F. 1962. Hill sheep and their pasture: a study of sheep grazing in south-east Scotland. *J. Ecol.,* **50,** 651–680.

HUNTING SURVEYS AND CONSULTANTS LTD. 1986. *Monitoring landscape change.* Borehamwood: Hunting.

INSTITUTE OF TERRESTRIAL ECOLOGY. 1978. *Upland land use in England and Wales.* Cheltenham: Countryside Commission.

KRANSE, E. H. L. 1892. Die Heide. *Bot. Jahrb.,* **14.**

LANCE, A. N. 1987. Estimating acceptable stocking levels for heather moorland. In: *Agriculture and conservation in the hills and uplands,* edited by M. Bell & R.G.H. Bunce, 109–115. (ITE symposium no. 23.) Grange-over-Sands: Institute of Terrestrial Ecology.

LOFTHOUSE, R. G. A. 1980. *The Berwyn Mountains area of Wales: an appraisal.* Cardiff: HMSO.

MacEWEN, M. & SINCLAIR, G. 1983. *New life for the hills: policies for farming and conservation in the uplands.* London: Council for National Parks.

MALTBY, E. 1980. The impact of severe fire on *Calluna* moorland in the North York Moors. *Bull. Ecol.,* **11,** 638–708.

MARRS, R. H. 1986. The role of catastrophic death of *Calluna* in heathland dynamics. *Vegetatio,* **66,** 109–115.

MARRS, R. H. 1987. Studies on the conservation of lowland *Calluna*. *J. appl. Ecol.,* **24,** 163–175.

MARRS, R. H. 1988. Vegetation change on lowland heaths and its relevance for conservation management. *J. environ. Manage.,* **26,** 127–149.

MARRS, R. H. & LOWDAY, J. E. 1989. *Management of lowland heaths.* Peterborough: Nature Conservancy Council. In press.

MARRS, R. H., HICKS, M. J. & FULLER, R. M. 1986. Losses of lowland heath through succession at four sites in Breckland, East Anglia, England. *Biol. Conserv.,* **36,** 19–38.

MILLER, G. R. & BAYFIELD, N. G. 1988. *Seed banks of organic soils.* (Three Peaks Project, report no. 5.) (NERC contract report to Yorkshire Dales National Park Committee.) Banchory: Institute of Terrestrial Ecology.

MILLER, G. R. & CUMMINS, R. P. 1987. Role of buried viable seeds in the recolonization of disturbed ground by heather *(Calluna vulgaris* (L.) Hull) in the Cairngorm mountains, Scotland, UK. *Arct. alp. Res.,* **19,** 396–401.

MILLER, G. R., MILES, J. & HEAL, O. W. 1984. *Moorland management: a study of Exmoor.* Cambridge: Institute of Terrestrial Ecology.

MILNE, J. A., BAGLEY, L. & GRANT, S. A. 1979. Effects of season and level of grazing on the utilization of heather by sheep. 2. Diet selection and intake. *Grass forage Sci.,* **34,** 45–53.

MOORE, N. W. 1962. The heaths of Dorset and their conservation. *J. Ecol.,* **50,** 109–129.

MORE, D. 1976. *The bee book.* New York: Universe Books.

MORISON, G. 1963. *The heather beetle* (Lochmaea suturalis *Thompson*). Aberdeen: North of Scotland College of Agriculture.

MUIRBURN WORKING PARTY. 1977. *A guide to good muirburn practice.* Edinburgh: HMSO.

MYRBERGET, S. 1983. Desertion of nests by willow grouse. *Fauna norv. Ser. C. Cinclus,* **6,** 109–113.

NATURE CONSERVANCY COUNCIL. 1987. *Changes in the Cumbrian countryside.* Peterborough: NCC.

NATURE CONSERVANCY COUNCIL. 1988. *Changes in the Grampian countryside.* Peterborough: NCC.

NIELSEN, B. O. 1986. Outbreaks of the heather beetle *(Lochmaea suturalis* Thoms.) in Danish heathland 1900–1984 (Coleoptera: Chrysomelidae). *Ent. Medd.,* **53,** 99–109.

NOIRFALISE, A. & VANESSE, R. 1976. *Heathlands of western Europe.* Strasbourg: Council of Europe.

NORTH YORK MOORS NATIONAL PARK COMMITTEE. 1982. *The future of the moorland.* Helmsley: Committee.

PARRY, M. L. 1977. *Mapping moorland change: a framework for land-use decisions in the Peak District.* Bakewell: Peak Park Joint Planning Board.

PEARSALL, W. H. 1968. *Mountains and moorlands.* (New Naturalist.) London: Fontana.

PEARSALL, W. H. & PENNINGTON, W. 1973. *The Lake District.* (New Naturalist.) London: Collins.

PERRING, F. H. & WALTERS, S. M., eds. 1962. *Atlas of the British Flora.* London: Nelson for BSBI.

PHILLIPS, J., YALDEN, D. W. & TALLIS, J. 1981. *Peak District moorland erosion study. Phase 1.* Bakewell: Peak Park Joint Planning Board.

PICOZZI, N. 1971. Breeding performance and shooting bags of red grouse in relation to public access in the Peak District National Park England. *Biol. Conserv.,* **3,** 2311–215.

PORCHESTER, LORD. 1977. *A study of Exmoor.* London: HMSO.

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

RATCLIFFE, D. A. & BIRKS, H. J. B. 1980. *Classification of upland vegetation types in Britain.* Peterborough: NCC. (Unpublished.)

RAWES, M. 1975. *The botany of Moor House.* (Aspects of the ecology of the northern Pennines no. 8.) Garrigill: Nature Conservancy Council, Moor House Field Station.

ROELOFS, J. G. M. 1986. The effect of air-borne sulphur and nitrogen deposition on aquatic and terrestrial heathland vegetation. *Experientia,* **42,** 372–377.

ROYAL SOCIETY FOR THE PROTECTION OF BIRDS. 1984. *Hill farming and birds. A survival plan.* Sandy: RSPB.

RÜBEL, E. A. 1914. Heath and steppe, machia and garigue. *J. Ecol.,* **2,** 232–237.

SCHEIKH, K. H. 1969. The effects of competition and nutrition on the inter-relations of some wet-heath plants. *J. Ecol.,* **57,** 87–99.

SCOTTISH AGRICULTURAL COLLEGES. 1988. *Heather moorland – a guide to grazing management.* (Technical note.) Aberdeen: Macaulay Land Use Research Institute.

SHEAIL, J. 1979. Documentary evidence of the changes in use, management and appreciation of the grass-heaths in Breckland. *J. Biogeogr.,* **6,** 277–292.

SPECHT, R. L., ed. 1979. *Heathlands and related shrublands.* (Ecosystems of the world 9A & 9B.) Amsterdam: Elsevier.

STEWART, A. J. A. & LANCE, A. N. 1983. Moor drainage: a review of impacts of land use. *J. environ. Manage.*, **17,** 81–99.

TUBBS, C. R. 1986. *The New Forest.* London: Collins.

VAN DER ZANDE, 1984. *Outdoor recreation and birds: conflict or symbiosis?* Thesis, University of Leiden.

WATSON, A. 1982. Effects of human impact on ptarmigan and red grouse near ski lifts in Scotland. *Annu. Rep. Inst. terr. Ecol. 1981,* **51.**

WATSON, A. & MILLER, G. R. 1976. *Grouse management.* 2nd ed. Fordingbridge: Game Conservancy.

WATSON, A., MILLER, G. R. & GREEN, F. H. W. 1966. Winter browning in heather (*Calluna vulgaris*) and other moorland plants. *Trans. bot. Soc. Edinb.*, **40,** 195–203.

WATT, A. S. 1947. Pattern and process in the plant community. *J. Ecol.*, **35,** 1–22.

WEBB, N. R. 1985. Habitat islands or habitat mosaic? A case study of heathlands in southern England. In: *Inselokologie – Andwendung in der Planung des landlichen Raums,* edited by W. Zielonkowski & H.-J. Mader, 62–69. Laufen-Salzach: Akademie für Naturschutz und Landschaftspflege.

WEBB, N. R. 1986. *Heathlands.* (New Naturalist.) London: Collins.

WEBB, N. R. 1989. Studies on the invertebrate fauna of fragmented heathland in Dorset and the implications for conservation. *Biol. Conserv.* In press.

WEBB, N. R. & HASKINS, L. E. 1980. An ecological survey of heathlands in the Poole basin, Dorset, England, in 1978. *Biol. Conserv.*, **17,** 281-296.

WELCH, D. 1984. Studies in the grazing of heather moorland in northeast Scotland, UK. 2. Response of heather. *J. appl. Ecol.*, **21,** 197–207.

WILLIAMS, J. C. 1974. *Mathematical analysis of red grouse populations.* BSc thesis, University of York.

WOODIN, S. J., PRESS, M. C. & LEE, J. A. 1985. Nitrate reductase activity in *Sphagnum fuscum* in relation to atmospheric nitrate deposition. *New Phytol.*, **99,** 381–388.

YALDEN, D. W. 1986. The status of golden plovers in the Peak Park, England, in relation to access and recreational disturbance. *Wader Study Grp Bull.*, **46,** 34–35.

YALDEN, P. E. & YALDEN, D. W. 1988. The level of recreational pressure on blanket bog in the Peak District National Park, England. *Biol. Conserv.*, **44,** 213–227.

# Glossary to abbreviations used in text

| | |
|---|---|
| ADAS | Agricultural Development Advisory Service |
| *c* | *circa* |
| DOE | Department of the Environment |
| ECOLUC | Ecological consequences of land use change |
| EEC | European Economic Community |
| ESA | Environmentally Sensitive Area |
| FC | Forestry Commission |
| GB | Great Britain |
| ha | hectare |
| HLCA | Hill livestock compensatory allowances |
| HFRO | Hill Farming Research Organisation |
| HTS | Hunting Technical Services Ltd |
| ITE | Institute of Terrestrial Ecology |
| kg | kilogram |
| km | kilometre |
| m | metre |
| mm | millimetre |
| MAFF | Ministry of Agriculture, Fisheries and Food |
| MLC | Monitoring landscape change |
| MLURI | Macaulay Land Use Research Institute |
| MOD | Ministry of Defence |
| NCC | Nature Conservancy Council |
| N | nitrogen |
| NERC | Natural Environment Research Council |
| NRR | National Nature Reserve |
| NRSC | National Remote Sensing Centre |
| OD | Ordnance Datum |
| OS | Ordnance Survey |
| P | phosphorus |
| ppbv | parts per million by volume |
| PTA | Practical Training Area |
| RSPB | Royal Society for the Protection of Birds |
| s | second |
| SSSI | Site of Special Scientific Interest |
| TM | Landsat thematic mapper |
| yr | year |
| UK | United Kingdom |
| < > | less than and greater than |

Printed in the United Kingdom for Her Majesty's Stationery Office Dd 291050 5/89 C10 12521

HMSO publications are available from:

**HMSO Publications Centre**
(Mail and telephone orders only)
PO Box 276, London, SW8 5DT
Telephone orders 01-873 9090
General enquiries 01-873 0011
(queuing system in operation for both numbers)

**HMSO Bookshops**
49 High Holborn, London, WC1V 6HB 01-873 0011 (Counter service only)
258 Broad Street, Birmingham, B1 2HE 021-643 3740
Southey House, 33 Wine Street, Bristol, BS1 2BQ (0272) 264306
9-21 Princess Street, Manchester, M60 8AS 061-834 7201
80 Chichester Street, Belfast, BT1 4JY (0232) 238451
71 Lothian Road, Edinburgh, EH3 9AZ 031-228 4181

**HMSO's Accredited Agents**
(see Yellow Pages)

*and through good booksellers*

## Heather in England and Wales

In response to widespread concern over heather decline, this project aimed to give a rapid assessment of the distribution and status of heather, the historical changes that had occurred and the potential for its restoration. The study was carried out over a six-week period in summer 1988, using satellite imagery. The main agents of change in both upland and lowland areas are identified and it is noted that lowland heaths (such as those in East Anglia) have suffered a proportionally greater loss of heather. The study concludes with a call for more research and long-term monitoring into the dynamics of heather moorland.

ISBN 0-11-701422-2

9 780117 014220

£5.90 net