Natural
Environment
Research
Council

The Distribution and Status of Heather in England and Wales

A Report to the Department of the Environment

Project Leader : Dr R G H Bunce

1st September 1988

The Institute of Terrestrial Ecology
Merlewood Research Station
Winderemere Road
Grange-over-Sands
Cumbria

THE DISTRIBUTION AND STATUS OF HEATHER IN ENGLAND AND WALES

CONTENTS

SUMMARY

The area of heather in England and Wales depends upon the definition chosen. For this project 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) and divided into three categories. The heather categories were :-

i. Dominant - where the heather community covers more than 50% of the land.
ii. Sub-dominant - where groups of species not associated with heather dominate, but heather is still identifiable by satellite.
iii. Managed - where land is managed for heather (usually for grouse) by burning, producing a habitat may be totally dominated by *Calluna*.The managed area occurs predominantly in the north of England.

The total area of heather in the three categories in England is 460,418 ha while Wales has 124,733 ha. These figures are of the same order of magnitude as other published estimates of heather area such as the Monitoring Landscape Change and ITE land use statistics. Estimates were further divided by county and for areas such as National Parks and Environmentally Sensitive Areas.

The accuracy of the identification was tested by a small scale field survey and by comparison with the ITE land use dataset. In general the identification was accurate and no areas were identified where heather had been omitted. However it cannot be stated that heather is absent from areas where it was not detected by satellite, it may be present but at a low level.

The status of heather is described for major regions in England and Wales, the initial division is between heather moorland, which is found in the north of England and Wales, and heaths, which have a more southerly distribution and occur at a lower altitude. 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 and beetles), decline in grouse shooting, erosion by trampling, accumulation of plant nutrients, unsympathetic management practises (including inappropriate burning) and to a lesser extent afforestation. The lowland heaths have declined due to changes in management, loss to agriculture and eutrophication due to an accumulation of chemicals from both agricultural runoff and possibly atmospheric pollution.

The main interests and value of heather as a cover type are highlighted for different regions of England andWales. These include; agriculture, conservation, tourism and sport. The report identifies areas where current knowledge and information is lacking and suggests potential research projects. The major topics are :-

i) better definition of heather areas and coordinated monitoring,
ii) studies into the dynamics of heather moors and heaths, and
iii) the consequences of different management practises.

ABBREVIATIONS

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
GB	Great Britain
ha	hectare
HCLA	Hill Livestock Compensatory Allowances
HFRO	Hill Farming Research Organization
HTS	Hunting Technical Services Ltd.
ITE	Institute of Terrestrial Ecology
K	kilo
Kg	kilogram
Km	kilometre
LFA	Least Favoured Areas
m	metre
M	million
MAFF	Ministry of Agriculture, Fisheries and Food
MLC	Monitoring Landscape Change
MLURI	Macaulay Land Use Research Institute
MOD	Ministry of Defense
NCC	Nature Conservancy Council
N	nitrogen
NH_3	amonia
NH_4^+	amonium ions
NO_3^-	nitrate ions
NRSC	National Remote Sensing Centre
P	phosphorus
ppmv	parts per million by volume
RSPB	Royal Society for the Protection of Birds
SSSI	Site of Special Scientific Interest
TM	Landsat Thematic Mapper
µg	microgram
y	year
UK	United Kingdom
WOAD	Welsh Office Agricultural Department
< >	less than and greater than

Abbreviations used in journal titles are World Title standard.

1. INTRODUCTION

1.1 OBJECTIVES

This report provides details of a study carried out by the Institute of Terrestrial Ecology in conjunction with Hunting Technical Services, Limited for the Department of the Environment in August 1988.

The principal objectives of the study were:

i) the production of maps showing the distibution of the principal areas of heather in England and Wales

ii) an assessment of the current status and historical changes in areas of heather, giving an indication of the potential for restoration of heather cover.

1.2 OUTLINE OF STUDY

Heather is an environmentally important cover type for two main reasons.

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 in flower. The scenic value of heather has led to large areas being protected through designation in National Parks, Environmentally Sensitive Areas and Areas of Outstanding Natural Beauty. Although not for the sole purpose of nature conservation, such protection status constitutes an important conservation measure.

ii) Ecological

Heather is not only ecologically interesting as a species, but also has a wide range of associated habitat species. This poses a major problem in defining "heather", in the strictest sense it is *Calluna vulgaris* but for the purposes of this study the definition includes *Ericaceous* dwarf shrub species but not *Vaccinium* species. 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 and not the latter. An important point to stress is that depending upon the strictness of definition, one can produce a variety of estimates for heather cover in Great Britain. Taking a conservative figure, there were approximately 1.9 million hectares in 1978, of which 1.5 million hectares is in Scotland, emphasing the importance of the Scottish moorlands in a Great Britain context. Figures from the current project are of the same relative order of magnitude.

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

i) The Nature Conservancy Council has expressed concern about the loss of heather and the associated loss of habitat for wildlife. Species such as the merlin are particularly at risk since their prey, including moths, butterflies and other insects are dependant upon heather as a source of food.

ii) The general concern over the loss of heather in a wider context is that it indicates an increase in agriculture and forestry in the uplands, resulting in a loss of habitats. Heather acts as an indicator of change from semi-natural vegetation to more highly managed systems.

iii) There is a link between the decline in heather moorland and the decline in grouse. This has important economic consequences in the north of England in particular.

1.3 THE APPROACH

Maps, showing the distribution of heather in England and Wales, were produced at 1:250,000 scale using Landsat Thematic Mapper (TM) satellite imagery in conjunction with available ground data. The satellite imagery was digitally processed by HTS to produce enhanced and geometrically corrected false colour composite images in photographic format. Using these images it was possible to carry out a visual interpretation in order to identify the principal areas of heather in England and Wales.

A visual interpretation approach was chosen for this study in preference to a digital classification. This was because the basic requirement was for a distribution map of vegetation containing *Ericaceous* species and this map had to be produced in a relatively short time. The use of proven techniques of visual interpretation was therefore considered essential in order to meet the required schedule.
The alternative to visual interpretation is the use of computer-aided classification of the digital data. Whilst such techniques do have merit, it was decided that they could not be

digital data. Whilst such techniques do have merit, it was decided that they could not be used in this case 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 make judgements on the extent of heather by refering to topography, geographical context and available map data;

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

Details of the methods used are included in Section 2.1

Maps showing three categories of heather were reproduced at 1:250,000 and 1:750,000 scale 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.

Accuracy assessment involved comparison of the maps with ground data for a sample of 1 km grid squares throughout the country. The ITE Ecological Consequences of Land Use Change (ECOLUC) database was used to provide ground data, however additional field survey was necessary to gather sufficient data for assessment of areas of heather cover.

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

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

1.4 AUTHORS AND ACKNOWLEDGEMENTS

Project Leader : Dr Bob Bunce

The satelite imagery was processed and heather maps produced by the following people at HTS

i) Peter Bradbury
ii) Graham Deane
iii) Anne Hawkins
iv) Alison Thwaite

Maps were digitized and estimates of areas by county produced at ITE Merlewood by:

i) Kathy Troll
ii) David Howard

Peter Bradbury and Kathy Troll carried out the field survey needed for accuracy assessment. The following individuals provided regional assessments of heather status as a part of this study:

i) Penny Anderson, Consultant Ecologist based in Chinley, Derbyshire.
ii) Steven Chapman, ITE Furzebrook, Wareham, Dorset.
iii) Rob Marrs, ITE Monkswood, Huntingdonshire.
iv) Geof Radford, ITE Bangor, Wales
v) David Fowler, ITE Bush, Penicuick, Scotland
vi) Gordon Miller, ITE Brathens, Banchory, Scotland

In addition to these individuals 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:

i) ITE Bangor Research Station, Gwynedd
ii) Resource Planning Group, ADAS, Aberystwyth
iii) Soil Survey of England and Wales, Aberystwyth
iv) Nigel Webb, ITE Furzebrook, Wareham, Dorset
v) Lake District National Park Special Planning Board
vi) Yorkshire Dales National Park Authority
vii) North Yorkshire Moors National Park Authority
viii) National Remote Sensing Centre, Farnborough

2. PRODUCTION OF MAPS AND ESTIMATES OF AREA

2.1 METHODOLOGY

2.1.1 Production of hard-copy satellite imagery

In order to undertake a visual interpretation of Landsat TM imagery precision photographic hard-copy was produced in the Consultants' own laboratories using a computer-based image processing system linked to a precision film writing instrument.

Prior to filmwriting contrast enhancement of Landsat TM Bands 3 (red), 4 (near-infrared) and 5 (mid-infrared) was undertaken in order to highlight areas of heather cover. The imagery was also geometrically rectified to fit the Ordnance Survey 1:250,000 scale base maps and the 10km grid was overlaid onto the imagery.

Colour prints were subsequently produced from the enhanced and rectified imagery with Band 4 displayed in red, Band 5 in green and Band 3 in blue. Figures 2.1.1 and 2.1.2 are colour photocopies of 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 2.1.3 shows the Landsat scenes which cover England and Wales whilst Table 2.1.1 lists the dates of imagery used for this study. In the case of some of the scenes partial cloud cover necessitated the use of two dates of imagery to acquire all four quadrants of the scenes.

Hard-copy imagery was produced of all the scenes listed in Table 2.1.1 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 35mm slides produced at the National Remote Sensing Centre at Farnborough during the latter stages of the study.

Figure 2.1.1 Landsat TM image of the Berwyn mountains in North East Wales.

A Heather dominant vegetation with little managed burning

B Heather sub-dominant vegetation

C Coniferous woodland

D Agricultural grassland

E Lake Bala

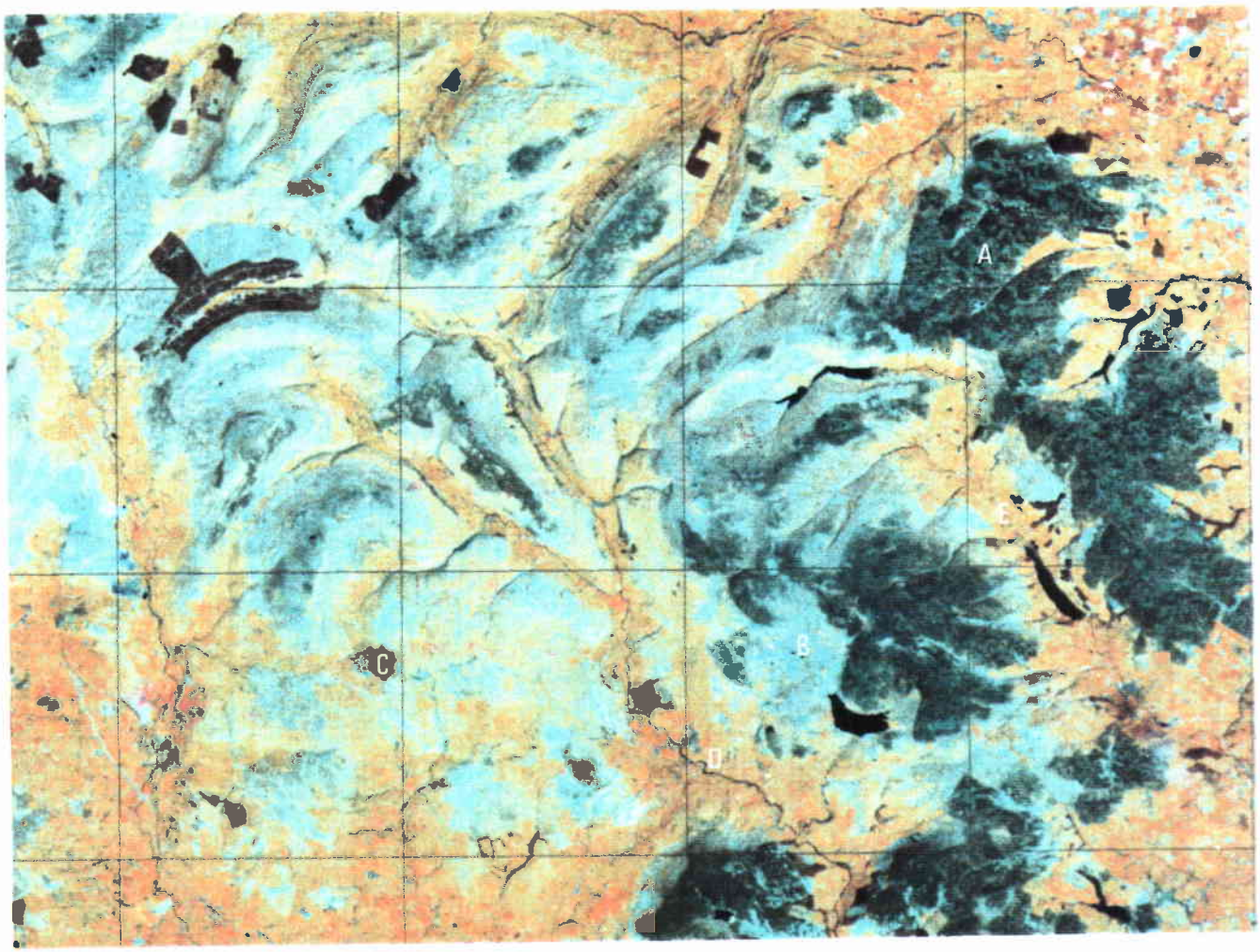

Figure 2.1.2 Landsat TM image of Wharfedale and Nidderdale in the Yorkshire Dales

A Heather dominant vegetation with significant managed burning

B Upland grassland

C Malham Tarn

D Wharfedale

E Nidderdale

Figure 2.1.3 The approximate location of Landsat TM images and county boundaries

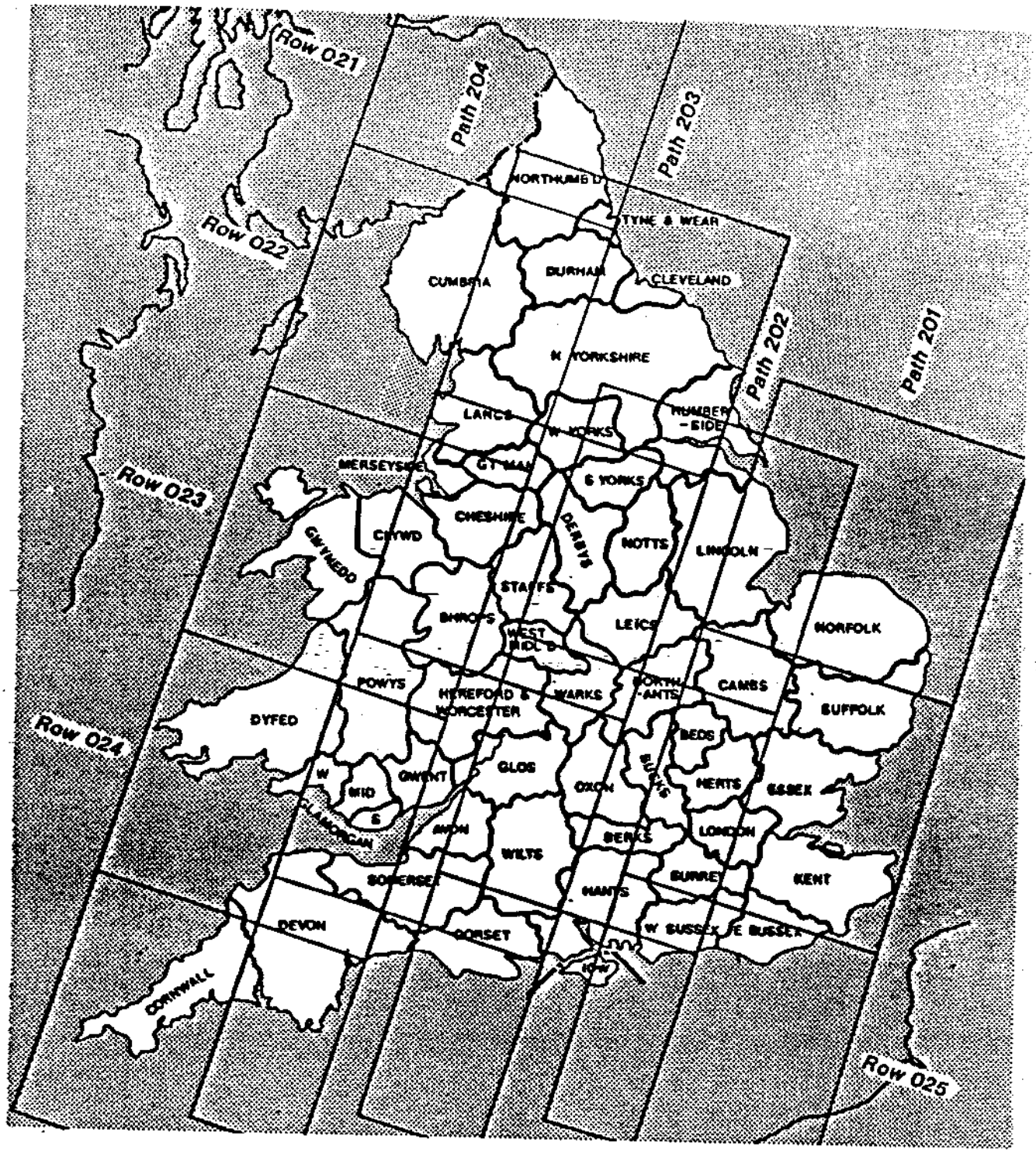

Table 2.1.1: Landsat TM scenes used for this study

Path	Row	Quad	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

2.1.2 Heather categorization

Heather occurs throughout England and Wales over a variety of soil and climatic conditions and is found both on lowland heathland and upland moorland in association with a variety of vegetation species and under differing management conditions. Furthermore, although *Calluna vulgaris* is the main species of heather, there are several *Erica* species which 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 the species of other vegetation which occur mixed with heather. The following heather categories have been used for this study based upon an an initial analysis of the imagery and discussions with ITE ecologists and NRSC experts:

Figure 2.1.4 Heather dominant vegetation with little managed burning, on Raubon Mountain, Clwyd, Wales.
Note bracken encroachment in valley areas

Figure 2.1.5 Heather dominant vegetation with significant managed burning, in Nidderdale, Yorkshire Dales (point A on figure 2.1.2)

Figure 2.1.6 Heather sub-dominant vegetation. Nardus moorland with heather as a sub-dominant species. Forest of Bowland, Lancashire

i) Dominant - where *Calluna vulgaris* and other *Ericaceous* dwarf shrubs represent more than 50 % of the vegetation cover. The category is further divided into :-

   a) unmanaged where there is little burning (called Dominant)
   b) managed with significant managed burning(called Managed). In the recently burned patches bare soil and *Vaccinium myrtillus* are commonly found.

ii) Sub-dominant vegetation where *Ericaceous* dwarf shrubs represent less than 50 % of vegetation cover (called Sub-dominant). In some areas other species dominate whilst, occasionally, it 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 the confusion between heather cover and coniferous woodland, deciduous woodland in winter, certain types of urban land use, shaded north-facing moorland slopes and certain moorland vegetation types. However, by the use of available map data and by the analysis of image context most of such identification errors may be avoided.

The distinction has been made between heather dominant cover with little managed burning and with significant managed burning based upon the appearance on the imagery of a distinctive pattern of strips or blocks caused by burning in the managed areas. Such patterns normally indicate moorland which is managed for grouse shooting. Figures 2.1.1 and 2.1.2 show satellite images of the two classes of heather dominant vegetation whilst figures 2.1.4 and 2.1.5 show ground photographs of these localities.

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, proximity to heather dominant vegetation and available ground data. Areas of heather sub-dominant vegetation have been identified on both Figures 2.1.1 and 2.1.2 of the satellite imagery. Figure 2.1.4 shows an area of heather moorland which has been invaded by bracken.

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 (*Vaccinium myrtillus*) or bracken (*Pteridium aquilinum*) often represent the dominant vegetation and have sub-

dominant heather. Matt grass (*Nardus stricta*) is also commonly found in association with heather in upland areas. In lowland heaths heather may occur as a sub-dominant vegetation where gorse (*Ulex* species), bracken or grass species represent the dominant vegetation type.

Given appropriate management techniques it may be possible to encourage the growth of heather within some of the areas where heather is sub-dominant. In areas 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 the analysis of available ground data and limited field work. The acquisition of ground information on vegetation cover was necessary in order to establish the appearance of the three heather categories on each date of imagery. Ground information also enabled distinctions to be made between heather and vegetation types which gave a similar appearance on the imagery, such as is the case with Cotton Grass and Bilberry at certain times of the year.

Image interpretation first involved the analysis of the major features in the imagery in order to recognize 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 little 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 systematically mapped. In many areas, particularly in lowland England, heather occurred in proximity to woodland and there was the possibility of misclassifying woodland as heather. In such situations the woodland shown on the 1:250,000 scale Ordnance Survey basemaps was used as the basis for the distinction of these two often spectrally similar categories. The assumption was therefore made that the woodland areas mapped by Ordnance Survey are accurate. This assumption was shown to be broadly correct when tested by the Forestry Commission in their 1982 census. However it is recognized that within some woodlands small areas of heather do occur, which cannot

easily be recognized on satellite images.

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

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

ii) The ITE ECOLUC database which provided very detailed information on vegetation species for a sample of 1km grid squares throughout the country.

iii) National Park maps of moorlands and heathlands produced in the early 1980's as required by Section 43 of the Countryside Act 1980. These maps were obtained or 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 based upon surveys carried out by Geoffrey Sinclair in the late 1960's and early 1970's. 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 nature reserves published by Ratcliffe (1977).

viii) Monitoring Landscape Change project information (HTS 1986)

In order to relate the heather categories to specific colours and textures on the imagery field visits were undertaken in the Lake District, north west Lancashire, north and mid-Wales and the Yorkshire Dales. This involved approximately five days field work undertaken by the HTS image interpreter. In addition to this field work the mapping of randomly selected 1km grid squares was carried out by ITE as an assessment of 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 35mm slides of the imagery. In this instance the interpretation was carried out by projecting the image onto 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 5 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 production of the 1:250,000 scale maps was by traditional cartographic techniques and resulted in the production of black and white Dyeline maps. Heather categories were represented by shading on these maps together with the coastline, 800 foot contour and County boundaries.

The production of the 1:750,000 scale map was achieved using a Versatec plotter from digitized map data and resulted in the production of a colour digital map showing the distribution of the three heather categories over England and Wales.

2.1.5 Accuracy assessment

In the time available for the project it was not possible to perform detailed and rigorous accuracy tests. It was considered important that some measure of the correlation between satellite images and cover types identifiable in the field was made. So in order to assess the accuracy of identification of heather moor and the classification into dominant, sub-dominant or managed a rapid field survey was mounted. A total of 34 1km^2 were visited (Table 2.1.5) and the areas of heather assessed by eye. Since travel time is a major component in ground truth survey the 1km^2 were selected in pairs, by drawing random coordinates from areas of known heather.The randomly selected 1km^2 was visitedalong with a neighbouring 1km^2 offset 2km to the east. As a seperate test that areas of heather had not been overlooked on the satellite image a sample of the ITE land use survey data collected in 1984 was compared with the final maps.

The map accuracy was checked by comparing the areas assessed by ground survey with those produced by digitizing the heather maps.

Table 2.1.5 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. Yorks Moors
283291	Wales	478501	N. Yorks Moors
281341	Wales	464508	N. Yorks Moors
264332	Wales	466508	N. Yorks Moors
266332	Wales	330490	Cumbria
292358	Wales	332490	Cumbria
294358	Wales	312487	Cumbria
323348	Wales	314487	Cumbria
325348	Wales		
301329	Wales		

2.1.6 Area measurement

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 coordinates. These were then converted into raster format to enable rapid estimation of areas. The results were presented by 1km^2 giving the proportion of heather of the 3 categories in each. The information was amalgamated to produce totals by county by incorporating the county information held on the ITE land use database.

2.1.7 Heather status assessment

The present project arose from the requirement of the rural directorate of the Department of the Environment to produce a map of heather of England and Wales. This, however, would have presented a purely static image of the current situation. The great variability of the

status of the heather in upland and lowland situations and with also regional variations meant that in the view of ITE it was necessary to specify the state of the heather in the various regions. This report is largely concerned with the statement of the dynamic information that is currently available and an ecological statement of what the dynamics are in particular areas and particularly what measures can be taken to encourage heather regeneration.

2.2 RESULTS

2.2.1 Heather distribution maps.

The 6 maps produced by HTS are supplied under a seperate cover.

2.2.2 Accuracy Assessment

The short period available for the study prevented a detailed analysis of accuracy being made. However a number of checks were carried out, namely :-

i a comparison of parcels identified from the satellite with those on the ground the results (table 2.2.7) show that the presence of heather in either of its dominant forms was always detected, but the field surveyors recorded more sub-dominant heather than was identified on the maps. The field survey was performed by recording heather within a $1km^2$, at the scale of the heather maps the area is represented by $4mm^2$ so comparison of areas is not meaningful. However the parcel boundaries on the satellite produced maps will be more accurate than those produced by a field surveyor on the ground.

ii Using squares drawn at random from the ITE land use database it was possible to compare the distribution of heather over a larger sample area. Unfortunately it was not possible to divide the field data in the database into the three categories within the time available. Of the squares inspected all those containing heather were identified from the satellite.

Table 2.2.7 The occurence of heather categories on maps derived from satellite images.

		Field Survey Categories	
		Recorded	Absent
Satellite based maps	Recorded	50	8
	Absent	11	-

2.2.3 Area Measurement by County

The estimates of area by county, National Park and ESA are presented in Tables 2.2.1 to 2.2.3; all areas are measured in hectares. Table 2.2.4 presents a comparison with data for 1947, 1969 and 1980 from the MLC project and the ITE 1984 land use survey. The MLC data were estimates of areas from the interpretation of aerial photographs and presented by standard DoE regions. Several categories may include heather either as a dominant or sub-dominant cover, the major categories are :-

Upland heath	D1	heather, ling and bilberry
Upland grass moor	D2	including blanket bog
Bracken	D3	bracken
Lowland heath	D4	heather and grass
Gorse	D5	

The ITE field survey data refers to areas with more than 25% cover of *Calluna*. The information was collected during a field survey of a random sample of 1km^2.The sample was stratified into 32 land classes. Regional estimates were produced by calculating the product of the mean coverage per 1km^{2}for each land class and the area of that land class within the region, then summing the land class estimates. Table 2.2.6 presents a comparison of the MLC data for 1980 and the new areal estimates by county.

2.2.4 Area Measured by 1km2

Whereas the total area covered (as presented in tables 2.2.1 to 2.1.4) gives a measure of quantity, by counting the number of 1km2 which contain heather and comparing this with the true area, a measure of the extent and geometry of the heather is gained, which has very important ecological implications. The results are provided in table 2.2.5

Table 2.2.4 Comparison of Heather areas (in hectares) with MLC estimates for 1947, 1969 and 1980. MLC estimates are from aerial photography interpretation.

DOE Region	Total area	MLC 1947	MLC 1969	MLC 1980	TM 1984	ITE 1984 survey
North	1541500	167300	162100	155500	170780	208989
North West	735400	19600	18800	18000	20250	31082
Yorkshire & Humberside	1542500	218500	136300	151200	128974	137810
West Midlands	1299800	3000	1300	1300	11801	16049
East Midlands	1563900	21600	21200	21100	28686	19310
East Anglia	1262200	3000	0	0	10892	5913
South West	2389300	45400	35200	32400	50870	41153
South East	2730500	2300	12800	13700	38165	39864
England	13065100	480700	387700	393200	460418	500170
Wales	2082300	130000	124500	116600	124466	104253
Total	15147400	610700	512200	509800	584884	604423

Table 2.2.2 The area (in hectares) of heather in National Parks in England and Wales

National Park	Area (ha)	Sub-dominant	Dominant	Managed	Total area	%NP
Dartmoor	94535	12312	2066		14398	15.23
Exmoor	68635	10189	2525		12714	18.52
Brecon Beacons	134679	951	3958		4909	3.64
Pembrokeshire Coast	58275	444	9958		10402	17.85
Snowdonia	216782	18065	20007		38072	17.56
Peak District	140377	12525	18409	4268	35202	25.08
Yorkshire Dales	176119	13619	10932	15458	40009	22.72
North Yorks Moors	143226	6574		32696	39270	27.42
Lake District	224293	15822	9494		25316	11.29
Northumberland	103082	12521	8286	6701	27508	26.69
Total	1360004	103022	85655	59123	247800	18.22

Table 2.2.3 The area of heather (in hectares) in Environmentally Sensative Areas in England and Wales

Location	Area of heather			Total
	Sub-dominant	Dominant	Managed	
Cambrian Mountains	6962	7170		14132
Penrhyn Llyn	27	113		140
Breckland	4136	926		5062
South Downs				0
The Broads				0
Suffolk River Valleys	2097	236		2333
West Penwith	1138	2424		3562
North Peak	9835	5618	4098	19551
Somerset Levels				0
Pennine Dales				0
Shropshire Borders				0
Test Valley				0
Total	24195	16487	4098	44780

Table 2.2.5 The number of 1km squares containing heather in England and Wales by county

County	Area	Sub-Dominant	Dominant	Managed	Total	% Total heather
Bedfordshire	123460		5		5	0.06
Cheshire	232846		13		13	0.16
Cornwall	354792	104	58		162	2.04
Cumbria	681012	376	292	126	794	10.02
Derbyshire	263094	140	211	24	375	4.73
Devon	671088	172	80		252	3.18
Dorset	265375	19	15		34	0.43
Durham	243592	152	255	235	642	8.10
East Sussex	179512	27	6		33	0.42
Greater Manchester	128674	11	11		22	0.28
Hampshire	377698	92	273		365	4.60
Humberside	351212	6			6	0.08
Lancashire	306346	63	157	17	237	2.99
Norfolk	536776	70	6		76	0.96
North Yorkshire	830865	332	228	890	1450	18.29
Northumberland	503165	268	249	271	788	9.94
Shropshire	349014	51	71		122	1.54
Somerset	345094	149	66		215	2.71
South Yorkshire	156049	30	22	30	82	1.03
Staffordshire	271615	42	34		76	0.96
Suffolk	379663	60	14		74	0.93
Surrey	167924	66	31		97	1.22
West Sussex	198935	5			5	0.06
West Yorkshire	203912	140	74	24	238	3.00
ENGLAND	8121713	2375	2171	1617	6163	77.75
Clwyd	242650	124	263		387	4.88
Dyfed	576577	165	162		327	4.13
Gwent	137599	4	13		17	0.21
Gwynedd	368708	304	332		636	8.02
Mid Glamorgan	101867	16	5		21	0.26
Powys	507471	117	240		357	4.50
West Glamorgan	81657	10	9		19	0.24
WALES	2016529	740	1024	0	1764	22.25
TOTAL	10138242	3115	3195	1617	7927	100.00

Table 2.2.6 The area (in hectares) of heather in England and Wales by county from MLC interpretation of aerial photography and the new satellite imagery estimates.

County	Area	1980	1984	1984/1980
Bedfordshire	123460	0	426	
Cheshire	232846	0	726	
Cornwall	354792	8610	12881	1.50
Cumbria	681012	30370	61476	2.02
Derbyshire	263094	21140	28686	1.36
Devon	671088	11220	18598	1.66
Dorset	265375	6690	2698	0.40
Durham	243592	27840	49330	1.77
East Sussex	179512	3930	2435	0.62
Greater Manchester	128674	7790	1881	0.24
Hampshire	377698	4650	27612	5.94
Humberside	351212	0	137	
Lancashire	306346	8600	17643	2.05
Norfolk	536776	0	4823	
North Yorkshire	830865	138990	104638	0.75
Northumberland	503165	72780	59974	0.82
Shropshire	349014	0	6192	
Somerset	345094	2590	16693	6.45
South Yorkshire	156049	8090	6009	0.74
Staffordshire	271615	0	5609	
Suffolk	379663	0	6069	
Surrey	167924	5080	7344	1.45
West Sussex	198935	0	348	
West Yorkshire	203912	4130	18190	4.40
ENGLAND	8121713	362500	460418	1.27
Clwyd	242650	30550	26799	0.88
Dyfed	576577	6730	25797	3.83
Gwent	137599	0	1454	
Gwynedd	368708	30750	39472	1.28
Mid Glamorgan	101867	1170	1687	1.44
Powys	507471	37090	27837	0.75
West Glamorgan	81657	1330	1420	1.07
WALES	2016529	107620	124466	1.16
TOTAL	10138242	470120	584884	1.24

3.1 LOWLAND HEATHLANDS OF CENTRAL AND SOUTHERN ENGLAND.

3.1.1 Introduction.

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

The origin and meaning of the term "heathland" has been discussed by Graebner (1901), Rubel (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, fynbos etc). The vegetation of such areas are generally evergreen, contain members of one of the "heather" plant families, and occur on soils that are low in plant nutrients.

Within NW Europe, the term heathland 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 of *Calluna* were summarized by Beijerinck (1940) as a soil containing low levels of plant nutrients, soil 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 Luneburg heathlands in Germany were the result of deforestation. and subsequent grazing by cattle and sheep. However. later work by Graebner (1925) suggested that heathlands represented climax vegetation upon podsolised soils under the conditions of an Atlantic climate. whilst not excluding the role of man, he suggested that natural regeneration of woodland on podsolised soils would be precluded. These ideas were responsible for the initial non-intervention management policy on the Luneburg heathland nature reserve. Subsequent events have shown that, especially in the absence of grazing, such a policy can result in widespread recolonisation by birch and pine, and does not maintain heathland.

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 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, when combined with grazing and burning these activities prevented the establishment of trees and scrub, and maintained a low nutrient status in the soil. 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 rabbits removed any residual grazing, and in the absence of alternative 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 heathland. 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 & de Smidt (1983). Turf, and peat cutting on lowland heathland have now almost ceased, and as a result there has been an increase in the rate at which shrub and tree species have invaded some areas. Only small areas of relict heathland now remain in previously traditional heathland areas, with consequent effects on the remaining plants and animals (Webb, 1985; Webb, in press).

3.1.2 Variation within lowland heathland in lowland Britain.

The small number of plant species associated with dry heathland show distinct patterns of distribution which result in a series of well marked types of heathland 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 the 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 areas of heathland that are intermediate in character between lowland and upland areas. Heathlands in these areas show an almost continuous range of vegetation in a succession from open *Calluna* to areas of woodland that contain only relict areas of heathland.

Studies of production and nutrient budgets (Gimingham *et al* 1979) have often assumed *Calluna* heathlands to be a single entity. Chapman & Clarke (1980) have examined some

of the relationships between soil, climate and production, and shown that lowland heathlands in southern England are characterized by higher temperatures, lower rainfall, and lower soil nutrients; whilst upland heaths are characterized by lower temperatures, higher rainfall and generally higher nutrient levels in the soil. Studies of land use, and management of heathland in the Netherlands (Gimingham & de Smidt 1983, Hiel & Diemont 1983. Hiel 1984) suggest that losses of phosphorus by leaching may not be so great on some heathlands as in Dorset.

A range of soils from heathlands in southern England have been examined (Chapman *et al* , in press) in relation to their phosphorus adsorption characteristics, which can be placed into three categories. The first characteristic of soils derived from Tertiary sands, show adsorption maxima of less than 100 $\mu g\ g^{-1}P$ soil. The second show adsorption maxima which can rise to levels in the order of 4000 $\mu g\ g^{-1}P$ of soil. Other heathland soils show values between these two extremes.

There is a clear relationship between the phosphorus adsorption capacity, and the rates of change of the vegetation on individual sites (Figure 3.1.1). In the absence of grazing, or alternative management, succession to shrub and woodland is slower on open *Calluna* heathland where the phosphorus adsorption maximum of the soil is less than about 70 $\mu gP.g^{-1}$ soil. but, in the absence of grazing, invasion by *Ulex europeaus* is likely where the adsorption maximum is between about 70 and 700 $\mu gP.g^{-1}$ soil. Where the adsorption maximum exceeds 700 $\mu gP.g^{-1}$ soil, succession to birch wood is most likely if grazing, or positive management techniques are not maintained. Sites that have remained as *Calluna* heathland, despite being on soils with phosphorus adsorption levels in excess of 300 $\mu gP.g^{-1}$ soil, are all on areas that are still actively grazed, or managed, such as 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.

3.1.3 The future for lowland heathland.

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 once more extensive landscape. Heathlands in lowland Britain are, largely, the result of particular forms of land use on suitable soils. Changes of land use, of 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, of 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 arrest 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, in the control of birch and bracken, have 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. The practice of mowing, and removal of the cut heather as bales, as has been done in the New Forest, may be more effective than burning in the removal of nutrients. Turbary, or sod-cutting as practised by Diemont

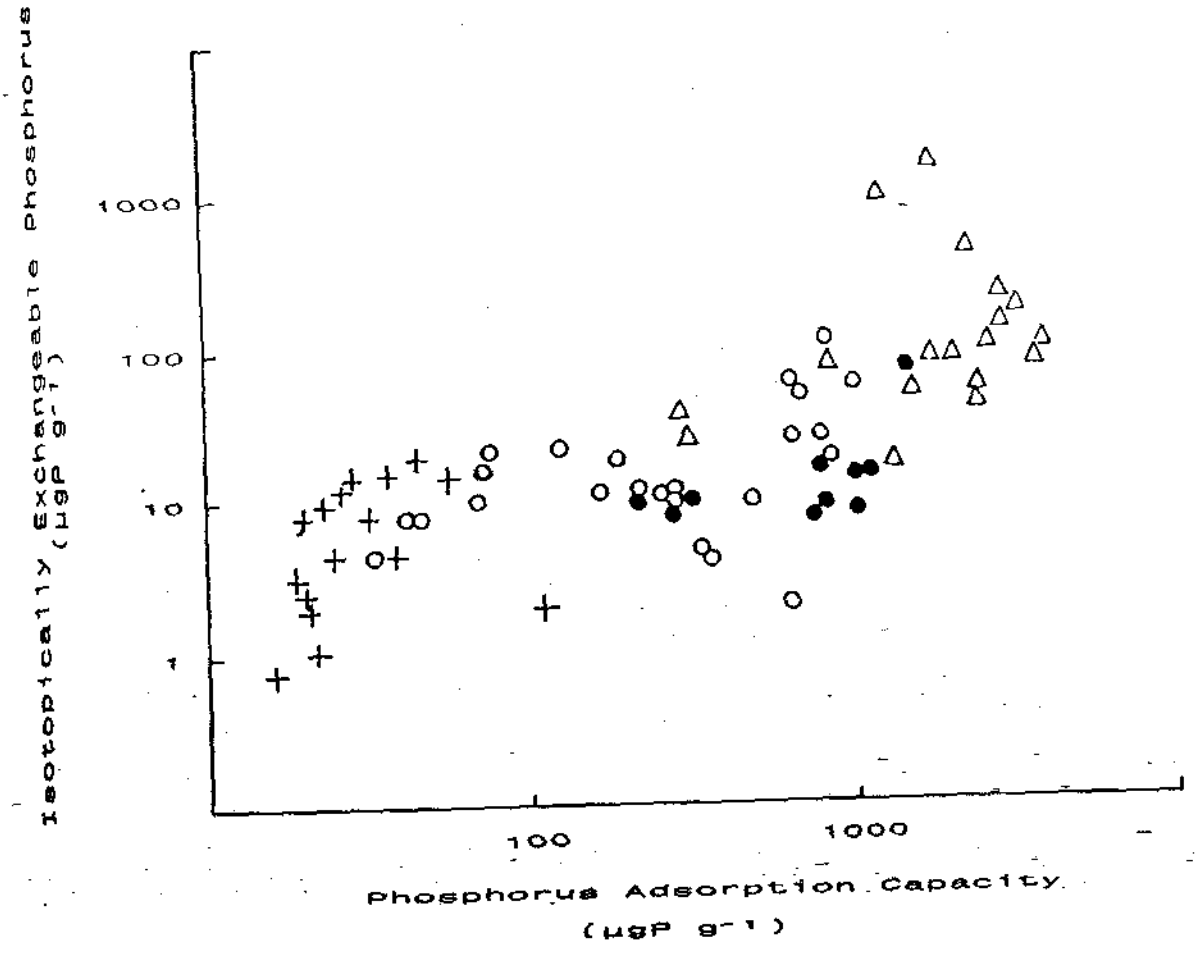

Figure 3.1.1 The relationship between the vegetational state of heathland sites in southern England, phosphorus adsorption capacity and level of isotopically exchangeable phosphorus in the soil

(✚) Ungrazed *Calluna* heathland

(Δ) Grazed *Calluna* heathland

(O) Ungrazed heathland sites subject to invasion by gorse

(●) Ungrazed heathland sites subject to invasion by birch, and other species.

(1982) and Diemont & Hiel (1984) upon 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.

3.1.4. The current status of heathland in lowland Britain.

The major areas of heathland that remain in lowland Britain (excluding East Anglia) occur in the New Forest and Dorset, in parts of Ashdown 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 "lowland Britain".

Dorset Heathlands.

The previous extent, subsequent losses, and fragmentation of heathland in Dorset have been described by Moore (1962), and Webb & Haskins (1980). The remaining heathlands were surveyed, in 1978 & 1987, by ITE Furzebrook using a 4 hectare recording grid, and the resulting data used to produce computer drawn maps (Figures 3.1.2 to 3.1.4), and to obtain estimates of the areas of different heathland vegetation types (Table 3.1.1). The areas of types of vegetation associated with *Calluna* heathland are important they are part of a complex of vegetation types that make up the "heathland" system in the wider sense (Figure 3.1.2). The survey data obtained in 1978 has been discussed by Chapman, Clarke & Webb (in press) in relation to the need to define survey criteria, and the assessment of heathland for conservation, and possible restoration. The heathlands in Dorset contain a number of notable species of plant, and animal not found in the same abundance elsewhere in Britain.

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 in the Forest. A number of smaller areas of heathland remain in the area, but are similarly threatened by successional change. Some areas are maintained as heathland by virtue of their management as nature reserves (Chailey Warren), or as their use as golf courses (Crowborough Common).

Heathland in Surrey, and Greater London, has similarly been greatly reduced, and important sites such as Thursley Common, and the Devil's Punchbowl are in danger through invasion by birch, pine, and bracken. Areas such as Frensham Common remain as open heathland. but in the absence of sufficient grazing will require continuing management if open heathland is to be maintained. Heathland conditions can only survive on many smaller sites if considerable management is undertaken, and in many cases such management may well be in the form of landscape architecture rather than wildlife conservation.

The heathlands, apart from the New Forest, remaining in Hampshire are mostly in the north-east of the county. These heathlands are different from the New Forest and should be

Figure 3.1.2 Distribution of Heathland, (ie open Calluna heath and associated associated vegetation types) in dorset 1987. Size of circles proportional to area in each 4ha square.

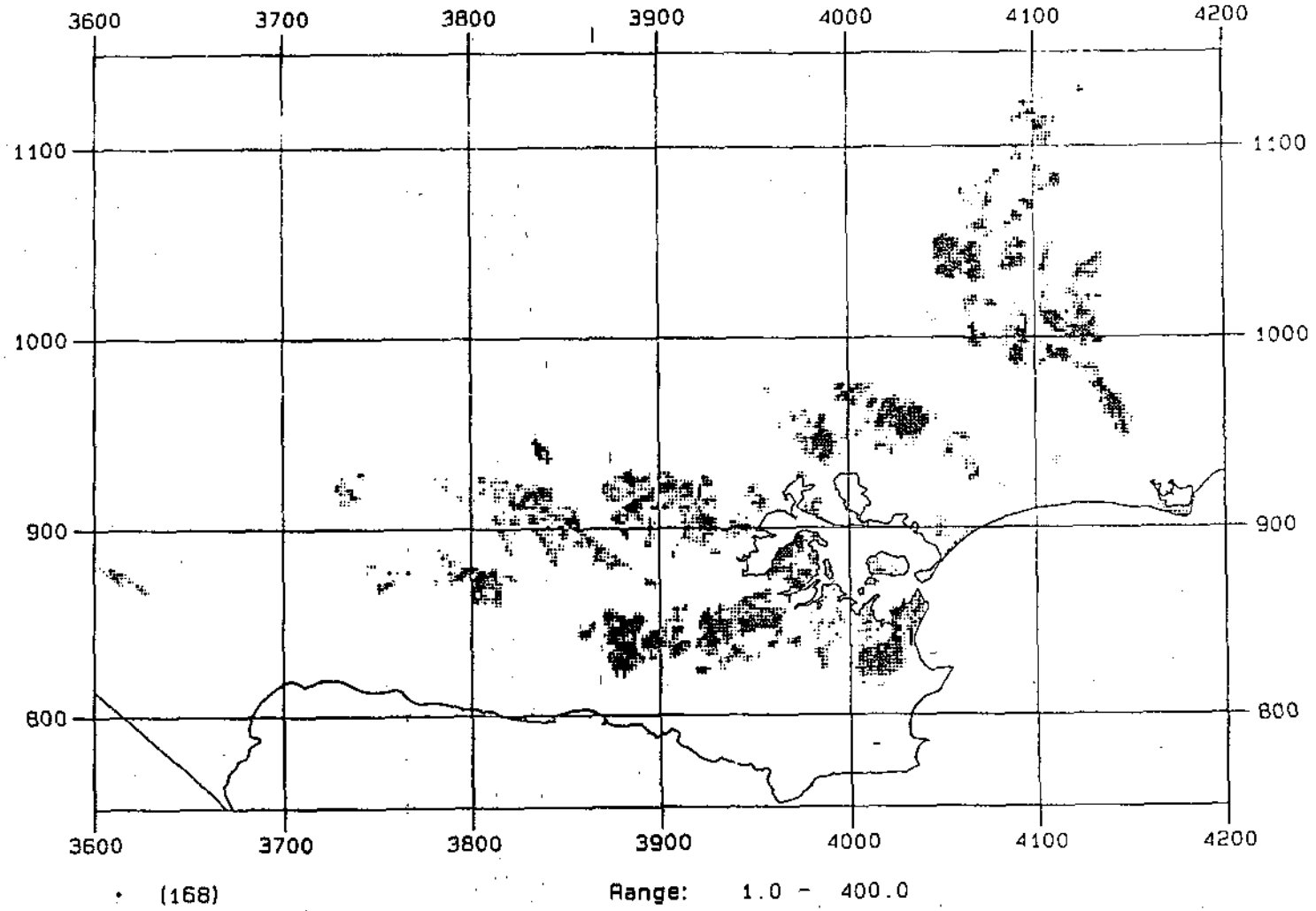

Figure 3.1.3 Distribution of Calluna heathland, (ie Wet Humid and Dry heathland) in dorset 1987. Size of circles proportional to area in each 4ha square.

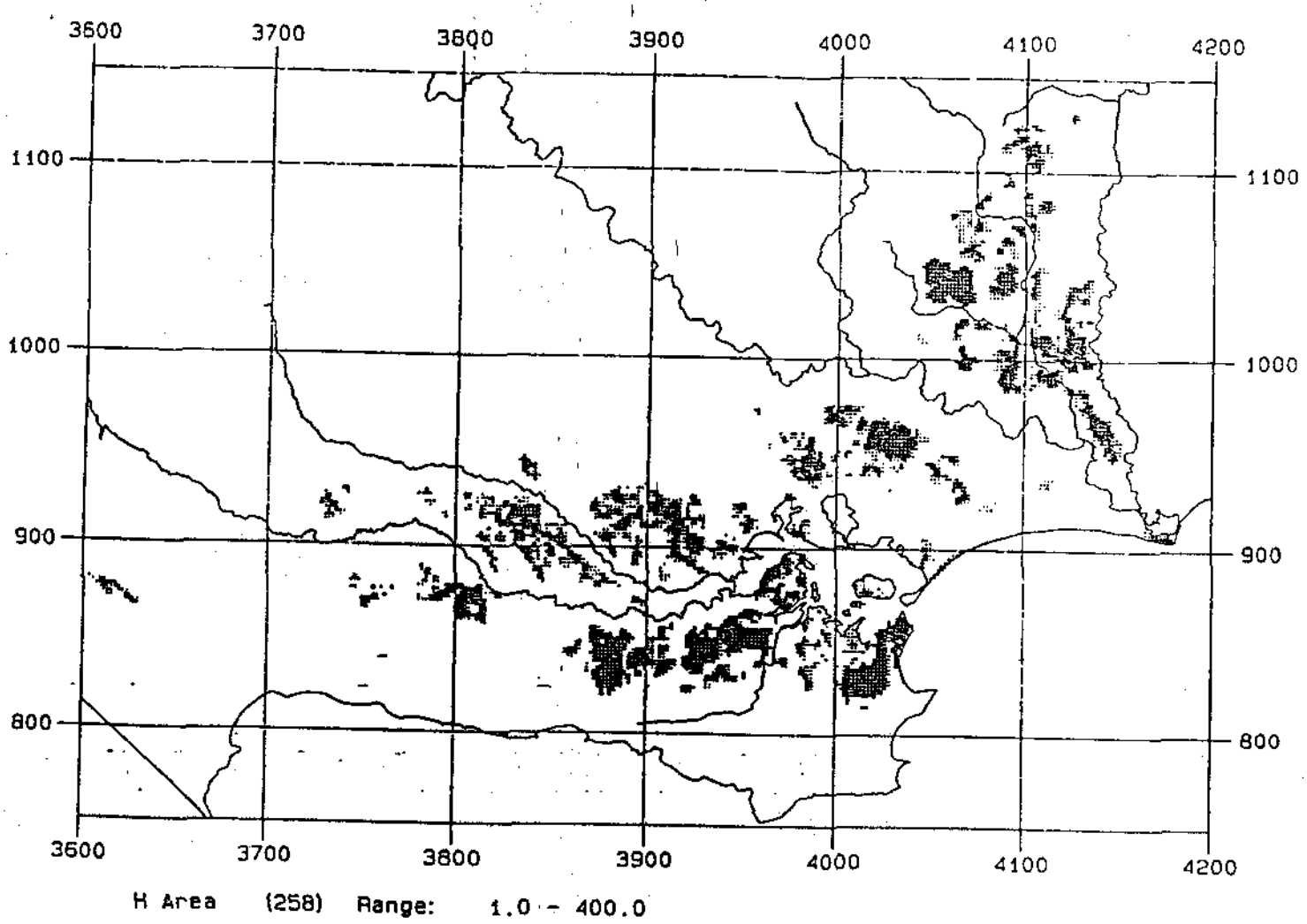

Figure 3.1.4 Distribution of Dry heathland in dorset 1987. Size of circles proportional to area in each 4ha square.

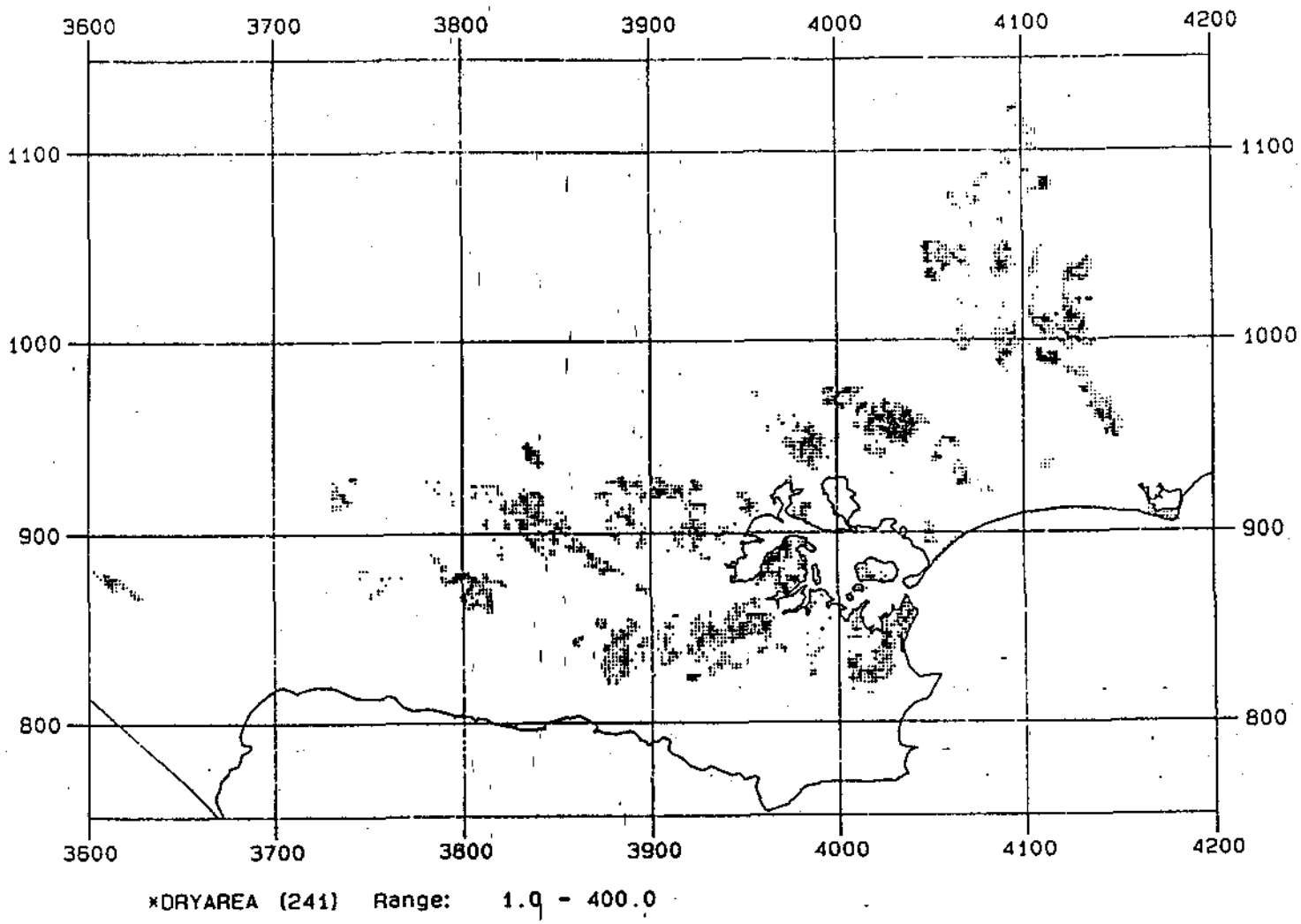

Table 3.1.1 Changes in the area of heathland vegetation in Dorset between 1978 and 1987.

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

considered with the adjacent heathlands 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 results 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. Like a number of the smaller sites elsewhere in southern Britain several of these sites are of particular importance because of the habitat provided for certain demanding species of plants and animals.

3.1.5. Needs for heathland research.

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

3.1.5.1 Monitoring.

i) Resurvey Dorset heathlands to extend existing data base at suitable intervals. Such intervals must depend upon rates of change, but an interval of 10 years is suggested.

ii) Extend the methodology developed with the Dorset Heath Survey to other heathland areas in lowland Britain.

iii) Examine data held in 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 site by comparisons with previous surveys, and air photographs.

3.1.5.2 Successional Studies.

i) Develop existing nutrient, and other models (Chapman *et al*, in press) 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 *et al*, in press.

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

3.1.5.3 Management and Restoration.

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

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

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

3.2 THE STATUS OF HEATHER IN WALES

3.2.1 Overview

Heather (*Calluna vulgaris*) grows widely in Wales and has been reported from all but 19 of the 282 10x10 kilometre squares containing land, ie. 93 percent (Ellis 1983). Within that range it occurs in several contrasting habitats, from the coast to the uplands. The major of these, 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 heather or bell-heather (*Erica cinerea*), and mixed with dwarf furze (*Ulex gallii*). Away from the coast but still at low altitude, heather is most abundant on wetland habitats, notably on the drier parts of valley and basin mires, but also on 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 metres.

Despite its widespread occurrence in Wales, there are relatively few areas, even in the uplands, where it 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 dominant vegetation over a much wider area.

Vegetation dominated by *Calluna*, particularly in upland heaths, is at risk because it can relatively easily be replaced by agriculturally more productive acidic grassland. A combination of severe burning and sheep grazing has resulted in the disappearance of a great deal of *Calluna* heathland, and 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 Cadair 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 in a

similar way on blanket bog, but although it can achieve good heather regeneration, it is difficult not to affect adversely the cover of bog moss, and to 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 representing conflicting land use interests in the area: NCC, FC and WOAD (Lofthouse 1980)).

Another large area of *Calluna* dominated heath occurs on the Denbigh Moors, where management for grouse has ensured 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 also been under greater agricultural pressure from sheep grazing. *Calluna* heath in the Glamorgans, for example, occurs 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 *Calluna* heath are: the Berwyns, Denbigh Moors, Clwydian Hills, Ruabon and LLantisilio Mountains, parts of Snowdonia, and the Rhinogau. An estimated 32,000 hectares of upland dry *Calluna* heath remain in Wales (NCC unpublished figure).

Although *Calluna - Eriophorum* blanket mire is a widespread upland habitat in Wales, there are relatively few examples that are both extensive and largely intact. Among the major of these are the Migneint, the Berwyns and Duallt in North Wales, and Pumlumen, Radnor Forest and Cwm Ystwyth in mid Wales. Further south, the blanket bog is often fragmented, heavily disturbed or less well developed at the lower altitudes. Heather dominated blanket bog is currently not well represented in Brecknock or the Glamorgans, for example, although opportunities exist for its rehabilitation on those areas where it remains.

3.2.2 Surveys of *Calluna* habitats

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 (Ratcliffe 1980) and the Upland Vegetation Mapping Programme. Both exist as 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 & Birks (1980). Categories with a significant component of heather include:

Dwarf shrub heaths
Sub-montane *Calluna* heaths
Blanket bogs
Molinia caerulea - *Calluna* mire
Calluna - *Eriophorum vaginatum* mire

3.2.3 Current threats

The major threats to heather are: habitat destruction, largely through 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, for example on the Rhinogau and in parts of Snowdonia; sympathetic management as a natural resource, for example the grouse moors of Denbigh and Ruabon; or by statute, or management as nature reserves, for example some of the coastal and lowland heaths on Anglesey.

Coastal heaths are under threat from a tendency to extend improvement as near as possible to the cliff edge. This puts many heath remnants 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 through subsidized and efficient drainage operations.

The threats to upland moorland habitats supporting heather come mainly from overgrazing and uncontrolled burning. In the case of grazing and severe burning on upland heaths, the effect is to open up the heather canopy, allowing the invasion of grasses, such as bents (*Agrostis* spp) and fescues (*Festuca* spp), or of bracken (*Pteridium aquilinum*). In those areas which escape severe burning, but where it is largely uncontrolled, the heather plants grow straggly and again allow the invasion of grasses, such as purple moor grass (*Molinia caerulea*) or mat grass (*Nardus stricta*), or the stronger development of bilberry (*Vaccinium myrtillus*), 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. These cause the removal of the dwarf shrub cover and a gradual drying of the mire's surface, 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 (*Eriophorum vaginatum*), but the growth of 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 habitat, but the process is not rapid, and demands long term commitment to a management regime not conducive to agricultural production.

3.2.4 Research needs

1. Trials on recolonization

   i. The history of some recently destroyed lowland heathland habitats is relatively well known. They 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 that has now almost all 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 demonstrate the effects of altered management in areas of different densities or sources of recolonizing heather, and allowing for the isolation of effects from any differences in previous grazing pressure or burning pattern. Experiences at Moor House National Nature Reserve would be of direct relevance (Rawes 1975). (Attention is also needed to the prevention of further erosion on areas of blanket bog.)

2. Digest of habitat survey data

The raw material for an inventory of much of the heather habitat in Wales is to hand, but requires substantial working up before it becomes available in summary form. Example figures from the upland survey include the estimates of upland dry *Calluna* heath given above, and provisional areas for heather dominated blanket bog in Clwyd, Brecknock and Gwent of 7434, 1485 and 235 hectares, respectively. Summary data on lowland wetland data are available within the NCC, but preparation of running summary figures for upland habitats on a regional basis within Wales would be most, useful in anticipation of the current survey being completed. Understandably, the NCC priority is upon completion of the field work and site reports/maps as quickly as possible.

3. A synthesis of knowledge and experience in the ecology and management of habitats with an importance for heather in Wales, for the benefit of strategic planners and land managers.

3.3 HEATHLANDS IN EAST ANGLIA

3.3.1 Overview

In East Anglia the term 'heath' is often widened from its strict definition of 'a treeless tract that is dominated by evergreen low-growing shrubs that are mainly *Ericaceae*' to include semi-natural grasslands. In this overview the widened definition is used, but thereafter the report will concentrate on *Calluna* dominated areas. There are 3 main blocks of heathland in East Anglia (Fig. 3.3.1),

i the Breakland heaths around Thetford,

ii the Sandling heaths along the Suffolk coast, and

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 FRS of Cambridge Botany School.

In Breckland the heathland vegetation now present 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 were introduced to Breckland, and extensive rabbit warrens established. Moreover, a form of 'shifting cultivation' type 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 reversion to heath and sheep grazing when either the soil fertility declined, or it became unprofitable.

The vegetation found on Breck heaths ranges from various semi-natural grasslands (grass heaths) to *Calluna* heaths. The grass heaths themselves show a wide range of variation ranging from species rich calcareous grasslands to acidic ones dominated by *Agrostis* and *Festuca* spp., and on some very infertile soils the vegetation is dominated lichens (Webb 1986). Often these different communities reflect the depth of superficial deposits overlying calcareous substrata. At one site, Lakenheath Warren, at least 5 different grass and *Calluna* communities persist in close proximity. Intimate mosaics of plant communities reflecting soil differences also occur through differential sorting of soil particles by solifluction caused by glaciation. On level ground soil polygons have been formed, but on slopes stone stripes occur. On these striped areas grassland tend to occur on the coarser materials. and *Calluna* on the finer ones (Duffey 1976).

The Sandlings and North Norfolk heaths have also 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.

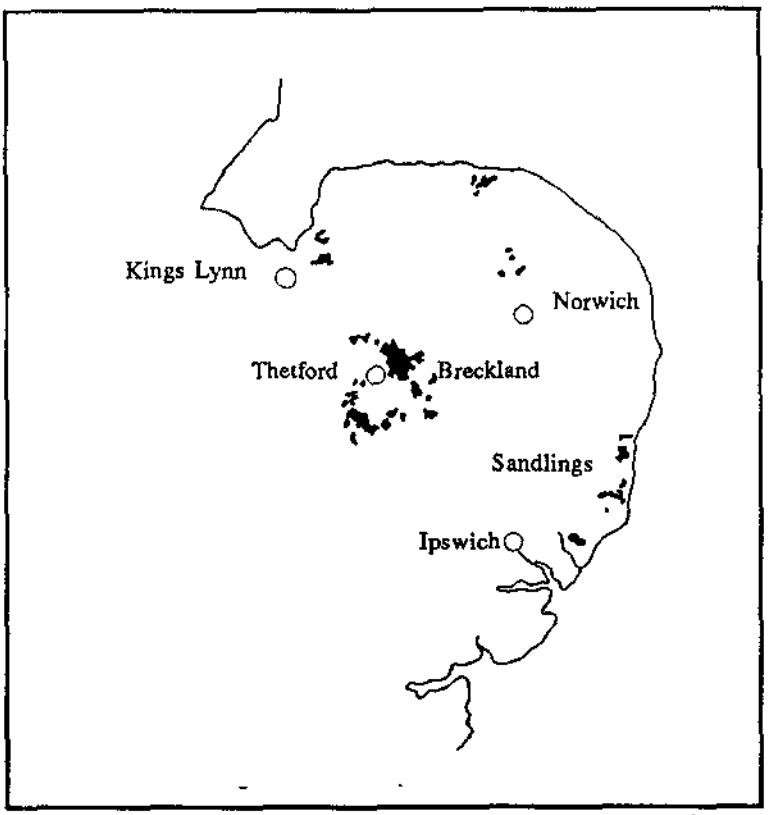

Figure 3.3.1 East Anglian Heaths

The East Anglian heaths have several features in common;

i They have all developed on infertile soils, and the *Calluna* heaths occur on extremely infertile sandy soils of low pH.

ii They were all formerly managed as sheep walks or rabbit warrens, or as commons with commoners having various management rights. These rights varied from place to place but included the right to (1) graze stock, (2) cut bracken and *Calluna* for thatch or bedding and (3) cut scrub or turves for fuel.

3.3.2 Special feature of East Anglian heaths

There are two particular reasons why the East Anglian heaths are important, these are their ;

i Rare species interest. Breckland in particular, partly because of the diversity of habitats, has many rare plant species (Table 3.3.1), and several others, eg *Goodyera repens* and *Ajuga chamaepitys* occur at the edge of their range (Webb 1986). Several coastal species, eg *Carex arenaria* and *Corynephorus canescens*. *Phleum arenaria* and *Viola tricolor* ssp. *curtsii* are found on inland sites. Moreover, some sites are important for rare reptiles and birds. Syderstone Common in North Norfolk has Natterjack Toads. and Breckland heaths are the main British centre for the Stone Curlew. Nightjars and woodlarks are also found on many East Anglian heaths.

ii Similarity to continental heaths. East Anglia in general, and Breckland in particular. have a more continental climate than the rest of Britain. The rainfall is low (c. 560 mm/year), 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 Dutch heaths is borne out by studies on *Calluna* dynamics. In Holland it has been shown that the regeneration cycle of *Calluna*, (first described by A.S.Watt in 1947) and used in Britain as a model for the description of heathland processes and management, may not apply. The general model of Watt implied that a given patch of even-aged *Calluna* heath will develop naturally into an uneven-aged patch through the natural death of individual bushes followed by recruitment of new plants. On the Dutch heaths this process does not occur, rather the cycle is interrupted by catastrophic events such as extreme climatic events (hot summers or cold winters), or outbreaks of heather beetle. Thus many large areas of *Calluna* heath have been killed at one time, and in some instances almost the whole site has been affected. When these catastrophic events occur regeneration must occur from seed, and there is an opportunity for other species to invade

Table 3.3.1 Rare Plants of Breckland

Group 1	Heath Sedge	*Carex ericetorum*
Ungrazed	Sickle Medick	*Medicago Falcata*
Turf Species	Purple stemmed Cat's-tail	*Phleum Phleoides*
Group 2	Breckland (or Spanish)	*Silene otites*
Perenial	Catchfly	
Species	Spiked Speedwell	*Veronica spicata*,spp .*spicata*
	Grape Hyacinth	*Muscari atlanticum*
	Field Southernwood	*Artemisia campestris*
Group 3	Dense Silky-bent	*Apera interupta*
Poor	Mossy Stonecrop	*Crassula tillaea*
Competitors	Wall Bedstraw	*Gallium parisiemse*,spp.*anglicum*
	Glabrous Rupturewort	*Herniaria glabra*
	Small Medick (Bur)	*Medicago minima*
	Striated (Sand) Catchfly	*Silene conica*
	Breckland Speedwell	*Veronica praecox*
	Fingered Speedwell	*V. tripyllos*
	Perennial Knawlweed	*Scleranthus perennis*,spp. *prostratus*
	Wild Thyme	*Thymus serpyllum*,spp. *serpyllum*

and change the course of succession away from heathland. Dutch conservationists are very worried about these events. because they allow grasses such as *Deschampsia flexuosa* and *Molinia caerulea* 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 a half of the *Calluna* heath, and the rest has been affected by severe winters since then. An attempt was made by Marrs (1988) to synthesise our knowledge of these differences between *Calluna* dynamics on British and Continental heaths into a simple decision-making model (Figure 3.3.2) to help heathland managers, but this 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 *Calluna* heath through successional change towards *Molinia caerulea* and *Deschampsia flexuosa* grasslands is driven by high inputs of nitrogen in polluted rain (Heil & Diemont 1983). *Deschampsia flexuosa* 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.

3.3.3 Current threats

In all 3 heathland areas there has been a great reduction in absolute heath area. In Breckland 60 000 ha of sheep walk and rabbit warrens has been reduced to < 10 000 ha divided between 19 sites of varying size (Ratcliffe 1977), and in the Sandlings 23 370 ha has been reduced to 5 412 ha (Armstrong 1975). In Breckland the largest site (4 740 ha) is the Stanford PTA (MOD), which is mainly grass heath; one site, Lakenheath Warren, is > 500 ha and 2 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 ha, and only 2 '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 invade. The losses, although a general feature of all British Heaths, have been documented in detail for 4 sites in East Anglia (Marrs *et al* 1986). At 3 of the 4 sites scrub invasion was the major problem, with a 10 % loss at Cavenham Heath, 30 % loss at Knettishall Heath and a 50 % loss at Lakenheath Warren between 1946 and 1984. Bracken was also increasing at 3 sites, but it was not as serious a problem as scrub on the sites investigated.

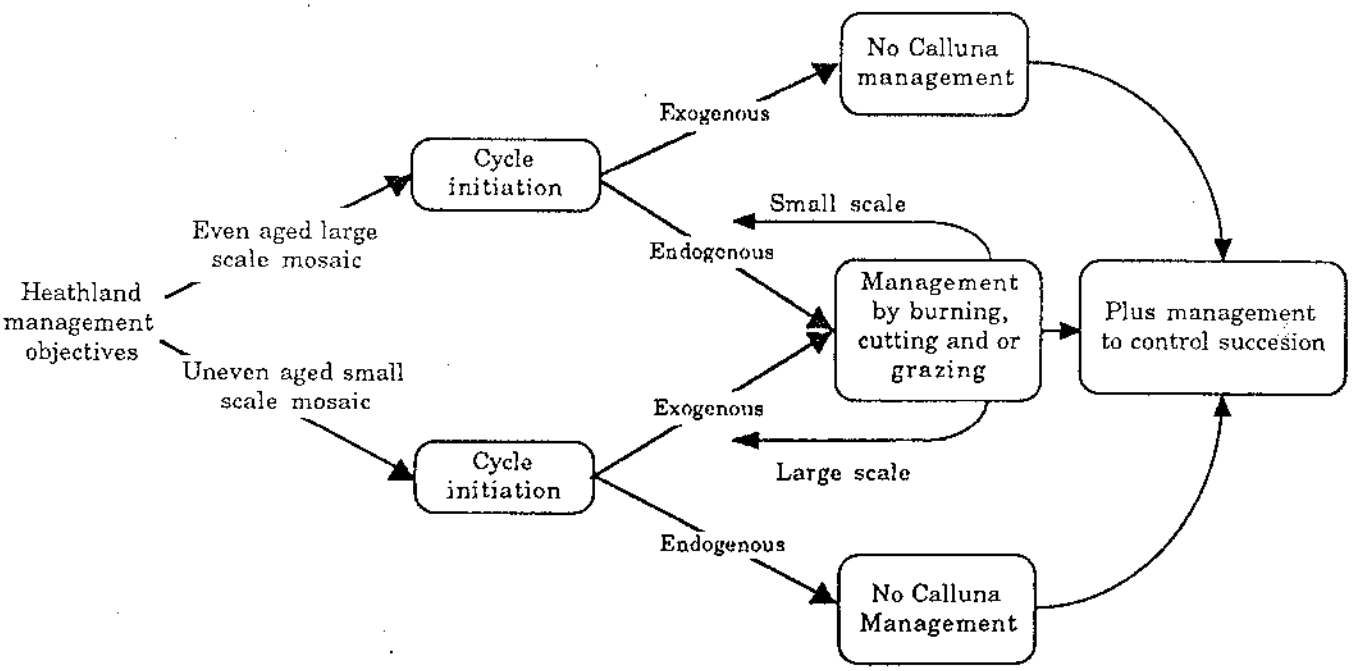

Figure 3.3.2 A decision tree showing four potential scenarios for managing lowland heath depending on the scale of the vegetation mosaic required on the site, and the type of initiation of the *Calluna*. regeneration cycle. After Marrs (1988).

The reasons for these successional losses are clear:

i Lack of grazing. The sites have not been grazed by stock for many years. and the grazing pressure has been reduced even further by the reduction in rabbit numbers following the introduction of myxomatosis.

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

The consequence of these changes in management have been to allow succession from early-successional communities (*Calluna* 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.

3.3.4 Research needs

The major problem in East Anglian heaths is that of successional change brought about by the invasion of bracken and scrub. Basically we know how to deal with this problem (Marrs & Lowday in press); with techniques available for both the management of existing *Calluna* heath, and the restoration of areas where succession has already proceeded. The major thrust of heathland conservation in East Anglia must now move into implementing these management strategies. This has already occurred to some extent recently with the 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 *et al* 1985). Moreover, the designation of Breckland as an ESA, means that there should be in the near future a major initiative in the restoration and management of heathland in Breckland. Currently, it is hoped to increase the areas of heath which are grazed, and also start a cereal cropping programme, designed to reduce soil fertility on arable land, with the hope of accerelating heathland reversion. With all of these initiatives, however, it is important to have properly designed monitoring schemes. 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 5 areas where further research on East Anglian heaths is needed, these are;

i A detailed monitoring of the current management being done by conservation agencies, and that proposed in the ESA proposals.

ii A reappraisal of existing data that relate to vegetation change over the last 50 Years. Two datasets at least are available, Dr A.S. Watts published species lists

are available for some sites, and species change could be picked up by resurveying these sites. A *Calluna* status survey was done for Breckland and one of the Sanding heaths in 1980 (Marss unpub.), and change could be detected by repeating this work.

iii An assessment of the amount of nutrients being added in wet, 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 experiments must be done to develop vegetation management techniques to prevent further damage.

iv An assessment of the scale of 'continental type' heathland dynamics. Clearly, if heathlands are to be managed effectively we need to know whether they are going to die *en masse*. Catastrophic death of large areas has only been documented in detail for one site, and long-term surveys of *Calluna* status are required to evaluate the scale of the problem. A modelling approach based on both the age structure of *Calluna* populations on different heaths. and physiological assessments of tolerance to drought. heat, frost and herbivore attack would also be useful.

v A 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 would also be worth developing.

3.4 HEATHER IN UPLAND ENGLAND (The Pennines Northward)

3.4.1 The Distribution and Nature of Heather Communities.

Heather (*Calluna vulgaris*) dominant or sub-dominant communities are not evenly distributed throughout upland England. Both quite extensive and smaller, more fragmented heather moorlands occur in the Peak District, in the southern Pennines. In the central Pennines, heather moorlands are scarce (although there once were grouse moors in this area), but the Forest of Bowland contains some significant examples. The northern part of the Yorkshire Dales National Park supports a significant cover of heather, as do some of the adjacent Durham moors. However, in Northumberland, heather communities are more restricted, as they are too in the Lake District where the only significant areas of heather moorland are confined to the northern hills around the Skiddaw and Shap Fells. Only the North York Moors, largely within the National Park, support extensive heather in the east of northern England.

The heather dominant communities tend to occur on drier hills, where the soils are peaty podzols, rather than deeper peats. Heather often forms pure stands, excluding most other species. However, after burning, temporary flushes of wavy hair grass (*Deschampsia flexuosa*) or purple moor-grass (*Molinea caerulea*) may occur. Bell heather (*Erica cinerea*) and some other moorland species such as bilberry (*Vaccinium myrtillis*), and cowberry (*Vaccinium vitis-idaea*) may occur in patches amongst the heather, especially on more rocky slopes.

Beds of bracken (*Pteridium aqualinum*) are a main feature of the lower edges of many of these drier moors, or occupy the sometimes grassy valleys below the moorland.

Sub-dominant heather communities on the drier mineral soils tend to be mixtures of *Ericaceous* shrubs (heather/bilberry/cowberry or, sometimes, crowberry (*Empetrium nigrum*), or of heather with grasses, principally mat grass (*Nardus stricta*) or purple moor-grass.

Heather is rarely dominant on the wetter, deeper, peaty soils, but co-dominates usually either with cotton grasses (mostly *Eriophorum vaginatum* but also *E. angustifolium*) on blanket bog, or with purple moor-grass on flushed peaty slopes.

These different types of heather community predominate in different upland areas. In the Peak District, 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. There is now little cotton grass/heather moorland though.

The nature of the heather communities in the Forest of Bowland is very similar to that in the Peak District but with a greater bracken incursion problem, whilst, in contrast, it is the wetter heather-cotton grass community which is most widespread on blanket peats in the North Yorkshire Dales. The drier heather moors here are limited to the drier gritstone based soils in the north and east around Wharfedale.

There is a similar distinction between the drier heather-dominated sandstone areas in the Durham and Northumberland moors, and the more extensive cotton grass/heather mixed communities of the plateau blanket bogs. Where the heather abuts limestone or flushed grassland, as on Widdybank Fell, a unique moorland habitat has developed. In the North York moors though, it is the drier pure heather communities which are more widespread, with extensive bracken beds on the slopes.

The Lake District's heather is more characteristic of the steeper, rounded, freely drained slopes of Skiddaw Forest, Shap and the Buttermere Fells than of the lower altitude, plateau moors so typical of the Pennines. Blanket bog is less common here, but bracken and acid grasslands are widespread intrusions into the edges of the heather communities.

Most of the communities described occupy quite extensive tracts of land. Heather is also a constituent of other communities which occur in the uplands. It shares the humid heath with cross-leaved heath, (Gimingham 1972), and the sedges and grasses of base-rich flushes, it occupies rocky ledges with sub-montane species, various grasses or ferns. It grows, uniquely, in limestone pavement in the Yorkshire Dales where it is rooted in leached soils in the crevices adjacent to the limestone specialists, and it is a characteristic colonizer of road-side banks and abandoned quarries, especially in the sandstone areas of the Pennines.

3.4.2 The Value of Heather

i) Landscape and Amenity

Extensive tracts of heather in flower are widely recognized as one of the most attractive sights in the hills, and therefore regarded with great pleasure and affection. Heather moorland too, often has strong literary and cultural associations with areas, and thus is an intrinsic element in our social history.

This high landscape and amenity value was reflected first in the 1981 Wildlife and Countryside Act 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.

ii) Wildlife Value

The Wildlife value of heather communities is also very high. The invertebrate diversity, and the bird populations in particular, are much higher, and contain more notable species than an equivalent area covered with upland grassland (mostly mat grass or purple-moor grass), (Pearsall and Pennington 1973). For example, RSPB (1984), list 10 bird species in the UK which depend on moorland habitats for breeding. Of these, hen harrier, merlin, red and black grouse, golden plover, dunlin, ring ouzel and twite 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. The area around Widdybank Fell is the best area for golden plover in the whole of Britain, while the moors in Bowland, with the Northumberland National Park, support important moorland birds of prey.

The expanse of heather dominated moorland, mixed heather and other *ericaceous* shrubs, and heather/cotton grass blanket bog has no parallel anywhere else in Europe or the World. Nowhere else is there grouse management, or the integration of grouse, sheep and red deer on moorlands. Together with the abundance of oceanic heathland species in Britain (such as western gorse (*Ulex galii*)), this makes the upland heathland communities of national and international ecological importance.

Many of the Sites of Special Scientific Interest (SSSIs) which have been selected in the English uplands by the Nature Conservancy Council (NCC) are specifically for upland birds, notably breeding merlin, hen harrier, and waders. Some are also scheduled for their invertebrate interest. The floral diversity and range of communities reflecting the local environmental variations of slope, soils and wetness are also all important features in many of these SSSIs. 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).

iii) Grouse

All commercial grouse moors include extensive tracts of heather. Young heather shoots are the staple diet of grouse, and heather moors have been regularly burnt for decades to regenerate heather. The characteristic pattern of burning long narrow strips (20-30m wide) and of aiming to maintain a heather growth cycle of 8-12 years are advocated in the widely used advisory booklet produced by the Game Conservancy (Watson and Miller 1976).

As the Earl Peel points out (in Hudson 1986), good Grouse Moor management whereby pure heather is regularly burnt, but steep slopes and more mixed plant communities are excluded from burning, and where only foxes and crows are controlled, also provide excellent wildlife habitats, and the attractive landscape which pleases so many.

iv) Agriculture

The general view held by farmers in the uplands is that heather is of only limited grazing value. It does, though, provide important winter browse, as it is evergreen, and young plants are also selected in July-October if available grasses are exhausted. Sheep are more selective grazers than cattle, and as sheep have increased and cattle declined on the moors, it is the grazing pressure and effect of sheep which determine the nature of the vegetation, (Anderson and Yalden 1981, Ball *et al* 1982). Sheep select the more palatable and preferred fine-leaved moorland grasses (bents, fescues and wavy-hair grass) in spring, but as the nutritional value of grasses 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).

Satisfactory levels of sheep performance can be achieved if, over the year as a whole, at least 50% of the diet consists of grasses, although the proportion will vary with the season. 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 in other seasons for sustenance, (Scottish Agricultural Colleges 1988). In addition, heather provides an adequate natural supply of copper in the sheep's diet, which may be deficient in the uplands from other vegetation types.

3.4.3 Changes in Heather Communities

i) The Extent of Change

The general view is 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 tends to be anecdotal rather than quantitative. Pearsall and Pennington (1973) for example, describe the loss of heather in parts of the Lake District; a process which still continues. Other studies provide more quantitative information. Parry (eg 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 this to affect only some 11% of the total moorland area (but this includes 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% loss/yr if a consistent rate of loss is assumed of the 6563 ha). In the North York Moors a 1% /yr loss has been calculated (North York Moors National Park, 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) have recorded a 65%

loss of heather moorland and a 12% loss of heather dominated blanket bog to unimproved grassland between 1940 and 1970.

The losses of heather moorland in other areas can be partly gauged from the statistics for afforestation. For example, in the Northumberland National Park, much of Kielder Forest, now covered with conifers, is reputed to have been grouse moor once. In other areas, heather has declined, and mat grass, purple moor-grass or bracken have taken its place (as in Cumbria - Pearsall and Pennington (1973), and in Bowland and the North York Moors. The fact that there are no actively managed grouse moors in the Northumberland National Park, and that they are rare in the Lake District, yet were known to have been more widespread in the past, also points to substantial losses of heather. Indeed, it is reputed that some 80% of the heather in Northumberland has disappeared in the last 40 years.

ii) The Causes of Losses

Heather communities disappear either directly by conversion to conifer forests or to agriculturally improved grassland, or they die out gradually as a result of a change in management. Direct losses have been extensive. Afforestation was a major threat and consumer of heather-covered land in the Lake District and Northumbria in particular, over the past few decades. Conversion of more accessible heather moor to improved grasslands has occurred everywhere, but the quantitative data are unavailable except for NCC (1987) and Anderson and Yalden (1981). However, it is felt that much of the decline of heather has been a more gradual process resulting from land management changes.

In complete contrast with lowland heaths, where, except for the New Forest, lack of management, summer fires and subsequent scrub or bracken invasion are major threats, the upland heaths have changed due to overgrazing, or the product of changing sheep management. The sequence of how heather moor is altered to a grass heath, and, ultimately, acid grassland, or to a cotton grass dominated blanket bog are well known (Hudson 1986, Anderson and Yalden 1981, Miller, Miles and Heal 1984). Heather loss can be the result of 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); of limited burning whereby sheep concentrate on and suppress too small an area of regrowth; of grazing in old heather with no burning when brittle stems are broken down and grasses replace the heather; or of too frequent burning combined with heavy grazing. Added to the decline in traditional shepherding, increasing stocking levels and the use of the moor in winter as well as summer, these various changes in land management account individually, or in combination for the decline in heather in many upland parts of northern England. For example, one estate of 12,000 acres (4856 ha) in Durham has lost 2,000 acres (809 ha) over the last 20 years due to winter feeding across the moor.

Although Ball *et al* (1982) found that stock numbers, with minor exceptions, have been broadly stable for the upland parishes they studied, this masked local variations. A few parishes showed a trend of rising stock numbers since the 1950's, but also decreasing livestock densities as hill farm size increases, and a trend towards amalgamation of small

units. However, much of the land in some of these areas is not 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 will, of course, be on heather moorland, 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 HFRO (now part of the Macaulay Land Use Research Institute) have shown how heather can tolerate consumption of up to 40% of its current year's growth without damaging its reproductive capacity, but 80% utilization is damaging whatever the season (Grant *et al* 1978, 1982, Milne *et al* 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 HCLA payments encourage increasing stock rather than better management or productivity per ewe. As a result the lambing percentages in general tend to be very low (down to 60%, but mostly under 100%), stock numbers are increased to provide an adequate financial return, and directly or indirectly, the heather moorland is lost. The moors now dominated by unpalatable grass or sedges (mat grass, purple moor grass or cotton grasses) provide a degraded plant community which is of lower nutrient value and palatability than the heather moors they replace. Even annual burning, which results in repeated loss of nutrients, does little in a free-range grazing system to improve the keep. The arguments in favour of re-seeding and draining such areas, or planting them with conifers, then become stronger, and all the wildlife and scenic value, as well as the potential of the moor for grouse, are lost.

That this process of heather degradation and eventual loss has been operating for several decades, if not longer, is witnessed by the widespread abundance of acid grasslands dominated by mat grass, or, on wetter, flushed soils, by purple-moor grass, and on blanket bog by cotton grasses. Under lower grazing pressures, and better sheep management, most of these areas would once have supported heather dominant or sub-dominant communities. These losses have been sustained throughout the uplands in northern England, from the Peak District to Northumbria, but are especially severe in the central Pennines (where heather moor is now scarce), the Lake District (the cover of heather here now is very restricted), the southern half of the Yorkshire Dales, (grouse butts still persist where there is no heather in the Three Peaks area), parts of Durham, and major areas of Northumbria.

A consistent element in those areas where losses have been greatest is the extent of common land. This is a main feature of the Lake District, parts of the Yorkshire Dales, occupies some 50% of the Durham Moors, and considerable areas in the North York Moors. Although stocking rates will vary on the commons, the general pattern is of high grazing pressures and low standards of land management; Hudson (1986), investigating grazing levels in Weardale (Yorkshire Dales), found levels as low as 0.05 ewes/ha and as high as 7 ewes/ha.

The generally accepted nominal grazing intensity is 1 ewe/ha on heather moorland, but the Scottish Agricultural Colleges (1988) leaflet recommends between 0.69 and 2.38 ha/ewe depending on the quantity of better native grasses, burnt heather and improved grass (amongst other things).

In many of these areas the heather cover has already been lost, whilst in others it is represented by damaged plants, incapacitated by heavy grazing and trampling, dying out with little or no regeneration of young plants. In this state, the moor has lost much of its landscape and ecological value, is of little use for grouse, and indeed, once it degenerates into an acid grassland dominated by mat grass, possibly with invading bracken, it has a substantially reduced value for sheep too.

Only where heather persists in the sward, or its seed remains dormant in the soil can these degraded moors be restored to heather moorland. In many, therefore, it is too late to reclaim heather moor without a substantial programme of re-introducing heather seed with appropriate cultivation to provide a suitable seed-bed.

3.4.4 Further threats to Heather Moorland Communities

Although afforestation had been a major pressure on heather moorland, particularly in Northumberland and the Lake District, this threat has declined in recent months. The recent statement by the Secretary of State for the Environment combined with the provisions in the 1988 Budget are both tentatively thought to have eased this pressure, particularly in the National Parks. Afforestation is still seen as a threat to heather moorland in Northumbria outside the National Park. Throughout the moorland areas, though, loss of heather through overgrazing and poor burning management is perceived as the main current threat, and one that is likely to continue unless major changes in grants and the subsidy system in the uplands are forthcoming.

These fears are despite the recent work at HFRO which has sought to develop a moorland management system whereby sheep grazing and grouse production are fully integrated, (as seen for example not only in the research already quoted, but also in the recent development of a computer model to assist in deciding how many sheep a heather moorland can support). Furthermore, MAFF are attempting to promote moorland management practises which are compatible with the retention of healthy heather moorland. This is exemplified by the recent Scottish Agricultural Colleges Technical note on grazing management on heather moorland which is available in England, and the new Dark Peak ESA in the Peak District where management prescriptions include a reduction of winter grazing levels and programmes of moorland restoration and heather regeneration.

Another widely acknowledged threat to heather moorland is bad burning practices. Fires

which are too hot and burn the thin peaty soils on slopes in parts of Skiddaw (Lake District) are resulting in erosion. Burning which is too hot or cold, too large, on steep slopes, on ground too wet (eg blanket bog) or where the grazing pressure is too high all result in loss of heather. This problem is related to the decline in labour on the moors, both in agricultural employment, and more especially, in the decline of game keepers. Hudson (1986) correlates the decrease in grouse in all the major moorland areas in upland England with the reduction of game keepers. The traditional, and long established expertise of upland management is disappearing in places, and moorlands are becoming degraded as a result, especially where there is no longer any grouse interest, and sheep farming predominates.

Threats to grouse moors are rather different. Here, 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 has resulted in better financial returns which many owners are reinvesting in moorland management. More keepers are being employed, more and better burning programmes are being undertaken, bracken is being controlled, sheep stocks controlled and their management improved.

Despite this general improvement of the condition of grouse moors, many owners are concerned about their future. The anti-blood sports groups pose a threat; in some areas merely seen as an irritation, in others as a real problem. Coupled with the access issue, the anticipated disturbance to birds and disruption to shooting could be sufficient to tilt the balance away from grouse management and towards sheep farming. If this occurs with the current system of agricultural support policies, the heather moors could disappear. Currently, it is only good grouse moor management which also provides the fine landscapes and good wildlife habitats unless land is being managed only 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 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. They support increased access to the moor, but would promote a rationalized, improved path and track network rather than the freedom to wander at will. If the free access is permitted, it would remove the possibility of challenging unwelcome intruders (eg. poachers, thieves of rare bird eggs, badger diggers), which is an important part of wildlife protection at present.

There is great concern that open access coupled with the promotion of tourism in Durham would disturb and reduce the very important wader populations on the heather moors and heather co-dominant blanket bogs. There are fears for merlins and hen harriers in the Forest of Bowland and elsewhere if open access were granted.

These fears are generally well supported by research into the effects of disturbance. Anderson (in prep.) 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 1 dog per

25 people, 8% of the dogs were running wild. Hudson (1983) emphasizes how damaging such dogs can be on a grouse moor.

Neither Picozzi (1971) or 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 as incubation proceeds, and Watson (1981) found a substantial decline in nesting success of ptarmigan and red grouse from an area around the ski slopes on the Cairn Gorm due to increased predation following the development of tourism.

Many ground nesting birds are very vulnerable to disturbance by people or dogs, and although grouse tend to sit tight until nearly trodden on, curlew, golden plover, and dunlin have all been shown to be highly disturbed by human presence (Van der Zande 1984, Yalden 1988). Where these, and other moorland species, are particularly important (eg on some of the Durham Moors, in the Trough of Bowland), and where recreational pressure is already very high and particularly extensive in areas already open to public access (as in the Peak District), there is grave concern that the wildlife value could be, or is being, eroded.

Footpath trampling is rarely regarded as a general threat to moorland, but paths over 50m wide are developing in parts of the Yorkshire Dales across what was heather moorland (the Three Peaks area), and the Pennine Way is particularly wide, and bare ground prevalent in parts of the Peak District (Bayfield 1985).

Moorland fires resulting largely from public access are major threats to heather moorland in drought years. 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. If public access increases, and heather moorland, or blanket bog, dries out in the summer, several more areas could be at risk.

Moorland erosion is seen as a threat to heather moor in a few places. In the Peak District and North York Moors several moorlands were destroyed by fires (mostly summer fires resulting from high visitor use), (Phillips *et al* 1981, Maltby 1980), in the Lake District bad burning is reputed to have initiated erosion. Peat erosion is characteristic of Pennine blanket bogs, and although the cause is unknown, (it may be natural, or may be initiated, induced or extended by human activities), any expansion could threaten areas of heather.

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

Moorland gripping was frequently undertaken in an attempt to increase the quantity of

heather. Often its success was limited to the edge of the grips (Stewart and Lance 1983), and instead, threatened grouse productivity by draining wet areas and blanket bog so vital in producing abundant insects (especially craneflies) on which grouse chicks depend for survival (Hudson 1988). Some gripping threatened heather moor by initiating gully erosion, but little gripping seems to be undertaken now.

Although the loss of keepers and of grouse moors to sheep walks has serious implications for heather moorland, there is also grave concern about predator control where protected species such as peregrine falcons and merlins are also reputed to be destroyed. This problem has been identified in the Yorkshire Dales, and is suspected at times in the Peak District, but is not generally felt to be as severe as in parts of Wales and Scotland. Although not a threat to heather itself it damages the wildlife value, and is illegal.

In contrast, grouse moors which have become progressively isolated by afforestation or sheep walk find it increasingly difficult to control predators (foxes and crows) adequately to ensure high grouse productivity. This could threaten the viability of the grouse moor and herald a move towards increased sheep grazing.

In general, there is no proven case that acid rain and other air pollutants threaten heather moorland, but an open view is being maintained in most areas. Other land uses are seen to take small areas of moorland such as for quarrying (eg. in Durham), roads, but none are large-scale or significant compared with the main issues. There is a fear that conservation of meadows in the Yorkshire Dales ESA could stimulate moorland improvement in allotments further up the valley sides which are excluded from the ESA boundary. Only where such areas lie in the Section 3 maps, could they be conserved as moorland.

3.4.5. The Current Situation And Future Requirements

i) The Present Situation

The current situation can be summarized by the generalization that the heather moorlands in the best condition to provide good landscape and wildlife value are those in productive management for grouse. There are many grouse moor owners who are restoring small areas of heather moor by spraying bracken, improving sheep management or reducing grazing pressures. In total, these will add up to several thousand acres of heather ground being improved for grouse, wildlife and landscape. In contrast, those which are used primarily as sheep walk are, or could, suffer from overgrazing or poor management practices which result in the deterioration of the heather, its eventual loss and the degradation of the whole moorland ecosystem. There are exceptions to the latter scenario. Where SSSIs have been designated, and where NCC have 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 ones, and as a result of Farm Grant

Notifications) to prevent moorland cultivation and agricultural improvement, and which seek better management to maintain a healthy heather-dominated habitat.

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. Other public ownership of moorlands is limited. The Peak Park Joint Planning Board is attempting to manage extensive heather moorlands in an integrated approach for wildlife, landscape, (which will also benefit grouse although no shooting is permitted where they own the shooting rights) and farming. The Lake District Special Planning Board own several moorland areas, and is looking 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 the management of Board-owned and adjacent SSSI land. The Yorkshire Dales not only owns no moorland, but has a policy which prevents them purchasing land. In the North Yorkshire Moors, in contrast, ownership of a major moorland estate, much of which is SSSI, has involved developing special management prescriptions.

The National Trust too owns large areas of moorland, much of which lies in the Lake District and Peak District. Not all of these areas support heather, but an active restoration programme in the Peak District is achieving significant reinstatement of heather and bilberry by removal of all sheep on part of Kinderscout.

Very little heather moorland is managed directly by public authorities, or by wildlife organizations, yet it is these which are promoting the major importance of the moorlands for landscape and wildlife. They are mostly dependent on moorland owners managing land within the economic framework for grouse or sheep to cater also for these other qualities. The National Parks have policies to promote and protect heather moorland, the NCC designate SSSIs, both can offer financial incentives in management agreements not to plough up or otherwise alter the nature of the moors, but few have so far been established. For example, for two areas in Durham, agreements on SSSIs with the NCC include facilities to reduce sheep stocks.

On the other hand, these other agents, along with academic and research institutions have established numerous research and monitoring projects investigating aspects of moorland ecology, dynamics and management. The Countryside Commission have 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, major research and restoration projects were initiated after the devastating 1976 moorland fires, and a programme of restoration still continues. Bracken control is now a major theme, with grants being provided to control bracken and restore heather moorland. The grants are provided as part of an agreed management package which incorporates moorland management for wildlife, and better grazing control.

In many upland areas, the RSPB and NCC have been monitoring moorland birds, and the Lake District Special Planning Board have recently undertaken their own survey, all in an attempt to identify the most valuable areas so that these can be protected from deleterious environmental changes in the future. Phase I and II habitat surveys have also been initiated as, for example, in the Yorkshire Dales and Peak District. The NCC are also establishing studies on the ecological status of several specific estates, in the Forest of Bowland where heather moorland has been lost, in an attempt to quantify the changes and develop a suitable management regime. They have also nearly completed a major review of their moorland SSSIs entitled "Conservation and evaluation of British Uplands" which includes heather communities. When completed, not only will the most important areas be identified for different species or communities, but data on the extent of heather communities will be available. More extensive monitoring is being carried out in various National Parks using remote sensing. Durham University and the National Remote Sensing Centre at Farnborough are both involved.

The North of England Grouse Research Project, which was established in 1979, continues to study grouse-related problems. Dr. Yalden (Manchester University Zoology Department) 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 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 re-introduced, are being undertaken on the 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 Newcastle University), as well as practical heather restoration and management. Other management experiments are being initiated in the Northumberland National Park on 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.

ii) The Future

In general there is considerable optimism over the future of heather moorland in the north of England. The interest in heather seems to be wider than ever, to the extent that it has become a topical subject. For the most part, there is confidence in the future sound management of grouse moors, and the concomitant production of good landscape and wildlife habitats. However, the nature of heather moorland has become polarized, with well managed grouse moors at one end of the spectrum and overstocked or poorly managed sheep walks at the opposite extreme. There is far less optimism, and indeed grave concern amongst those bodies and individuals who value heather-based communities, for the future of these where sheep farming predominates, particularly where there are no safeguards or deterrents to prevent or retard heather loss, and especially on common land.

The overwhelming, urgent, need is for a major review of the agricultural policies which support and produce incentives for grazing management in the Uplands. Not only are the existing moors where heather is still a major visual and ecological component at risk, but all those where heather and other *ericaceous* shrubs have nearly been eliminated could still be restored if the incentives were appropriate.

Various suggestions have been made for improvements in the upland agricultural support system. HLCA payments are generally regarded as the worst offenders. Just altering the count date from January to June might alleviate the urge to maximize the winter numbers on the moor. Alternatives include productivity or % lambs weaned payments to encourage better management, or some means of controlling stocking rates. There is the danger that productivity incentives might increase stocking further rather than improve lambing percentages and decrease stocking levels. The Dark Peak ESA is attempting to tackle some of these problems, and a system similar to this applicable to all moorlands (inside and outside National Parks). Any such system would have to be individually designed for each moor, and the prescriptions would need to vary geographically, even in a small area where conditions and sheep varieties vary. This is not the approach adopted in the Dark Peak ESA, but is the only one felt to be sufficiently sensitive to produce a healthy moorland environment. It would necessitate a high enough level of incentive payment to attract interest and support from the agricultural community, and would have to be organized on a local basis. A holistic approach is required whereby the vegetation of the moor/holding is mapped, the different vegetation types measured, and these and the management regime (shepherding or not, burning or not, etc.) fed into a computer model of the type being tested by HFRO but with greater emphasis on the needs of wildlife and landscape. Only in this way can a proper balanced approach be obtained, and the moors be managed based on their natural carrying capacity. Incentives (such as high levels of grant aid) to increase winter in-housing of stock and provide feed for indoor animals, could reduce winter use of moorlands (provided this did not encourage an increase in stock) and would ease the problems.

There seems to be a great need for better training in moorland management, particularly burning, and for incentives to encourage farmers not to winter feed on heather, to shepherd properly again, and to appreciate more the dynamics and ecology of moorlands. Improved shepherding is particularly important in the National Parks where there are often policies against moorland fencing. The Scottish Agricultural Colleges Technical note is an important contribution to the information farmers receive, but there needs to be some mechanism whereby such advice is not only heeded but put into practise. Better uptake of moorland management grants (eg. for heather burning) needs to be facilitated by altering the definition of those who are eligible.

Management of sheep grazed commons on heather moorland need special attention. The preparation of a management plan as proposed by the Common Land Forum is a welcome move, but only if it can incorporate a reduction of grazing or better standards of management where necessary. This implies a special need for incentives to achieve these. Only MAFF are regarded as the appropriate body to influence graziers of commons,

yet a greater input from other interests into a management plan to obtain the optimum balance seems essential. This might not always be straightforward (eg. where the NCC or National Park Authority had a vested interest due to an SSSI, Management Agreement or because of the Section 3 map).

Achieving this kind of more balanced land use will benefit wildlife, landscape, grouse and sheep productivity, and will go some way to satisfying the general demand for better integrated land management which is being articulated by conservation bodies and National Park Authorities. There is a general demand for further research on this subject, particularly to demonstrate the efficacy of the approach, but also to determine what the ecological and economic benefits of such a system might be.

An important element of such research would be the retention of jobs in the hill and an increase in local and traditional skills of land management. Another aspect is the need to develop practical methods based on Grant *et al*'s (1978) work of measuring the consumption of heather in the field, and translating this into appropriate grazing regimes, seasons, and shepherding programmes. In the past, it was the farmers and agricultural advisors who determined such things. Since so much heather has disappeared or become degraded under these regimes, confidence in the agricultural advice has diminished, and others not traditionally involved in agricultural land management feel the need to assist in determining an integrated land management prescription. In addition, National Park authorities and NCC are seeking management agreements to integrate wildlife and landscape considerations with agricultural or grouse interests. MAFF too need to be able to monitor the success or otherwise of their ESAs. In all these situations, heather needs to be monitored, and appropriate grazing regimes determined. It is particularly important to assess the carrying capacities of different types of heather moor. The growth rate, susceptibility to winter browning vary geographically, and with altitude, and these need to be included in research into appropriate management prescriptions along with consideration of the different sheep breeds.

As a measure of the urgency with which this research needs to be undertaken, it is important that a better idea of the losses of heather moorland is gained. Another important controversial element which needs special attention is the future management of common land, and the issues of access and conflict with wildlife and grouse shooting. The monitoring of key species, such as moorland birds, on a regular basis would be an essential prerequisite to facilitate evaluation of the efficacy of new management programmes. The more quantitative and extensive these data are, the stronger is the case for conservation of the remaining heather moorland, and that can only be to the benefit of all moorland users: its wildlife, the visitors who appreciate its fine landscapes, the grouse moor owner and hill farmer.

3.4.6. Summary

Although heather moorland is extensive in the uplands of northern England, it has suffered major losses over the last 10 years. Most of the healthy heather moorland is managed for grouse, which is benefitting from an economic revival. There is much heather moorland, though which is suffering from poor management and over grazing by sheep. Very little heather moorland is managed for integrated purposes by public authorities or other agencies.

The main threat to the future of heather moorland is generally agreed to be the agricultural support system which has resulted in a reduction in labour, reduced shepherding, an increase in stock and reduction in good management, reform of this support system is regarded as urgent.

Afforestation was, but is no longer, considered as a major threat; but future access and disturbance on moorlands is worrying grouse moor owners and those responsible for ensuring conservation of wildlife, especially breeding birds.

The spread of bracken is being tackled in some areas, but is not a problem everywhere. Other factors are of local importance.

There is currently considerable interest in, and research into, the issues of heather moorland, but outstanding requirements for future investigation (apart from reform of the agricultural support system) include monitoring the losses of heather moorland in order to prepare a better case for its conservation; monitoring key species like breeding birds to use as indicators of the degree of success of new management practices; research into the optimum integrated management systems and how to monitor their efficacy, and the development of new incentives to encourage the conservation of heather moorland.

4. DISCUSSION

'Gold under bracken, silver under gorse, famine under heather' is a traditional saying of Welsh hill farmers (Condry 1966), it highlights the nutrient poor soil conditions heather requires to grow. 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 reflect history as well as ecology. As illustrated in figure 4.1, heather is capable of growing throughout Great Britain, only avoiding rich fertile soils or those found on chalk or limestone. In order to promote or maintain heather it is necessary to manage the land so that nutrients are being continually removed and not allowing accumulation - 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 *Calluna*, whilst nearly a third of the NorthYorks Moors is covered. The Environmentally Sensitive Areas 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 of the 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 Luneberg heath. Having created a designation it is essential to support it by encouraging land owners to follow sympathetic management practises. 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 areas such as the dynamics of heather moorlands and the influences of management practises. Heather and its decline is a subject which has caught the imagination of many people and there are plenty of ideas as to the cause of change these must be investigated thoroughly. If policies are phrased to encourage heather it will be necessary to monitor heather areas. This can be done using satellite imagery and aerial photography as shown here and in the MLC project (HTS 1977).

However monitoring should not be solely by remote sensing, for the quality of the habitat is

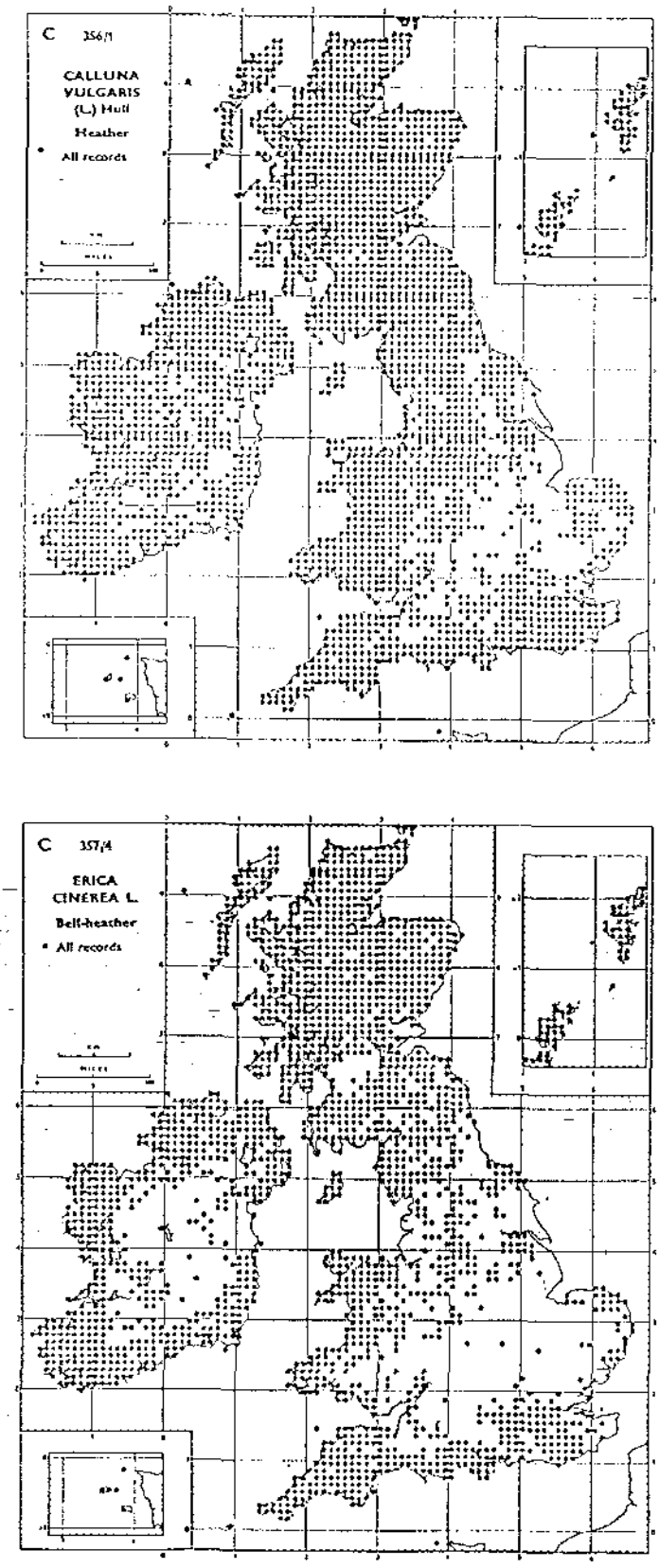

Figure 4.1 The distribution of *Calluna vulgaris* (L) Hull and *Erica cineria*(L) in 10km2 tetrads of Great Britain (from Perring and Walters 1962)

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. So, 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 within the MLC dataset the general trend of heather loss can be seen. However the estimates of heather cover presented in tables 2.2.4 and 2.2.6 show an increase between 1980 and 1984. A number of points must be taken into account, firstly the estimates are collected in very different ways, the aerial photography used in the MLC 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 since the areas involved are relatively small. Secondly 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 2.2.4 does illustrate a number of interesting points:-

i. contemporary estimates produced by three different techniques (satellite imagery, aerial photography and field survey) are of the same order of magnitude, despite differences in coverage and definition.
ii. major losses in lowland heaths can be seen in areas such as East Anglia and much of what reamains is becoming fragmented.
iii. losses of lowland heath are masked if national estimates are presented since heather moorland covers a much larger area.
iv. the heather moorland in the north of England shows proportionately less change and the changes may be due to differences in definition.
v measurements of cover cannot show changes of status of heather
vi. rates of loss of heather cannot be used to predict future losses, unless and until the relationships between management and land cover are known.
vii. The long life cycle of heather will act as a buffer to change, but catostrophic losses may occur due to changes in management made in the past.

The value of detailed local information for the designation of any new areas would also be

invaluable. For if table 2.2.1 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 the 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. Perhaps a micro-computer with a knowledge based system could help taylor advice to suit different conditions.

5. REFERENCES AND BIBLIOGRAPHY

Andersen, P. (1986) Accidental Moorland Fires in the Peak District : a study of their incidence and ecological implications.
Peak District Moorland Restoration Project PPJPB.

Anderson, P. (In Prep.). Moorland recreation and Wildlife, a review of the available information.
Moorland Management Project , PPJPB

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
I.T.E

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.* (eds. Bayfield, N.G. and Barrow, G.C.) RERG Report No .9.

Beijerinck, W. (1940). *Calluna* a monograph on the Scotch heather .
Vehr. Akad.Wet. Amst.(Srd Sect.), 38, 1-180.

Berendse, F. and Aerts, R. (1984). Competition between *Erica tetralix* L. and *Molinia caerulea* (L.) Moench as affected by the availability of nutrients.
Oecolgia Fl. 5, 1 13.

Birkett, N.L. (1970) Insects
In *The Natural history of th Lake District* (Eds Hervey G.A.K. & Barnes J.A.G.) Warne : London

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.
In *Proc. 5th Int. Symp. on Insect -Plant Relationships* (eds Vissier J.H & Minks A.K.) 215-223 Pudoek: Wageningen

Bunce, R.G.H. (1987). The extent of upland areas in Great Britain

In: *Agriculture and conservation in the hills and uplands*, (eds Bell, M. and Bunce R.G.H.) pp. 19-21 ITE, Grange-over-Sands.

Cameron, A.E., McHardy, J.W. and Bennett, T.T. (1944) The heather beetle (*Lochmaea suturalis*) its biology and control.
British Field Sports Society: Petworth

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.
Bulletin d' Ecologie , 11, 221-232.

Chapman, S. B., Rose, R. J. & Clarke, R. T. (1988). A model of the phosphorus dynamics of *Calluna* heathland.
J. Ecol (in press).

Chapman, S. B., Rose, R. J. & Basanta M. (in press). Phosphorus adsorption by soils from heathlands in southern England in relation to successional change.
J. Appl. Ecol. .

Chapman. S. B., Clarke. R. J. & Webb, N. R. (in press). The survey and assessment of heathland in Dorset for conservation.
Biol. Conserv.

Condry, W M. (1981). The natural history of Wales.
New Naturalist No 66. 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.
Annual Report of the Research Institute for Nature Management , 24-26.

Diemont, W. H. & Heil .G. W. (19??) Some long-term observations on cyclical and seral processes in Dutch heathlands.
Biol. Conserv. , 30, 283-290.

Duffey. E.A. (1976). Breckland.
In: *Nature in Norfolk: a heritage in trust*. Norwich: Norfolk Naturalists Trust/Jarrold.

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.

Gimingham, C. H. (1972). Ecology of heathlands.
Chapman & Hall, London.

Gimingham, C. H.. Chapman. S. B. & Webb. N. R. (1979). European heathlands.
In: *Heathlands and related shrublands* . (Ed. by R. L. Specht). Ecosystems of the World 9a ,pp. 365-413. Elsevier, Amsterdam.

Gimingham. C. H. & Smidt, J. T. de. (1983). Heaths as natural and semi-natural vegetation.
In: *Man's impact upon vegetation* . (Ed. W. Holzner,M. J. A. Werger & I. Ikusima). pp. 185-199, Junk. The Hague.

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)
Entomologists monthly mag. **98**, 196

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**, 311-320.

Graebner, P. (1901). (1st edn.).Die Vegetation der Erde, V. Die Heide Norddeutschlands Ed. Engler, A. & Drude, O., Leipzig.

Graebner P. (1925). Die Vegetation der Erde V. Die Heide Norddeutschlands.
Englemann. Leipzig.

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. Response of the sward.
J. Br.Grassld Soc. 33. 289-300.

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.

Heil, G. W. (1984). Nutrients and the species composition of heathland.,
Ph.D. thesis, University of Utrecht 1984.

Heil. G. W. & Diemont. W. H. (1983). Raised nutrient levels change heathland into grassland.
Vegetatio , 58.113-120.

Hunting Technical Services (1986) Monitoring Landscape Change
Hunting Technical Services Ltd: Borehamwood

Hudson, P. (1983) , Red grouse production and management in relation to tourism.
In: *Moorlands: Wildlife Conservation, Amenity and Recreation* (ed .Hearn K. A.) 45-54, Recreational Ecology Research Group Report No.8.

Hudson, P. (1984), Some Effects of sheep management on heather moorlands in Northern England.
In: *Agriculture and the Enviroment* (ed. Jenkins, D.) I.T.E symposium 13, 143-149.

Hudson, P. (1986), Red Grouse, the Biology and management of a wild gamebird.
North of England Grouse Research Project, The Game Consevancy Trust.

Hunter, R.F. (1962), Hill sheep and their pasture: a study of sheep grazing in South-east Scotland.
J.Ecol. 50 , 651-680.

I.T.E. (1978), Upland land use in England and Wales, a desk study compiled by I.T.E. for the Dept of Enviroment.
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,* (eds Bell M. and Bunce R.G.H.) pp. 109-115. ITE, Grange-over-Sands.

Lofthouse, R G A. (1980). The Berwyn Mountains area of Wales: an appraisal.
Cardiff: HMSO

MacEwan, M. and Sinclair, G.(1983), New life for the hills : policies for farming and conservation in the uplands.
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 *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. 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.

Marrs. R.H. & Lowday, J.E. (in press). Management of lowland heaths.
Peterborough: Nature Conservancy Council.

Miller, G.R. & Bayfield, N.G. (1988) Seed banks of organic soils.
Three Peaks Project: 5th report to Yorkshire Dales National Park Committee. ITE, Banchory.

Miller, G.R. & Cummins, R.P. (1987).
Arctic Alp. Res. **19**, (in press).

Miller, G.R., Miles, J. & Heal, O.W. (1984). Moorland management: A study of Exmoor
ITE, Cambridge.

Milne, J.A. ,Bagley, L. and 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
Universe Books: New York

Morison, G. (1963) The Heather Beetle (*Lochmaea suturalis* Thompson)
North of Scotland College of Agriculture, Aberdeen

Muirburn Working Party (1977) A guide to good muirburn practice.
HMSO, Edinburgh.

Myberget, S. (1983), Desertion of nests by willow grouse.
Fauna norv. Ser. C. Cinclus, 6, 109-113

NCC (1987). Changes in the Cumbrian countryside.
NCC, Peterborough.

NCC (1988). Changes in the Grampian countryside.
NCC, Peterborough.

Nielsen, B.O., (1986). Outbreaks of the heather beetle (*Lochmaea suturalis* Thoms.) in Danish heathland 1900-1984 (Coleptera: Chrysomelidae).
Entomologiske Meddelelser 53, 99-109.

Noirfalise. A. & Vanesse. R. (1976). Heathlands of western Europe .
Council of Europe. Strasbourg.

North York Moors National Park (1982), The future of the Moorland.

Parry, M.L. (1977), Mapping moorland change: a framework for land-use decisions in the Peak District.
Peak District National Park.

Pearsall, W.H, (1968), Mountains and Moorlands.
Fontana New Natrualist.

Pearsall, W.H. & Pennington, W. (1973), The Lake District.
New Naturalist, Collins.

Perring, F.H. & Walters, S.M. (1962) Atlas of the British Flora
BSBI: Norwich

Phillips, J. , Yalden, D.W. & Tallis, J. (1981) Peak District Moorland Erosion Study Phase 1 Report.
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 , 211-215

Porchester, Lord (1977). A study of Exmoor.
HMSO, London.

Ratcliffe, D A. (1977). A nature conservation review (vols 1 and 2)
Cambridge: CUP

Ratcliffe, D A & Birks, H J B. (1980). Classification of upland vegetation types in Britain.
Unpublished NCC report.

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

R.S.P.B. (1984), Hill farming and Birds. A survival plan.

Rubel. 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 prepared by 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. (1979). (ed.) Heathlands and related shrublands .
Ecosystems of the world **9a & 9b**. Elsevier. Amsterdam.

Specht, R. L. (1979). Heathlands and related shrublands of the world.
In: *Heathlands and related shrublands* . Ecosystems of the world **9a**, 1-18. Elsevier, Amsterdam.

Stewart, A.J.A. & Lance, A.N. (1983) Moor draining: a review of impacts of land use.
J. of Environ. Manag. **17** , 81-99.

Tubbs, C. R.(1986). The New Forest .
Collins. London.

Van der Zande, (1984), Outdoor recreation and birds : conflict or symbiosis?
Thesis, University of Leiden.

Watson, A. and Miller, G.R. (1976), Grouse management. (2nd edit.)
Fordingbridge, Game Concervancy.

Watson A. (1981), Effects of human impact on ptarmigan and red grouse near ski lifts in Scotland.
In: Institute of Terrestrial Ecology : Annual Report 1981, 51, ITE.

Watson. A.. Miller, G.R. & Green, F.H.W. (1966)
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 mosaics? A case study of heathlands in southern England.
In *Inselokologie - Andwendung in der Planung des landlichen Raums* (ed. W. Zielonkowski & H.- J. Mader). Akademie fur Naturschutz und Landschaftspfledge. Laufen-Salzach.

Webb. N. R. (1986). Heathlands.
Collins, London.

Webb, N. R. (in press). Studies on the invertebrate fauna of fragmented heathland in Dorset and the implications for conservation.
Biological Conservation

Webb, N. R. & Haskins, L. E. (1980). An ecological survey of heathlands

in the Poole basin, Dorset, England. in 1978.
Biological Conservation 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. and 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 Group Bulletin 46, 34-35.

Yalden, P.E. and Yalden, D.W. (1988). The level of recreational pressure on blanket
bog in the Peak District National Park, England.
Biol. conserv., 44, 213-227.

A useful annotated bibliography of research into heather management has been produced by :-

Hooper, S. (1987) Heather, grouse and land use management
The Agricultural Environment Research Group: University of Newcastle upon Tyne

APPENDICES

6.1 THE DECLINE OF HEATHER MOORLAND IN THE UK

6.1.1 Background

Heather-dominant vegetation was formerly widespread in north-west Europe but has been substantially reduced during this century. In the British Isles it occupies some 1.4 M ha (Bunce 1987). About 70% of this area is thought to be in Scotland. It is therefore necessary to appraise the data on England and Wales in the context of Great Britain as a whole.

Heather moorland is esteemed by conservationists because of its distinctive flora and fauna. It is much used by universities, polytechnics and schools for student exercises. The open, treeless landscape, purple-hued in late summer. is also a peculiarly British *tourist attraction. As sheep walk, deer forest or grouse moor, it is vital to the economy of* many upland estates. Heather moorland is thus much valued by a wide range of different interests. scientific, educational. cultural and economic. However. many heather moors occupy a pivotal position in successions leading, on the one hand, to scrub and on heather, to grassland. They are therefore vulnerable to changes in management..

6.1.2 Recent changes in the area of heather moor

Loss of heather moor often results from a deliberate change of land use. There can be little doubt that large blocks have been transformed into sown grassland or coniferous plantation during the past 40 years. Such losses are generally not well documented, although Porchester's (1977) study of Exmoor is an exception.

However, this paper is principally concerned with the more insidious shifts in vegetation composition that can result from the application of traditional grazing and burning practices. There is fragmentary but convincing evidence of the gradual conversion of heather moor to unimproved semi-natural grassland. Most quantitative information comes from England. For example,

i Anderson & Yalden (1981) attributed a 36% loss of heather moorland over 66 years in the Peak District to increases in sheep stocking rates.

ii Miller *et al.* (1984) related an encroachment of grasses and bracken around heather moor at Exmoor to heavy grazing and haphazard burning.

iii *In Cumbria, NCC (1987) recorded a 65% loss of heather moorland and a 12% loss* of heather-dominant blanket bog to unimproved grassland in 1940-1970.

Less information is available for Scotland. where losses may not be so great. anyway. However, NCC (1988) have reported a 25% conversion of heather moor to semi-natural grassland in Grampian Region; work in progress indicates losses of 6-30% elsewhere in Scotland. Also, the remarkable decline since the 19th century in red grouse bags on many western Scottish estates (Williams 1974) is circumstantial evidence of a loss of heather cover.

6.1.3 Causes of the conversion of heather moor to semi-natural grassland

There are 3 principal ways in which heather cover may be reduced.

i Grazing which removes >60% of annual growth can reduce competitive vigour or even kill the plant altogether. 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 *et al.* 1966). Defaecation and urination can 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. On the other hand. however, frequent or severe burning can kill both heather plants and any buried seeds. again leaving gaps for competitors (Miller *et al.* 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.

A combination of (i) and (ii) is particularly effective in eliminating heather whenever 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.

6.1.4 Restoring heather-dominant vegetation

The problem of maintaining heather dominance has been much researched and appropriate management prescriptions have been devised (Muirburning Working Party 1977). However, research is still needed on ways of restoring heather dominance where cover has been decreased or lost by improper management. In such situations, regeneration must come from seeds, whether newly shed, released from the seed bank, or deliberately sown.

MLURI, under contract to the Joseph Nickerson Heather Improvement foundation, have recently begun a new and ambitious research programme on the regeneration of heather from seeds .

6.1.5 Heather seed banks

Work by ITE in the eastern Highlands (Miller & Cummins 1987 and in preparation) has demonstrated that

i Large reserves of germinable heather seeds can accumulate in the soil, up to c. 100 K seeds m^{-2}

ii The half-life of heather seeds in the soil varies from 0.7 years to several decades, depending on local environment. In general, the greatest longevities are recorded at heather's upper altitudinal limit.

iii Although initial plant establishment from buried seeds is generally satisfactory, first winter mortality can be severe, especially at high altitude.

Evidence for the persistence of heather seeds in the soil comes also from contract work in the Yorkshire Dales (Miller & Bayfield 1988). Here, thousands of germinable heather seeds have been recorded from cotton-grass bogs where heather is either very sparse or totally absent.

The following areas of study can be highlighted as essential in understanding the decline of heather and most likely to yield results which can be translated in managment prescriptions.

i Determine the circumstances in which heather-dominant vegetation is most at risk. These 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.

ii Review published information on the relationships between herbivore stocking rates and the rate and direction of successional change on heather moorland.

This would take account mainly of work by MLURI (Grant and colleagues), ITE (especially Welch) and NCC (Lance 1987).

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

iv Surveys of the size and composition of seed banks in different vegetation types thought to have been dominated by heather at earlier successional stages.

v An investigation of the micro-distribution of heather seeds in the soil within vegetation types. In particular, evidence of consistent patterns of aggregation would be sought.

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

6.2 HEATHER DECLINE AND ATMOSPHERIC AMMONIA

6.2.1 Background

Species composition of heathland vegetation has been shown to be influenced by nutrient availability with increases in the inputs of nitrogen favouring the growth of grasses such as *Molinia carulea* relative to the heather *Calluna vulgaris*. 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 and Diemont, 1983).

6.2.2 The Netherlands

In the heathlands of the Netherlands a marked decline in the abundance of heather has been recorded (Diemont and Heil, 1983, 1984). Heather has been replaced by the grasses *Molinia caerulea*, and to a lesser extent *Deschampsia flexuosa* and *Festuca ovina*. The changes have been quite dramatic, with photographs showing *Calluna* dominated heathlands 15 years ago now dominated by the grasses noted above.

Many of the scientists in the Netherlands believe that the change is 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 in the Netherlands (Heil, 1984).

There are complications in the story, in particular that there have been changes in the use of some of this heathland and that the decline of the heather is also complicated by the role of the heather beetle (*Lochmaea suturalis*) which has certainly contributed to the change (Nielsen, 1986), but the extent to which the beetle has responded to changes in the nutritional status of the *Calluna* as a consequence of elevated NH_3 concentrations has not been quantified.

6.2.3 The UK

Concentrations of ammonia have only recently been monitored, and the methods rely mainly on 1 or 2 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 NH3. Norfolk, Suffolk and eastern Essex form the other 'high' zone, with annual average NH3 concentrations of 6 to 7 ppbv. The

west and north of Scotland show the smallest concentrations in the UK at 1 to 2 ppbv with the remaining areas of northern England, eastern and southern Scotland showing NH_3 concentrations of 2 to 4 ppbv. The other inputs of N from the atmosphere in rain as NH_4^+ and NO_3^- show a more complicated pattern, as shown in the attached results from the secondary acid deposition/wet deposition network. We do not have good spatial data for N deposition for the 1950s and 1960s, but have evidence that the areas with 'large' inputs (> 10 kg N ha-ly-l) are probably a factor of 2 larger now. These values are smaller, but of the same order as those for the Netherlands. However, there are important uncertainties in both the inputs and the species composition changes in the UK.

6.2.4 Deposition

We have been measuring NH_3 deposition onto moorland at ITE Edinburgh, and have shown that the process is limited by atmospheric rather than surface properties, and that large deposition rates generally apply. It is a fairly straightforward matter to calculate annual inputs for the moorland areas from air concentration, wind speed and vegetation height data, and this will be done as a part of our NH_3 deposition studies, but has not been done so far. We do not know enough about the exchange of NH_3 between agricultural crops and the atmosphere. The flux may be towards or away from the surface, depending on the fertilizer regime, soil chemistry and biology and the physiological state of the crop.

The deposition of NH_3 on forests is also poorly understood and may well represent a large component of the nitrogen inputs from the atmosphere. These two areas therefore require more work.

6.2.5 Species Composition

The studies in the Netherlands have stimulated interest here, but as yet little has been done. Work on the Penines by the University of Manchester (Woodin *et al.*, 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 will form part of an NCC sponsored study scheduled to begin in October 1988 at ITE Edinburgh. Related work at Imperial College and ITE Bangor is also just beginning. The current position in the UK is therefore that we do not know whether or not there is a pollution induced change in species composition, with the exception of sphagnum in the Penines, but appropriate studies are beginning.

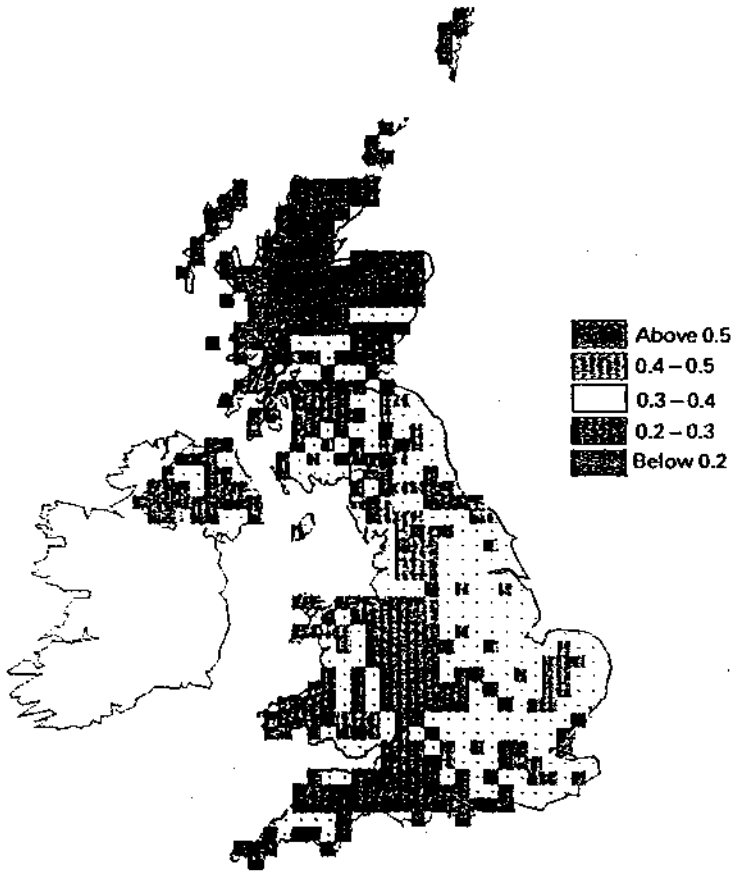

Figure 6.2.1 Wet Deposited Nitrate (g N m-2)

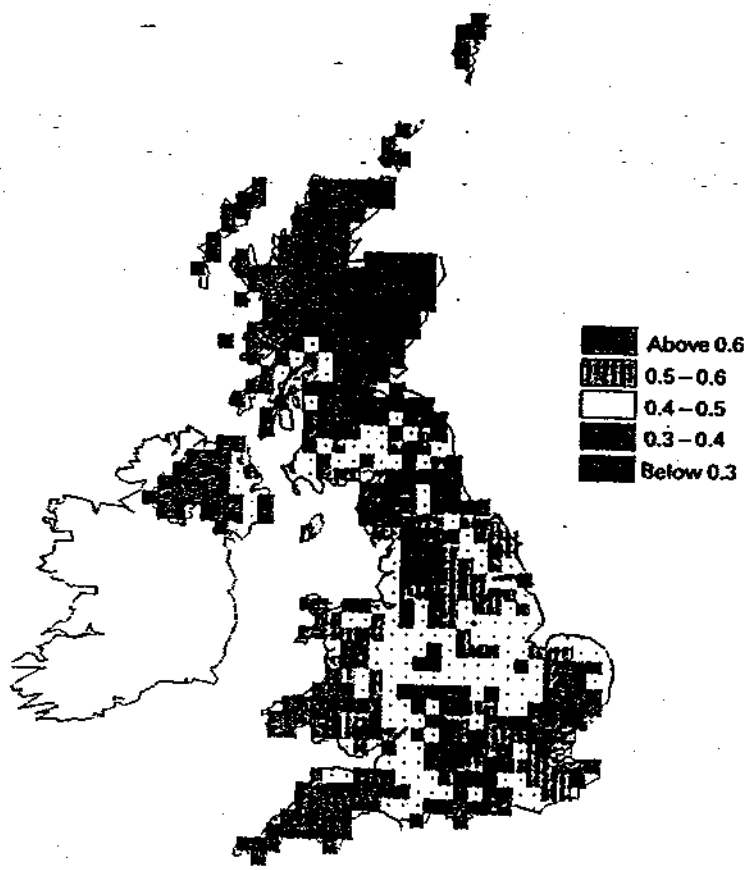

Figure 6.2.2 Wet deposited Ammonium (g N m-2)

6.3 THE HEATHER BEETLE *Lochmaea suturalis*

6.3.1 Life cycle

Moorlands and heaths are generally considered to be semi natural areas whose flora and fauna are stable until influenced by external factors such as land use management or pollution. The habitat, however, is only a transient successional stage and even while it is dominant it can suffer catastrophic defoliation by members of the heathland community. One insect species, the Heather Beetle, can acheive virtual pest status on heather moors. It is a member of the family *Chrysomelidae* (the leaf beetles), which is totally dependant upon *Calluna* 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 varies from region to region. In England and Wales most damage occurs in the north, with major outbreaks on southern heaths only occuring once every 10 years or so (Webb 1986). Despite the beetles requirement for a moist environment the worst outbreaks generally follow sequences of 2-3 warm dry summers (Morison 1963) .

Eggs are laid in damp heather litter or *Sphagnum* moss in March and April, if the conditions are suitable (relative humidity approximately 70%) hatching occurs in 3-4 weeks. The larvae feed on the *Calluna* 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 *Calluna* 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 et al,1944, Birkett 1970 and Webb 1986).

6.3.2 Control

The problem of defoliation of large areas of heather has been recorded since the middle of the last century and the beetle has been linked with invasion of Dutch heaths by grass species (Diemont & Heil 1984). Interest has been shown in natural predation and parasites, Cameron et al (1944) considered insect predators could limit populations but there is no hard evidence of this. Potential agents for biological control include a parasitic wasp (Golightly 1962) and a fungus (Brunstung 1982) further investigations of these agents would be needed before they could be used.