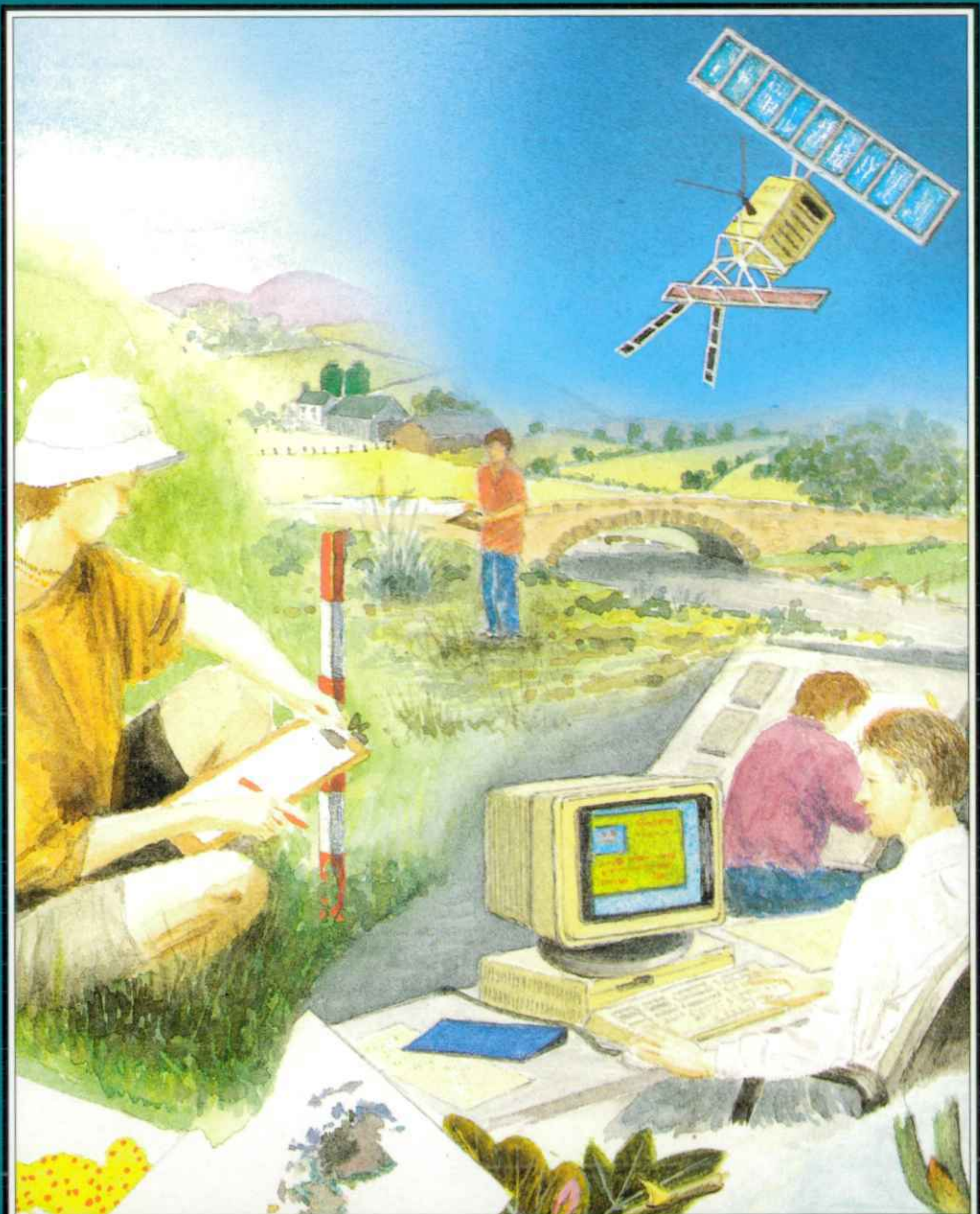
Department of the Environment

Countryside Survey 1990



Countryside Survey 1990
Main Report

Department of the Environment

COUNTRYSIDE SURVEY 1990

MAIN REPORT

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PREFACE

The countryside is changing – but how quickly and in what ways? This series of 'Countryside 1990' reports gives an up-to-date and comprehensive picture of the current state of the countryside and recent changes in it. The series is based on the programme of work sponsored by the Department of the Environment and associated with Countryside Survey 1990. By combining for the first time pioneering techniques in satellite image analysis and detailed ecological field survey, the study provides a comprehensive overview of land cover, landscape features and habitats in Great Britain. The information from this programme will be central to the evaluation and development of Government.

The Environment White Paper 'This Common Inheritance' and the Department of the Environment's paper on 'Action for the Countryside' have reviewed the Government's policies for the countryside. These policies and related initiatives concentrate on action to maintain a prosperous economy and thriving communities in the countryside, to protect and enhance the landscape, to provide for public enjoyment of the countryside, and to protect and conserve wildlife. They are not put forward in isolation but are firmly based on principles presented in the White Paper. Two of these are particularly relevant here: the need to base policies on the best evidence and analysis available; and the need to inform public debate by ensuring the publication of facts. This series of reports reflects the Government's commitment to these principles.

Whilst Countryside Survey 1990 is primarily a foundation for the future, it also provides an analysis of changes in the land cover and vegetation of the British countryside between in 1978 and 1990. Some of the changes which this study describes are a matter of public concern and the Government has already taken action to address them. The causes of some of the other changes identified are complex and not fully understood, and more work will be required to assess their significance.

'Countryside Survey 1990 – Main Report', the second volume in the series, presents the main results of this innovative survey of the British countryside. The report includes details about the stock, distribution of, and recent changes in the land cover, landscape features, vegetation, soils and freshwater animals. The data collected form a baseline against which future changes in the countryside can be measured and the effect of Government policies evaluated. Countryside Survey 1990 will make an important contribution to the UK Strategy for Sustainable Development and the UK Biodiversity Action Plan.

This Main Report is accompanied by a non-technical Summary Report which is available from the Department of the Environment.

ACKNOWLEDGEMENTS

With a project of this size, many people have contributed to the end-product. It would be difficult to identify and thank all of those involved. However, the authors are most grateful to all those who have helped in designing this project, carrying out the field-, desk- and computer-based operations, and checking this and other reports. We are especially grateful to the Department of the Environment (DOE), the British National Space Centre/ Department of Trade and Industry, the former Nature Conservancy Council and the Natural Environment Research Council, who have funded this work.

In particular, the authors acknowledge and appreciate the pivotal role that **Prof Bill Heal** (ITE) and **Mr John Peters** (formerly DOE) played in setting up the Countryside Survey 1990 (CS1990). It was their belief, commitment and hard work in the late 1980s that gained the support of their respective organisations.

Others to whom the authors are grateful for their help and encouragement along the way include, in DOE, **Mr Robin Sharp, Mr Patrick Leonard, Dr Richard Shaw, Dr Sarah Webster,** and especially **Dr Terry Parr** (now with ITE) and **Dr Andrew Stott**. Similarly, in NERC, **Prof Mike Roberts** (ITE), **Prof Alisdair Berrie** (formerly of the Institute of Freshwater Ecology (IFE)), **Dr Barry Wyatt** (ITE), **Dr John Wright** (IFE) have all played significant parts in providing resources and encouragement. Members of the **CS1990 Advisory Group** have been extremely helpful and supportive both in their official capacities and as friends and colleagues.

At *ITE Merlewood*, from where the field survey was administered, special thanks go to **Eamonn Molloy, Diane Pearson** and **Rod Pilbeam,** and to all of the staff (see below) who helped with fieldwork, data preparation, digitising and analysis.

The co-ordinators of the field survey, based at the ITE research stations, were: **Graham Bell, Alan Buse, Roger Cummins, Geoff Radford,** and **Rowley Snazell.**

The field surveyors, including ITE staff and temporary employees, were: **Tanya Barden, Karen Burke, Jim Campbell, Jo Clark, Jane Clayton, Maureen Cochran, Max Coleman, Liz Cooper, Jim Conroy, Ruth Cox, Imogen Crawford, Simon Cuming, Anita Diaz, Rebecca Dunn, Noranne Ellis, Doug Evans, Karen Findlay, Don French, William Gray, Nick Greatorex-Davies, Martin Hayes, Jason Kerry, Ewan Laurie, Gabby Levine, Kevin McGlyn, Amanda Marler, Neil Matthews, Eamonn Molloy, Tom Murray, Miles Nunn, Colin Pendry, Karen Pollock, Mike Prosser, Catherine Pumphrey, Rob Rose, Fred Rumsey, Dave Scott, Owen Smith, Stuart Smith, Ian Taylor, Hilary Wallace, Mark Watson, and Gwyn Williams.**

Those involved with the lengthy and often tedious task of digitising field data included: **Tanya Barden, Mike Brown, Jim Conroy, Simon Cuming, Roger Cummins, Mark Harrison, Tim Haythornthwaite, Eamonn Molloy, Tom Murray, Stuart Powling, Barbara Strathern, Diane Pearson, Rod Pilbeam, and Dave Scott.** Important methodological developments, associated with analysis of the digitised data using Geographical Information Systems, were undertaken by **Ruth Cox**.

At *ITE Monks Wood*, **Arwyn Jones** was involved in most of the land cover mapping on which the CS1990 remote sensing work was based. **Nigel Brown, Andrew Mort, Marlies Sanders, Andy Thomson, Jacqui Ullyett and Sue Wallis** all played active parts in the production of land cover and pattern data and in their integration with the CS1990 field survey.

At *IFE River Laboratory*, the running-water samples from CS1990 were collected by the field survey teams (as above). Samples were sorted by **Marc Ingelrelst, Angela Matthews, Kay Symes and Jessica Winder**. Most Chironomidae and Oligochaeta were mounted on slides by **Angela Matthews**, preparatory to identification. Specimens were identified by **John Bass, John Blackburn, Rick Gunn and Marc Ingelrelst.** The 1988 feasibility study samples were collected by **Rick Gunn** and **Hazel Johnson** and processed by them and **John Blackburn.**

The authors are grateful to the many people who have provided comments and suggestions relating to the drafting of this report, to **Karen Threlfall** who was responsible for preparation of the final document, and also to **Penny Ward** for assisting with proof-reading.

Last, and most importantly, the authors would like to take this opportunity to thank all of the landowners, farmers and other land managers who have given their permission for surveyors to visit their holdings. Without such co-operation, field surveys of the type reported here would not be possible.

CONTENTS

EXECUTIVE SUMMARY

Introduction

1 Countryside Survey 1990 (CS1990) is one of the most comprehensive surveys of the British countryside that has ever been carried out. It is also the first survey to be based on the integration of information from satellite imagery and traditional field survey methods. The primary aims of the survey were to provide information on the stock of land cover, landscape features and habitats in Great Britain (GB) in 1990, to identify change in these by reference to earlier data, and to establish a new baseline for the measurement of future change. Although some aspects of the survey include urban areas, the main focus was on the rural environment.

2 The survey was undertaken by the Institute of Terrestrial Ecology (ITE) and the Institute of Freshwater Ecology (IFE), and principal funding was provided by the Department of the Environment (DOE), the Department of Trade and Industry (DTI), the British National Space Centre (BNSC), and the Natural Environment Research Council (NERC). Additional funding was provided by the former Nature Conservancy Council (NCC).

3 The British countryside is complex; CS1990 combined detailed recording of species and landscape features, together with a census of the principal land cover in GB. For the first time, these were integrated by co-ordinating field survey with satellite imagery on a national scale. The former provided information on the quality of habitats, whereas the latter enabled information to be collected from a complete national coverage of broader land cover categories. The primary output of the survey was a data base, but the main objective of this report is to convey the principal findings of initial analyses of these data. The Countryside Information System (CIS), a computer-based system, has been developed to enable ready access to more detailed results.

Methods

4 The field survey methodology was developed during previous baseline surveys carried out by ITE in 1978 and 1984, and the IFE methodology was tested in a pilot study in 1988. During the same period, techniques for classifying satellite imagery to provide information on land cover classes were being developed in ITE. As a method of linking these different sorts of data, ITE developed a stratification system which acts both as a framework for sample surveys, and as a means of integrating survey results. This approach, the ITE Land Classification, classified all 1 km squares in Britain into 32 relatively homogeneous 'Land Classes'. For the purpose of the analysis of CS1990 data, these Classes have been aggregated into four landscape types: '**arable**', '**pastural**', '**marginal upland**' and '**upland**'.

5 The main source of information on broad-scale land cover information was obtained from satellite imagery. A satellite land cover map of GB was produced from Landsat Thematic Mapper imagery using images for dates as close as possible to 1990. Land cover data were summarised in 17 cover classes for all c 240 000 1 km squares in GB. Although the information is presented here in terms of these 17 classes, further subdivisions of these main cover types have been identified. Similarly, information is available at 25 m x 25 m pixel scale, although it has been summarised at the 1 km square level for CS1990 and CIS.

6 To give greater detail on components within the countryside, a stratified random sample of 508 1 km squares was drawn from the 32 ITE Land Classes and data recorded, through field survey of each 1 km square, about land cover, landscape features, habitats and vegetation. Simultaneously, data were collected on freshwater fauna (macro-invertebrates) in flowing watercourses. Soil information was also obtained for the 508 sample squares. A rigorous programme of quality control was carried out, including a Quality Assurance Exercise, to ensure that methods and results were objective, reliable and repeatable.

7 Species data for over 1200 vascular plants and a limited list of mosses and liverworts were recorded from three types of plot in

1978 and 1990: **Main plots** were placed at random throughout the 1 km squares; **linear plots** were placed along hedgerows, streams and verges; and **Habitat** plots were targetted to provide additional information on areas of semi-natural vegetation. These data were analysed by statistical techniques developed specifically for vegetation data, to derive stock and change information.

8 The land cover and landscape features for 1984 and 1990 were recorded using a Geographical Information System (GIS) - ARC/INFO. The GIS enabled automated measurement of change, but also provides a baseline digital data base for future monitoring. For the current report, the descriptors of the land cover used in the field survey have been summarised into 58 categories but they can be analysed at any required level of detail.

9 Integration of the satellite land cover map with data from the field survey has been demonstrated. In addition, subsets of the 508 sample 1 km squares were used to determine the correspondence between the 17 land cover categories from the satellite image classification, and the field survey data. This provides a calibration between the two surveys and greatly extends their applications.

Land cover

Satellite land cover map

10 The land cover of Great Britain was mapped from satellite imagery. A total of 17 key cover classes were used to compare with the CS1990 field data categories. The data have been summarised at a 1 km square level, and incorporated into the CIS. Managed grass covered the largest area in Britain (27%), followed by tilled land (21%) and open shrub heath moor (12%). England was predominantly tilled land and managed grass (66%), whereas semi-natural vegetation dominated in Scotland (57%) and Wales (39%).

11 Although in the arable landscapes tilled land comprised 41% of the land cover, managed grasslands were significant at 29%. The pattern was reversed in the pastural landscapes, with 39% managed grasslands and 22% tilled land; more land was also covered by semi-natural vegetation categories. In the marginal upland landscapes, managed grasslands covered 28%, with heath and moorland at 18%, indicating a mixture of contrasting land cover types within the landscape. The upland landscapes were dominated by dwarf shrub heath and bog, with the combined totals for open and dense heaths, moors and bogs being over 68%.

12 Pattern analysis was also carried out for the whole of GB using the satellite data to determine, for example, boundary lengths between the 17 cover classes. Pixels which adjoin or cross over boundaries represented 44% of the total, and their distributions were compared within landscapes.

Comparison of field survey and satellite data

13 The results from the land cover survey of the sample 1 km squares in the field show good general agreement with the satellite-derived land cover map for most classes. For example, for tilled land, both figures were 21%, and managed grass covered 29% (field) compared with 27% (satellite). Some categories, eg open shrub heath/moor (12% - satellite; 6% - field survey) differed due to inherent differences in the methods used to identify them and in the ways they have been defined. However, to integrate the two sources of information, the field data can be broken down into more detailed categories. For example, the field data showed that 44% of the managed grass (satellite cover class) was actually intensively managed. Most figures for crops correspond to Ministry of Agriculture, Fisheries and Food (MAFF) and Department of Agriculture and Fisheries for Scotland (DAFS) statistics. For example, for oil-seed rape, both figures were 410 000 ha. Although the total figure for wheat and barley combined was similar, the breakdown between the two crops was different between the CS1990 estimate and the MAFF/DAFS figures.

14 Differences between data from field survey and satellite imagery were quantified by inter-comparison of digital maps using GIS. Direct correspondence was 67%, though this figure increased to at least 71% if boundary pixels were excluded from the comparison (and was better for some cover types than others). Differences were due to the image analysis procedures, discrepancies in field recording, and minor geometric registration errors.

15 The CIS can be used to compare summaries of regions using the two procedures. The

information from the field survey can also be used in conjunction with the satellite land cover map categories to estimate species composition in vegetated cover categories, such as woodland or moorland.

Change in land cover 1984 to 1990

16 Figures for change in land between 1984 and 1990 were obtained from 381 squares visited in the field on both occasions. Tilled land in GB has declined by 4% of its area and within this category there were increases in non-traditional crops such as maize, which increased three-fold. Within the grasslands category, there was a shift within the managed grasslands towards weedy grasslands and away from less weedy types. There was a small overall gain in semi-natural cover types, though some types have declined, including moorland grass (by about 3%), whereas others, such as open-canopy heath, have increased (by about 5%). Non-cropped arable land more than doubled, perhaps due to the introduction of set-aside schemes in 1988. Broadleaved woodland increased by less than 1%, whereas coniferous woodland increased by 5%. Built-up land, including unsurveyed urban land, increased by 4%.

17 A matrix of change shows the movements between cover types as well as the overall net change which, on its own, can mask the degree of change taking place. Most of the large changes were due to the shifts between the major agricultural categories, principally tilled land and managed grass. The built-up category has expanded at the expense of grassland and tilled land, and much of the increase in broadleaved woodland has come from managed grass. Conifer forest expanded in area, mainly at the expense of open shrub heath. At this level of aggregation, there was a high degree of stability with little or no movement between most cells in the matrix; about 87% of land had not changed category.

Boundaries

Stock in 1990

18 Field boundaries were often composed of different elements, such as a hedge with a fence and, in the present report, the data are expressed as some 25 multiple categories, to reflect this complexity. Fences were the most widespread boundary type, occurring in over 70% of the total boundaries in GB; they predominate in Scotland, where they form over 60% of boundaries. Boundaries containing hedges form 31% of the total boundaries, and were mainly in England. Walls form 13% of boundaries in Britain, of which nearly half were in Scotland.

19 Hedges and hedges-with-fences were found mainly within the arable landscapes, but the total length of boundaries with a hedge was highest in pastural landscapes. Although walls occurred in all landscapes, they were concentrated in the marginal uplands. Fences occurred in similar lengths in the arable and pastural landscapes, and less extensively in the marginal upland and upland landscapes. About 70% of all boundaries in Britain were composed of single elements, with 79% in Scotland, 67% in England and 59% in Wales.

Change in boundaries 1984 to 1990

20 ITE has previously reported to DOE on change in hedgerows identified from CS1990 data. The full analysis of boundaries presented here shows a net decrease in the length of hedgerows by 23% between 1984 and 1990. Most of this loss was due to a change in form of the hedges, eg from a managed hedge to a line of trees, but 10% of hedges were removed completely.

21 In general, the length of hedges lost was proportional to the original stock, with no one type being lost to a greater degree than any other. Relict hedges showed a greater proportional increase than any other boundary category (over 50%), whereas walls and walls-with-fences declined by 10%. The greatest overall lengths of wall were lost in the marginal uplands, although a high proportion were lost in the arable landscapes. The length of single fences increased by 11%, of which almost half were in the pastural landscapes, with a smaller increase in the marginal uplands.

22 Only 43% of boundaries containing hedges remained completely unchanged in terms of recorded boundary elements. The major directional trends were from hedges-with-fences to fences alone, and complete removal of hedges. The major individual shift was from walls-with-fences to walls, but in landscape terms the complete loss of walls was likely to be more important. Fences were the most stable boundary category, with almost two-thirds remaining as fences over the period of time.

Vegetation analysis

23 Vegetation plots from surveys in 1978 and 1990 were classified into types that were relatively homogeneous, using standard statistical techniques. These were then used to describe the composition of vegetation and to examine changes. Botanical diversity was considered by reference to both overall species numbers, and numbers of different species groups (each having similar ecological affinities).

Main plots

24 The random **Main plots** were classified into 29 **plot classes** which were then aggregated into six major plot groups. The plot classes were ordered according to their relative positions on a vegetation gradient which was interpreted as being from high intensity of management (arable fields) to low intensity (upland vegetation, eg bogs and moorland). Thus, the arable landscapes contained plots associated with arable fields and managed grassland, whereas pastural landscapes were dominated by plots of managed grassland. The marginal upland landscapes included both upland and lowland plot classes, and the uplands contained high frequencies of a limited number of upland plot classes.

25 In Britain as a whole and considering all plots recorded in 1978, three of the six major plot groups (semi-improved grass, woodland, and upland grass) showed significant losses of species between 1978 and 1990. Only one plot group, moorland, showed a significant increase. These changes include plots in which the species composition has altered sufficiently for that plot to have moved to a different plot group by 1990. For a more sensitive analysis of change, based only on plots which have remained within the same plot group see below (section 28).

26 Within arable landscapes, most of the vegetation changes involved rotation between arable fields and improved grassland. In pastural landscapes, there was movement towards the plot classes with fewer species. Within the marginal uplands, there was more variation, with some plots becoming more intensive and others less intensive, whereas the uplands remained relatively stable.

27 A total of 20 plot groups/landscape combinations occurred and, of these, eight showed statistically significant reductions in species number, between 1978 and 1990, varying from two to ten species per plot, and one showed a significant increase, of four species per plot. The percentage change in species varied both between plot class and between landscapes. For example, in the marginal uplands, the woodland plot group showed a 41% reduction in species number but the moorland plot group a 33% increase.

28 Examination of the species data from only those plots which did not change between 1978 and 1990 from one broad plot group to another provided a more sensitive test of changes in vegetation quality. The plots of the arable fields plot group, occurring in the arable landscape, showed a significant loss of species (from 7 to 4) per plot. The lowland semi-improved grassland plot group only showed a significant loss of species in the pastural landscape, from 22 to 19 species per plot. The woodland plot group showed losses of species in the pastural, marginal upland and upland landscapes. The moorland plot group showed a significant increase in species in both the marginal uplands and the uplands. The upland grass mosaics plot group remained stable in all landscapes in which it occurred.

Habitat plots

29 The **Habitat plots** in the lowlands were placed mainly in agricultural grassland, unmanaged grassland, and woodland. In the uplands, the emphasis was on open vegetation, especially diverse bogs and flushes. In addition, the Habitat plots have extended the coverage of scarce habitats such as marshlands and aquatic habitats compared with the Main plots. The data will form an important baseline for monitoring the changes in these habitats, which are of particular interest to the conservation agencies.

Linear plots

30 Of the **Hedge plots** recorded in 1978, 25% were no longer part of a hedge in 1990 (due to removal or change in boundary category). The Hedge plots were classified on the basis of both woody and herbaceous species. In terms of woody species, hawthorn (*Crataegus monogyna*) hedges were the most common. Different types of hedge showed different patterns of distribution, eg elm (*Ulmus* spp.) hedges occurred mainly in the arable landscapes. Changes in the herbaceous species of the Hedge plots in the

arable landscapes, between 1978 and 1990, showed a shift towards the species characteristic of arable cropland. There was an overall loss of herbaceous species, from 15 to 13 species per plot in the Hedge plots, in the pastural landscapes. The groups of species have also declined in this landscape type, especially those from meadow, calcareous and scrub groups. In the marginal upland landscapes, the herbaceous vegetation showed a pronounced trend away from woodland species towards species associated with intensive grassland.

31 The roadside **Verge plots** showed a full range of plot classes, from the lowland landscapes through to the uplands; from rank tussocky grass-dominated plots in the lowland landscapes to dwarf heath-dominated plots in the upland landscapes. Between 1978 and 1990 there was considerable interchange between the verge types but with a trend towards those typical of overgrown conditions. In terms of species number, the only statistically significant change in road verges was from 15 to 13 species per plot in the arable landscapes. The trend was towards a loss of meadow species groups.

32 As with the verges the **Streamside plot** types showed no distinct separation between upland and lowland landscapes, but representation from across the range of plot classes. The plot classes showed a relationship with watercourse category; thus, reed beds were frequent by larger rivers. In terms of the overall balance of plot classes between 1978 and 1990, there was a general decline in the lightly grazed grassland type and an increase in ungrazed grassland types. Streamside vegetation, however, was the only habitat to lose species throughout all the landscapes, although only the pastural (from 18 to 15 species per plot) and upland (from 24 to 21 species per plot) landscapes had significant changes. The losses were throughout almost all species groups, but especially meadow and wet habitats, as well as from species groups from more overgrown conditions. The Quality Assurance Exercise (see section 6) showed that there were only small differences entirely due to annual variation, which suggests that these changes were not entirely due to the drought in parts of GB in 1990.

33 The species data were also used to compare the contribution of linear and Main plots to floristic diversity in the British countryside. The linear plots in the lowlands contained more species than the Main plots, even though the linear plots had only 5% of the area of the Main plots. Furthermore, the linear plots contained species that were absent from the wider countryside, such as water plants. In the uplands, the vegetation of the Main plots contained high numbers of species, but they were representative of few species groups. Although the linear plots were more restricted in their occurrence, they contained different species from the surrounding countryside. Therefore, linear features were important in all four landscapes in terms of their contribution to floristic diversity; they also contained more of the total resource of meadow species, which had declined throughout all landscapes and plot types.

Freshwater samples

34 All 508 squares surveyed in 1990 were considered for sampling for running-water macro-invertebrate assemblages. A total of 361 squares had suitable watercourses and a single pond-net sample was taken from each of these squares. Most watercourses sampled were small channels within 2 km of their source. The numbers of samples from each landscape varied between 66 (marginal upland) and 110 (pastural). The IFE RIVPACS system was used to determine the environmental quality of each site, as indicated by their macro-invertebrate assemblages. On average, the poorest quality was recorded at sites in arable landscapes, with successive improvements through pastural and marginal upland to upland sites.

35 A total of 479 distinct taxa (mainly at species level) were found in at least one of the sites. The total numbers found in arable and pastural landscape sites were each approximately 50% higher than the total numbers found at marginal upland and at upland sites. When unpolluted sites only were compared, the mean number of taxa per site was highest at arable sites but only just higher than pastural. Mean numbers per site showed a marked decrease between pastural and marginal upland and again between marginal upland and upland sites.

36 The data given in the present report act as a baseline against which future change may be measured. More detailed analysis of the results of CS1990, and other complementary data sets, will be included in a separate thematic report. Appropriate data will also be included in the CIS.

Soils

37 Soil data derived from the data bases of the Soil Survey and Land Research Centre (SSLRC) and the Macaulay Land Use Research Institute (MLURI), and based primarily on the 1:250 000 national soil maps, have been used to determine the dominant soils in each 1 km square in GB, and in the landscapes used as a framework for this report. In addition, detailed soil maps were produced by field survey of each of the 508 field sample 1 km squares.

38 Brown soils and surface water gleys dominated the arable and pastural landscapes. The marginal upland landscapes contained a smaller proportion of brown soils but a larger proportion of podzolic soils than the lowland landscapes; surface water gleys were still important but are dominated by types which have a peaty surface. The upland landscape was dominated by peaty surface water gleys, peats and podzolic soils, with peaty surfaced podzols being widespread.

39 The similarities in the proportions of soils within the landscape types broadly agreed with the grouping of Land Classes used to derive the landscapes. More detailed examination of the data showed clear variations in the proportions of different soils between Land Classes and these are available through use of the CIS. The combined soil data provides a greatly improved characterisation of the Land Classification in terms of soils, and the data now available provide a sound basis for modelling exercises which require soil data.

Conclusions

40 CS1990 has demonstrated that an integrated survey approach, based on the ITE Land Classification, can:

- provide information about the British countryside at one point in time,
- determine change from previous surveys,
- form a baseline for the assessment of future change.

Two of the major products of CS1990 are a land cover map of GB (the first produced using satellite data) and a computer-based CIS.

41 In overall terms, the survey has shown that there has been relatively little change between the major land cover types in GB between 1984 and 1990, although, for example, there has been a small reduction in the area of tilled land and a small increase in urban land. Previously reported rates of loss of semi-natural habitat have decreased. However, there have been significant changes in the detailed composition and ecological quality of vegetation in the countryside, with an overall reduction in botanical diversity.

42 There is a need for further, more detailed examination of the data, especially in integrating CS1990 information to reveal relationships between different components of the landscape, leading to a better understanding of the processes at work. To examine the causes of observed changes, there is also a clear need for further research. Areas which have already been identified include:

- **expansion of the data base** – integration of the CS1990 data with other national data bases on agriculture, climate, pollution and biology;
- **availability of data** – development of the CIS and its wider availability for research and application;
- **spatial scales** – rigorous assessment of the application of results at national, regional and local scales and development of analysis (or synthesis) to express distinct zones of influence;
- **causal relationships** – exploration of correlative relationships to assess causality, eg by application of theory, field experiments, detailed case studies or by testing predictive models against observed spatial and temporal patterns;
- **policy targeting and analysis** – use of the CS1990 data base to establish objectives, to target policy in terms of spatial locations or subject, and to test the effectiveness of policies (adoption dynamics).

43 Meanwhile, there is already other ongoing work which either links directly into CS1990 or which has resulted from it. Projects include: further development of the CIS, especially the inclusion of other data sets and the incorporation of landscape graphics; the DOE-funded 'Changes in Key Habitat' project which aims to collect more information on rare habitats, not well covered in CS1990; the 'Processes of Countryside Change' project

funded by the Economic and Social Research Council and DOE, being undertaken jointly by Wye College and ITE to examine the underlying socio-economic causes behind land use change.

44 While capable of further improvement and development as a methodology, CS1990 has proved an important source of information and thus understanding of the British countryside. Outputs from the survey are especially important in relation to current developments on issues such as biodiversity and sustainability.

45 The CS1990 data bases and summary are now available for further research about the processes, causes and consequences of countryside change. It forms an important baseline for evaluating future changes and current plans are to repeat the survey in the year 2000.

Chapter 1 BACKGROUND TO COUNTRYSIDE SURVEY 1990

1.1 Introduction

1.1.1 In 1977 and 1978, the Institute of Terrestrial Ecology (ITE) carried out an ecological survey of rural Britain (Bunce 1979). The primary purpose was to collect information on vegetation and soils, and the survey used a sampling approach based on the ITE Land Classification (Bunce *et al.* 1983). A secondary activity was the collection of land cover and landscape feature information from each of 256 1 km sample squares.

1.1.2 In 1984, ITE completed a repeat survey of the 256 1 km squares and also surveyed a further 128 squares, increasing the sample number to 384. The survey was designed to answer questions on land use issues and so concentrated on land cover and landscape feature mapping, rather than data collection at the detailed vegetation plot level of the previous survey. The field methodology was identical to that described below, and is given in Barr *et al.* (1985).

1.1.3 During the 1980s, work in ITE (Fuller *et al.* 1989a, b; Fuller & Parsell 1990; Jones *et al.* 1988; Jones & Wyatt 1988; Bunce *et al.* 1993) demonstrated the potential of Landsat Thematic Mapper (TM) imagery as a land cover mapping tool, in both lowland and upland situations.

1.1.4 Separately, staff at the Institute of Freshwater Ecology (IFE) developed a system of river classification based on faunal communities, which could be used to assess water quality and pollution (RIVPACS), with obvious potential for research links to land use studies.

1.1.5 In 1990, the Department of the Environment (DOE) and the Natural Environment Research Council (NERC), with support from the Nature Conservancy Council (NCC), funded a major land use project called Countryside Survey 1990 (CS1990) (Barr 1990). The three-year project brought together four field survey components: land cover and linear features; vegetation plots; freshwater fauna; and soils. The inclusion of land cover information from satellite data was based on a foundation of funding provided by the British National Space Centre (BNSC) and the Department of Trade and Industry (DTI).

1.2 Objectives of Countryside Survey 1990

1.2.1 The overall objectives of CS1990 were:

- to record the **stock** of countryside features in 1990, including information on land cover, landscape features, habitats and species;
- to determine **change** by comparison with earlier surveys in 1978 and 1984;
- to provide a firm **baseline**, in the form of a data base of countryside information, against which future changes could be assessed.

1.2.2 For the first time in land use research, CS1990 provided an opportunity to combine remote sensing, field survey and ecological sampling to gain an integrated GB picture of land use, land cover, landscape features, habitats, vegetation, and plant and freshwater animal species, at one time.

1.2.3 The project was designed to collect data and to summarise them in a way which would be useful to policy-makers. It is intended that detailed ecological analysis and interpretation will follow the production of these results.

1.2.4 The data recorded during the 1990 survey are being held, and made available to users, in a computer-based Countryside Information System (CIS). This report describes the survey methodology, presents the results and highlights key findings. Further analysis of special themes in the data will be published in separate reports (eg on hedgerows – Barr *et al.* 1991).

1.3 Underlying principles

1.3.1 The survey has combined two contrasting ways of collecting land use information: census survey, in which a complete inventory is made; and sample survey, where information is collected from a representative sample of sites.

1.3.2 Analysis of satellite imagery has allowed a census of land cover over the entire surface of GB at a detailed level of spatial recording. As well as providing complete cover, the use of satellite data has potential to allow repeat surveys at regular intervals.

1.3.3 The field survey component of CS1990 has used a sampling approach. This has allowed more detailed information to be collected than could be achieved in the satellite land cover census but, because it relies on making national and regional estimates from a sample of points, there are associated statistical errors which have been calculated (see Appendix 3).

1.3.4 The sample of field survey sites has been stratified according to the ITE Land Classification: this uses combinations of environmental data which are already in a mapped form (such as geology, climate, topography) to allocate land to one of 32 different classes. The classification unit is a 1 km square and all of the approximately 240 000 squares in GB have been classified.

1.3.5 The ITE Land Classes have been characterised, not only in terms of their broad environmental characteristics, but also by land use and ecological data obtained from sample field surveys. As a way of expressing regional variation in the results from CS1990, the Land Classes have been aggregated into four landscape types, each of which is dominated by certain land cover types:

i. **arable landscapes** (34% of GB) – land dominated by cereals and other arable crops, as well as intensively managed grassland – concentrated in East Anglia and the eastern Midlands, but also in the central valley and eastern lowlands of Scotland. Present but less widespread in north-eastern England, the Midlands and south-east Scotland;

ii. **pastural landscapes** (29% of GB) – mainly grasslands – widely distributed in south-west England, west Wales, the west Midlands and north-west England – also in north-east England and scattered through the lowlands of Scotland and coastal areas throughout GB;

iii. **marginal upland landscapes** (16% of GB) – areas which are on the periphery of the uplands of much of north and west Britain, especially Wales, and which are dominated by mixtures of low intensity agriculture, forestry and semi-natural vegetation;

iv. **upland landscapes** (21% of GB) – land generally above a height suitable for mechanised farming and frequently dominated by sheep farming and semi-natural vegetation – distributed in central, west and southern Scotland, and the Pennine and Cumbrian mountains of northern England.

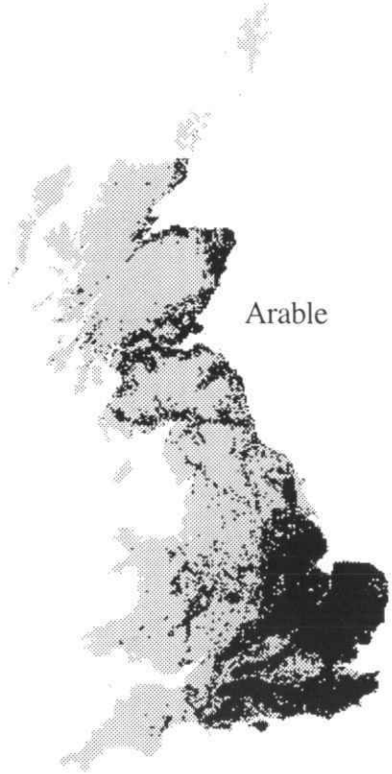
1.3.6 Further information on the ITE Land Classification, and the aggregation of ITE Land Classes into landscape types, is given in Appendix 1. The distribution of the landscape types is shown in Figure 1.1.

1.3.7 Names given to the four landscape types are a necessary simplification and do not reflect the full variation that occurs in the aggregated Land Classes. Thus, the arable landscape type is composed of Land Classes which are dominated by arable land, but does not contain all of the arable land in GB. Further, the same aggregated class does contain some pastural land and other land cover types which are not arable. However, giving results from CS1990 by landscape type provides a convenient way of summarising information for 'agro-ecological zones' within the country.

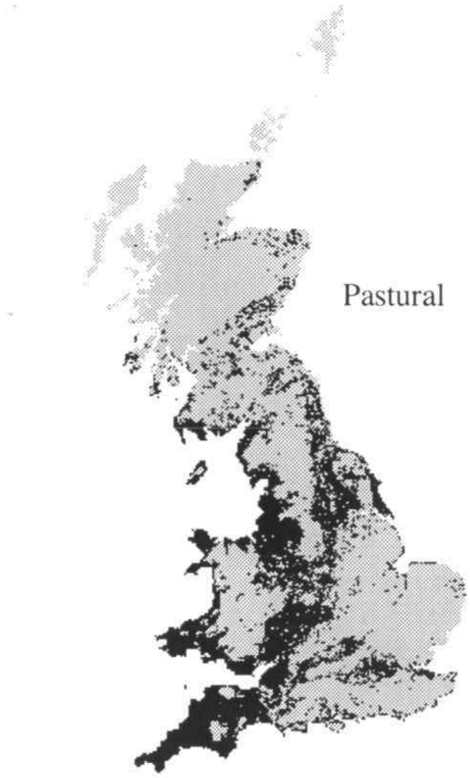
1.3.8 Although the surveys are primarily concerned with the rural environment, urban land has been included in the overall land cover statistics. Detailed ecological information has not been collected from 1 km squares which are dominated (>75%) by built land (see Appendix 3).

1.3.9 As stated above (1.2.4), one of the major products from CS1990 is a CIS. This contains those data that can be summarised with statistical confidence and is intended to make the results from CS1990 widely available. ITE will continue to support the basic data bases from which this and other reports have been compiled. It is not intended, therefore,

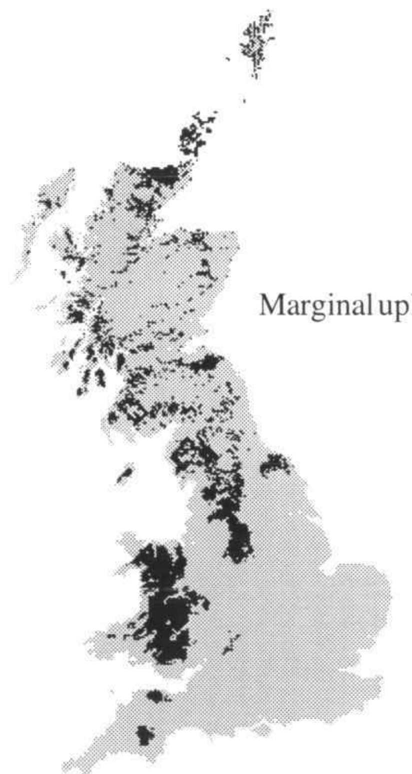
Figure 1.1 The distribution of 1 km squares in the four landscape types



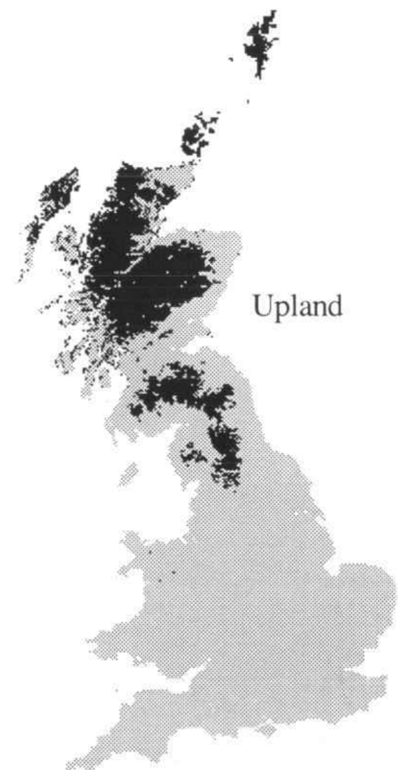
Land classes 2, 3, 4, 9, 11, 12, 14, 25 and 26



Land classes 1, 5, 6, 7, 8, 10, 13, 15, 16 and 27



Land classes 17, 18, 19, 20, 28 and 31



Land classes 21, 22, 23, 24, 29, 30 and 32 that the present report should contain details of all recorded features but, rather, the report picks out the broad patterns and key findings, and describes examples of the sorts of data that are held and how these might be interrogated.

1.4 Summary of Chapter 1

1.4.1 Following previous countryside surveys in 1978 and 1984, and the development of methods of survey using remotely sensed data and field-based survey and sampling techniques, the Institute of Terrestrial Ecology and the Institute of Freshwater Ecology undertook a survey of the British countryside in 1990. The work was principally funded by the Department of the Environment, the British National Space Centre, the Department of Trade and Industry, and the Natural Environment Research Council. Additional funding was provided by the former Nature Conservancy Council.

1.4.2. The primary objectives of the survey were to establish the **stock** of landscape features and habitats in GB in 1990, to identify **change** in these by reference to earlier data, and to create a new **baseline** for the measurement of future change.

1.4.3 For the first time at a national scale, the survey integrated remotely sensed data from satellites with field-based survey and sampled data on a common spatial basis. While interpretation of satellite imagery yielded census information for the whole of GB, field-based studies used the ITE Land Classification for sampling features in more detail.

1.4.4 Regional variation in the results of the survey was expressed using aggregations of the ITE Land Classes into four landscape types: arable; pastural; marginal upland; and upland.

Chapter 2 METHODS OF DATA COLLECTION AND ANALYSIS

2.1 Introduction

2.1.1 Countryside Survey 1990 (CS1990) brought together researchers from a variety of disciplines and backgrounds, each having specialised in their own field for some years. They included staff concerned with geographical, cartographic, and remotely sensed data, botanists, freshwater biologists and soil scientists.

2.1.2 The challenge of the project was to bring the collective skills and knowledge of these different groups together. The integrated basis on which the research was carried out was the expression of results in a common spatial framework, at the 1 km square resolution.

2.2 Land cover mapping from satellite imagery

Landsat image classification

2.2.1 This study forms an extension to a project funded by the British National Space Centre and the Natural Environment Research Council to map all of Britain from satellite images. This extension is aimed at integrating the Landsat-derived map data with the field survey data of CS1990. It allows improved estimation of landscape statistics by combining the detailed sample-based, field statistics with a full spatially referenced census of generalised cover. The outputs include:

- provision of land cover statistics by ITE Land Class, landscape type and for England, Scotland and Wales;
- provision of summary cover statistics on a 1 km grid for inclusion in the Countryside Information System (CIS);
- analysis of elements of land cover pattern, and summary at the 1 km square resolution for inclusion in the CIS;
- calculation of correspondence statistics to inter-relate field survey and Landsat data.

2.2.2 Unlike the field survey data, this element represents the first study of its kind in Britain. It provides stock information, not change statistics. The main outputs are in the form of digital data bases which can be interrogated for specific requirements, rather than forming tables which are an end in themselves.

2.2.3 This section of the report gives a brief description of the Landsat image classification, outlines the integration with the field survey and summarises the pattern analyses. Full details of the resulting correspondence statistics appear in the CIS and are fully described in the Final Report on Land Cover Definitions (LCD) (Wyatt *et al.* in prep.). The results of pattern analyses are available through the CIS.

2.2.4 The study was based on Landsat Thematic Mapper (TM) data, with its good spatial resolution and the inclusion of a middle infrared waveband which is important in separating a wide range of vegetation cover types (Townshend *et al.* 1983). Eight Landsat paths cover Britain. The orbits overlap very substantially in these northern latitudes, from about 45% in southern England, and exceeding 50% from mid-Scotland northwards. This meant that it was possible to use alternate paths of data in north Scotland to achieve full cover but, elsewhere, it was necessary to use every path.

2.2.5 The land cover mapping involved computer classification of paired summer and winter

TM scenes. The baseline date for the mapping was 1990 but, to accommodate any image shortages, an extended period of plus or minus two years was allowed. In practice, the dates of summer images (which essentially determine the cover) ranged between 1988 and 1991.

2.2.6 Summer and winter data, in composite, helped separate the various target classes (Fuller *et al.* 1989a, b). For example, arable areas alternated between full plant cover and bare ground in a year; semi-natural vegetation retained full cover, though perhaps of plant litter in winter; deciduous trees were distinguished from evergreens; deciduous rough grasslands differed from permanently green agricultural grasslands; urban areas and bare ground were distinguished by their bare appearance in both summer and winter (Fuller & Parsell, 1990).

2.2.7 The appropriate definition of 'winter' and 'summer' was clarified in discussion with ecologists and agriculturalists familiar with the phenology of the local vegetation in various regions of Britain. The consensus was that the summer period safely included mid-May to July, that August to mid-October represented a transition period and that winter covered the time from mid-October to around mid-March. Late March, April and early May were seen as transition periods which were best avoided. In practice, the useful periods shifted with altitude; they also varied from north to south, and east to west in Britain and were inevitably dependent on the year in question.

2.2.8 The search for images was based on the National Remote Sensing Centre quick-look photographs of TM images acquired by Landsat within the study period. Cloud-free scenes and quarter-scenes were identified from these. Image availability determined the timetable for image processing. In all, allowing for problems of cloud cover, about 25 paired, summer/winter, scenes or part-scenes required classification to give full cover of Britain.

2.2.9 Landsat TM data were geometrically corrected to the British National Grid (BNG). Control points were defined interactively on the International Imaging Systems (IIS) M75 image processor. The procedure used 1:50 000 Ordnance Survey maps mounted on a digitising table, to derive the 'true' position of control points identified on the input image. The relationship between image co-ordinates and BNG was calculated using a polynomial model. The image was then resampled to fit this polynomial model (Schowengerdt 1983), to produce an output image with a 25 m pixel size, and a BNG map projection. Cubic convolution resampling, which better modelled the natural variations in radiance across an image, was the most appropriate algorithm (Fuller & Parsell 1990).

2.2.10 The summer/winter composite images were made by co-registering scenes or part-scenes to give a single output image. This image contained six bands of data, three each from the original summer and winter data, namely TM bands 3, 4 and 5 – ie red, near and middle infrared (IR). These bands were chosen because they represent wavelengths with characteristic responses from vegetation (red for chlorophyll absorption and IR for mesophyll reflections). They were also less affected by haze problems than the blue-green end of the visible spectrum (Fuller *et al.* 1989a; Fuller & Parsell 1990).

2.2.11 An appropriate class selection was the key to an accurate classification, consistent as far as possible throughout Britain, and useful to ecologists and other environmental scientists. By reference to other surveys it was possible to draw on a wide range of experience in vegetation mapping, and to use the types of classification which had themselves been devised for applied uses. Ultimately, of course, the classification was determined by what was feasible from satellite images: here, the study was strongly influenced by the pilot exercises in Cambridgeshire and Snowdonia, but with evolution of the classifications based on experiences in the current survey, and on a consultative exercise involving other surveyors and end-users.

2.2.12 A final list of 25 target classes (land cover types) was derived for mapping throughout Britain (Figure 2.1). The classification may be simplified, if required, by aggregating rarer classes with related, more common, ones.

2.2.13 The procedure of classification was based on extrapolation from sample statistics for reflectances of each class. In reality, the target classes were achieved by defining a large number of spectrally unique

Figure 2.1 The land cover classification derived from LANDSAT IMAGERY, shown for 25 target land cover types and aggregations to 17 key cover types for provision of summary data (see section 2.2.22) and nine other major cover types (see section 2.2.28) for pairwise boundary analyses

Target land cover types (25 classes)	Key cover types (17 classes)	Major cover types (9 classes)
Continuous urban	Continuous urban	Urban/suburban
Suburban/rural development	Suburban	
Tilled ground	Tilled land	Tilled land
Mown/grazed turf Meadow/verge/semi-natural	Managed grassland	Pasture/meadow/ amenity grass
Bracken	Bracken	Bracken
Ruderal weed Felled forest Rough grass/marsh	Rough grass/marsh	Rough grasslands
Grass heath Moorland grass	Heath/moor grass	
Open shrub heath Open shrub moor	Open shrub heath/moor	Shrub heath
Dense shrub heath Dense shrub moor	Dense shrub heath/moor	
Lowland bog Upland bog	Bog	Bog (herbaceous)
Scrub/orchard Deciduous woodland	Deciduous/mixed wood	Deciduous/mixed wood
Coniferous woodland	Coniferous woodland	Coniferous woodland
Inland bare ground	Inland bare	*Classes not used in pairwise boundary analysis*
Saltmarsh/intertidal vegetation	Saltmarsh	
Beach and coastal bare	Coastal bare	
Inland water	Inland water	
Sea/estuary	Sea/estuary	

subclasses. This was necessary because the maximum likelihood classifier (MLC) assumes a normal distribution in the data (Kershaw & Fuller 1992), which could only be achieved by subdividing multi-modal data into component subclasses (eg taking specific crops as subclasses of tilled land).

2.2.14 The sample areas on which the classification were based were selected using knowledge derived in the field reconnaissance survey. Typically, field reconnaissance identified the cover in about 1200 land/water parcels per Landsat scene.

2.2.15 Training the image classifier involved outlining groups of pixels which were representative of the particular classes or subclasses intended for classification. Overall, 70–80 subclasses were typical for most scenes. Normally, there were five or more training areas per subclass with a minimum 30 pixels in total, but, more usually, there were 100-200 pixels per subclass.

2.2.16 Extrapolation was used to find all other pixels in the scene with the same spectral characteristics as the subclasses used in training. The maximum likelihood classifier allocated each pixel to its nearest subclass (in statistical terms) or rejected pixels if dissimilar to all available subclasses. By defining a rejection threshold, it was possible to reject more or less of the scene (Kershaw & Fuller 1992). In this case, all but the very rarest of subclasses were defined, so the threshold was varied in order to classify 98% or more of land/water parcels.

2.2.17 The process of training and classification was an iterative one, relying on preliminary classification, inspection of results, edition or addition of training subclasses, then reclassification, working towards a final cover map.

2.2.18 Some classes could not always be reliably separated purely on the basis of spectral differences. Contextual information, either drawn from outside sources or derived from the data, helped correct any errors. By defining a coastline, it was possible to impose the rule that terrestrial habitats are only found inland of the line, maritime habitats to seaward. The definition of the coastline was semi-automated. Maritime classes were extracted to form a mask, and this was smoothed using filters to remove holes in the mask, or erroneous 'inland maritime' areas. If necessary, the mask was then edited interactively on the image processor, before being used for correction. Using a masking procedure, it was possible to filter out small pockets of misclassified lowland habitat in an extensive upland area and *vice versa* (there remains a choice between using these distinctions, as described, or re-aggregating the upland/lowland classes, and using alternative contextual information, such as altitude, to make the distinction).

2.2.19 An urban mask was made from urban and suburban pixels, and holes in the mask were then filled using a majority filter. The resulting mask was used to correct misclassified urban areas, for example where the change in vegetation cover between summer and winter images (gardens, scrub areas) resembled the seasonal changes in arable land. Any such patches which fell under the mask were changed to suburban pixels. Classes such as deciduous and coniferous woodland, water bodies or grasslands were allowed to remain, as they are normal features of urban environments.

2.2.20 Local interactive corrections were needed: sometimes odd clouds obscured a small part of the summer or winter image; pockets of haze might also have caused very occasional difficulties. In such cases, it was possible to classify that pocket using just the one good date, cut out the area covered with haze, cloud or shadow, and insert a patch from the single-date cover map. In other areas, odd cover types (eg peat cuttings), perhaps too small to train as subclasses, were misclassified; in such circumstances, it was possible to take out a 'tile' of the cover map, renumber the cover value in a locality to the correct value, and place the corrected 'tile' back into the cover map.

2.2.21 In building a mosaic of full GB land cover, data have been stored as 100 km x 100 km tiles, for convenience of access. These tiles were made as 'jigsaws' from the appropriate sections of each scene. As a scene classification was completed, the sections were 'cut out' and stored in their 100 km x 100 km tile. Joins were made within the overlap between scenes, using a sinuous outline along uniform features which were classified in the same way in both scenes. Areas where there were known difficulties on a scene (eg haze

Figure 2.2 The land cover classification derived from FIELD SURVEY, shown for 59 dominant land cover types and aggregations to 16 key cover types, comparable to the satellite key cover classes, and 11 major cover types (see section 3.5.1)

Dominant land cover types (59 classes)	Key cover types (16 classes)	Major cover types (11 classes)
Railway Road	Communications	Built up
Agricultural buildings Residential buildings Other buildings	Built up	Built up
Wheat Barley Oats Mixed and other cereals Maize Turnips/swedes Kale Oil-seed rape Crucifer crops (not OSR) Peas Field beans Legumes Sugar beet Root crops Potatoes Other field crops Horticulture	Tilled land	Tilled land
Recreational (mown) grass Recently sown grass Pure rye-grass Well-managed grass Weedy swards with >25% rye-grass Non-agriculturally improved grass Calcareous grass Upland grass Maritime vegetation	Managed grass	Managed grass
Non-cropped arable (ploughed and fallow) Unmanaged grassland and tall herb Felled woodland Wetland Waste and derelict land	Rough grass/marsh	Rough grass/marsh
Dense bracken	Dense bracken	Dense bracken
Purple moor grass-dominated moorland Moorland grass (other than purple) Dune	Moorland grass	Moorland grass
Open-canopy heath Berry-bush heath Drier northern bogs	Open heath	Shrub heath
Dense heath	Dense heath	Shrub heath
Wet heaths and saturated bogs	Wet heaths and saturated bogs	Bog
Perennial crops Mixed woodland Broadleaved woodland Shrub	Broadleaved/mixed woodland	Broadleaves
Coniferous woodland	Coniferous woodland	Coniferous woodland
Inland rocks and screes Hard areas without buildings Quarries and extractive industries	Inland bare	Inland bare
Saltmarsh	Saltmarsh	*Classes not included in major cover analysis*
Hard coast with no vegetation Intertidal soft coast without vegetation	Coastal bare	*Classes not included in major cover analysis*
Still water Running water Wetland	Inland water	*Classes not included in major cover analysis*

patches) were avoided, and the better of two scenes was used if quality differences existed.

Integration of satellite and field survey data

2.2.22 Integration of field survey and satellite data required common definitions of land cover or, at least, an understanding of how definitions vary. A DOE-funded project on Land Cover Definitions (LCD) (Wyatt *et al.* in prep.), has aimed to evaluate and inter-compare different national/regional surveys, including the Landsat and field surveys of CS1990. The LCD project has recommended a list of 59 cover types as a classification of basic land cover types for Britain. The many combinations of field attributes (see section 2.3.5) have been fitted to this classification, and the dominant cover types, and their aggregations, are pesented in Figure 2.2. To match this 59-category classification, several of the 25 Landsat cover types have been aggregated to a list of 17 types (Figure 2.1): both of these aggregations were used when inter-comparing and integrating field survey and satellite surveys. Descriptions of the 59 dominant land cover types and the 25 satellite target classes are given in Appendix 2.

2.2.23 The results of the satellite land cover classification have been compared with data from the field survey of 1 km squares. There have been three levels of comparison:

i. vector-digitised field survey squares (ie as boundary line-work) were converted to raster format (ie as grid cells): the procedure was applied to 143 squares (a minimum of 4 per ITE Land Class). Field data were aggregated to give 25 cover types corresponding to those used in Landsat mapping: simple decision rules were made to deal with multiple cover attributes; for example, a land parcel, comprising both grass and tree cover, would have taken the visually and structurally dominant tree classification. Assessment of accuracy was made separately for boundary pixels and within-field pixels.

ii. scores of land cover on a grid of 25 points, within field survey 1 km squares and corresponding areas on the satellite land cover map, for 256 squares: 25 target cover types (and LCD aggregations to 17 key cover types (Figure 2.1)) were compared with a short list of 59 baseline cover types defined under the LCD project.

iii. a 1 km summary level, for all squares: 25 target classes (and LCD 17 key classes) were compared with the 59 LCD baseline cover types.

2.2.24 The comparison with field data has been completed and summary results are presented in this report. The full integration and analysis of correspondence are described elsewhere (Wyatt *et al.* in prep.).

Pattern analysis

2.2.25 Griffiths and Wooding (1989) outlined methods for analyses of landscape patterns, using data derived from a classification of Landsat images (as part of the DOE project 'Ecological Consequences of Land Use Change', Bunce *et al.* 1993). They employed concepts such as:

- patch size and frequency;
- fragmentation and isolation;
- boundary measures;
- density and diversity.

2.2.26 Within CS1990, similar measures were used nationally, with output data in summary form. Analyses in a vector GIS could not handle the large quantity of data.

2.2.27 The options within the image processing system were:

- to count number of classes per unit area;
- to measure boundary lengths (of any class or combination of classes);
- to measure cover per class per unit area;
- to identify and examine regions within fixed distances of a cover type (or combinations of cover types).

2.2.28 These procedures provided the basic 'tool kit' from which the following pattern measures were made:

- cover per class per 1 km square (using 17 key cover types (Figure 2.1) as in the LCD Project (Wyatt *et al.* in prep.)) – expressed as an integer percentage value;
- boundary length per class per square (using 17 key classes) – number of pixels bounding each class in each 1 km square;

- pairwise boundary combinations (based on cover simplified to nine major types (Figure 2.1)) – eg bracken-to-grassland boundary length.

2.2.29 The above analyses provided 70 layers of information as 1 km summary data. These have been constructed in a form suitable for incorporation into the CIS. It is important to realise that the provision of these pattern variables in CIS will allow users to make their own indices of pattern. The diversity measure can be calculated from these data within the CIS. An index of patch size per class could be made taking the area of a cover type divided by its boundary length (or users can devise their own measure, eg area divided by the square root of boundary length).

2.2.30 In order to examine the spatial relationship (eg proximity) between land cover types, 'buffer zones' were created around the 'core areas' of each land cover type. They were defined by inclusion of a set number of pixels which adjoined the core areas of each class, thereby allowing an examination of the composition of neighbouring land cover types.

2.2.31 Assessment of cover within buffer zones is computationally expensive, and can provide huge data sets, depending on the number of classes and the range of buffer zones selected. Such measures are better designed to meet specific user requirements and made 'to order'. However, demonstrator analyses were performed for three aggregate cover types (deciduous, moor/heath/bog and bracken).

GIS integration

2.2.32 End-users will wish to analyse the data in conjunction with a wide range of other maps and data. A geographical information system (GIS) allows the user to make complex overlays of multiple, spatially referenced, data sets (topography, soils, species maps, administrative boundaries, etc). The GIS can draw on other data (eg regression of species number against altitude, maximum acid tolerance of a species, hedgerow length per unit area of grassland). These facilities allow users to make sophisticated analyses of distributions, patterns or change. Users can build predictive models of environmental impacts, or test policies for environmental management. The satellite land cover map will be a vital element in the developing use of GIS.

2.2.33 GIS demonstration work has involved the export of sample areas from the IIS image analysis system to a Laserscan GIS. Basic experimentation has concentrated on a 75 km x 50 km test area centred on the Thames estuary. Analyses have included use of the land cover data in their original raster format and also raster-to-vector conversion (ie from grid-cell data to digital line data). In addition, a number of other studies have used the land cover data in applied environmental research.

2.3 Field survey

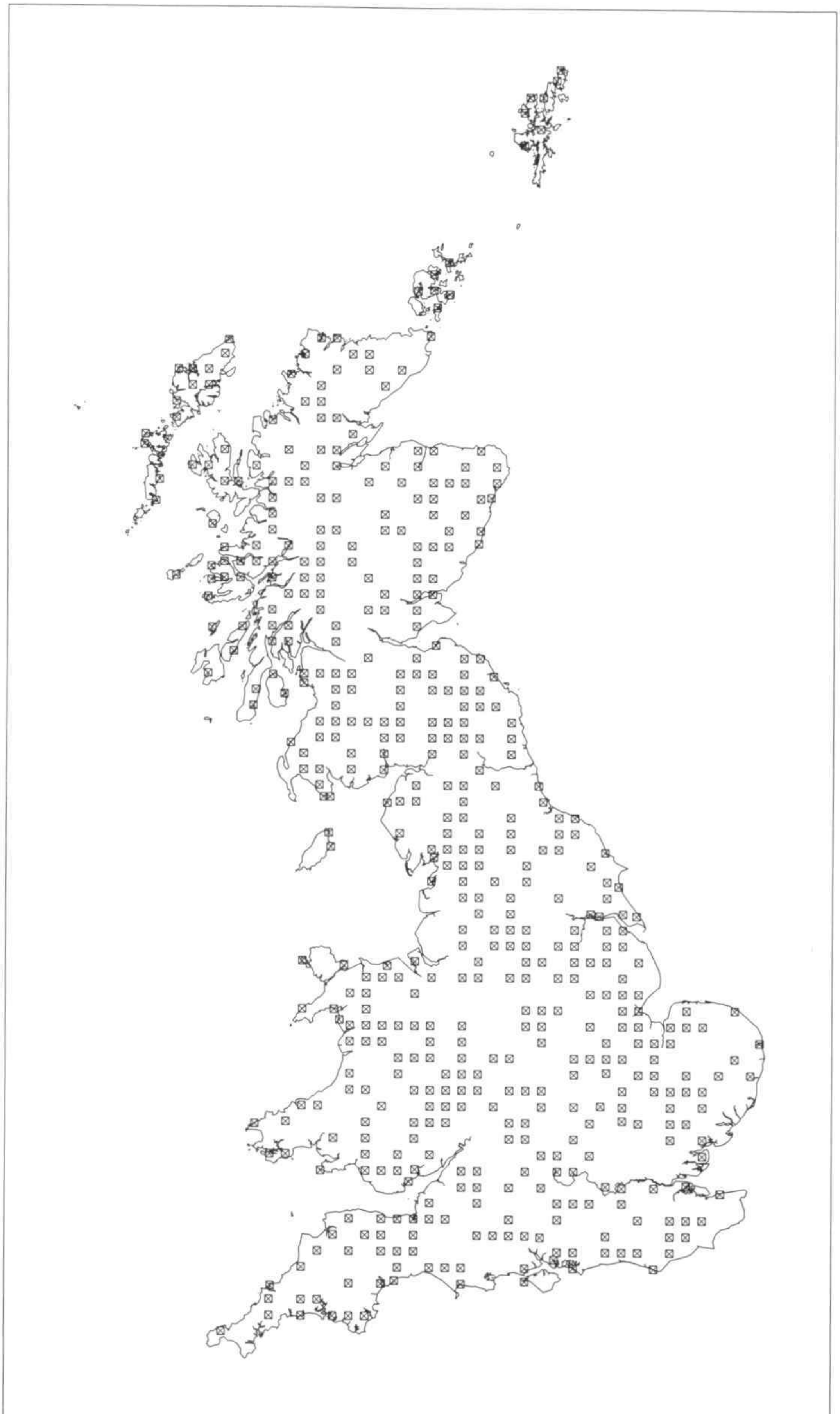
2.3.1 A full description of the field survey methods is given in a Field Handbook (Barr 1990) (which is available on request from ITE); they followed closely those used in the 1984 ITE survey. The following paragraphs summarise only those methods which are relevant to this report.

2.3.2 In 1990, 508 1 km squares in GB were surveyed, including the 384 1 km squares which had been visited in 1984 and which, in turn, included 256 squares which had first been surveyed in 1977–78. The sample of 1 km squares was structured using the ITE Land Classification (see section 1.3.4): the 1978 survey was of eight 1km squares from each Land Class; the 1984 survey used 12 squares from each Land Class (Bunce & Heal 1984). The 1990 survey used the same 12 squares in each class but additional squares were taken from some classes in proportion to their overall frequency in GB. The distribution of the 508 1990 field sample squares is shown in Figure 2.3.

2.3.3 Within each 1 km square, the following were surveyed:

i. land cover, which was mapped using OS 1:10 000 scale maps enlarged to about 1:7000;
ii. landscape features, such as walls, hedges, individual trees
The various aspects of (i) and (ii) were mapped on five separate maps covering: physiography; agriculture/semi-natural vegetation; forestry/woodlands/trees; boundaries; built

Figure 2.3 Map showing the distribution of 1 km squares surveyed in 1990



environment and recreation.

iii. up to 27 vegetation plots, both in open land and alongside linear features such as hedges, roads and streams.

Field mapping

2.3.4 The mapped features were described using a predetermined list of codes as shown in Appendix 2. Where a feature could not be described using the existing codes, unique descriptions were used and coded separately. Because such unique information has not necessarily been collected in an objective and consistent way, its use is limited.

2.3.5 In order to give as much information as possible about each area of land or landscape feature, combinations of data codes were used to annotate each category on the map. An example of a page from a field recording booklet is given in Figure 2.4. There were two types of code: **primary** (general descriptions of features, eg woodland) and **secondary** (giving more detail about the feature, eg tree species, age, management practices, in a wood). All features were annotated with at least one primary code and, where more than one primary code has been used (eg multiple land use), then the code reflecting the dominant use was recorded first.

2.3.6 The smallest area that field surveyors recorded (the minimum mappable area) was 0.04 ha (400 m^2). No vegetation type (except bracken) was mapped as a separate unit unless it achieved this size. The minimum mappable length of any boundary feature was 20 m.

2.3.7 The mapped area of each land cover parcel, and the length of each boundary, or boundary segment, was determined by the constancy of a combination of codes; where any one description differed, then a new area or length was demarcated and a new combination of codes was used. The same coded descriptions were used in both 1984 and 1990, except for minor amendments as shown in Appendix 2.

2.3.8 Boundary features were mapped and coded as 'single lines' on the map, even though there may have been several different elements associated with each (eg a hedge and a fence on top of a stone bank). For adjacent lines to be mapped individually, then a clear gap between all the elements of the two boundaries had to be identified. Boundaries of land associated with buildings (curtilage) were not mapped in detail. Boundary features within woodland were not mapped.

2.3.9 To assist in field mapping, limited aerial photographic interpretation was carried out for each square. Using photographs of various dates, but all taken since the 1984 survey, features that were no longer present, and those that were new to the map were marked on a 'master map' which was used as a base for field recording.

Vegetation recording in plots

2.3.10 Vegetation data were collected from up to 27 plots in each of the 508 CS1990 field squares. In 1977–78 vegetation data were also collected from a smaller number of plots, in 256 squares.

2.3.11 The vegetation plots were of three types.

i. five 200 m^2 vegetation plots in stratified random locations – '**Main plots**'
These plots were located at random within five equal-sized sectors of the 1 km square. If they fell on a linear feature, they were relocated at random.

ii. five 4 m^2 vegetation plots placed within semi-natural habitats only – '**Habitat plots**'
These plots were placed in semi-natural habitats not covered by the larger random plots, according to a random allocation procedure.

iii. up to 17 10 m x 1 m linear plots placed alongside field boundaries ('**Boundary plots**'), hedges ('**Hedge plots**'), watercourses ('**Streamside plots**'), and roads/tracks ('**Verge plots**').
*The five **Boundary plots** were placed at the nearest field boundary to each of the Main plots (if within 100 m) – only those Boundary plots that occurred adjacent to hedgerows have been included in the current analysis.*
*Two **Hedge plots** were also placed at random within each 1 km square.*
*Each of the **Streamside plots** was placed at the edge of running water, with a second, parallel, 10 m x 1 m plot being recorded on the water side to record any emergent macrophytic plants; two of the Streamside plots were located at random within the square and three more were placed to sample different sizes of watercourses.*
***Verge plots** were placed immediately*

Figure 2.4 An example of a page from the field recording booklet (see Appendix 2 for codes)

Agriculture/Natural Vegetation

Square: 4/366

Extra codes:

169 Poa annu

170 Agro repe

171 Urti dioi

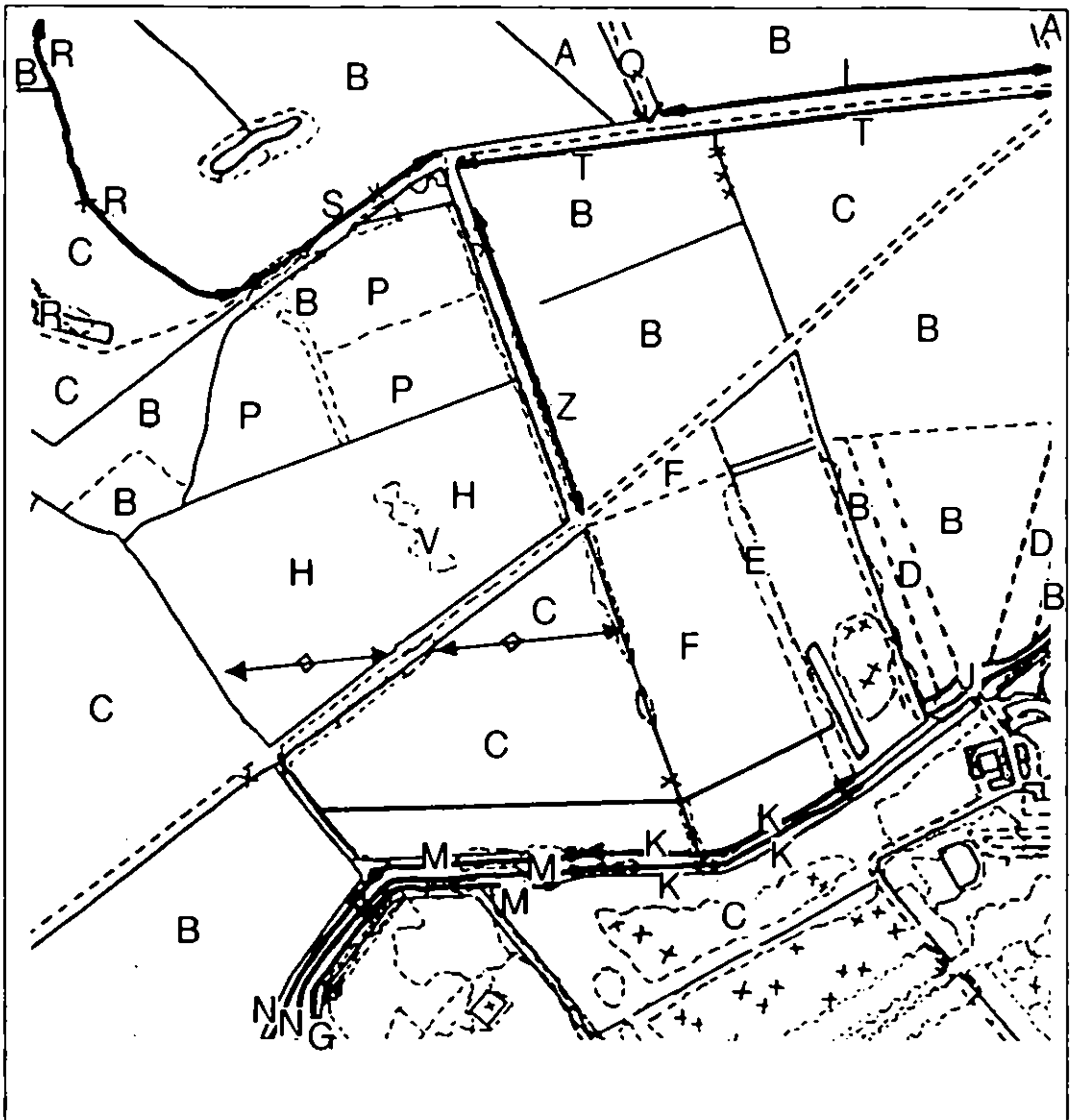
172 Arrh elat

173 Phra aust

174 Hera spho

1 ha

mmu



A	120		B	117		C	118		D	133	139	145	169	175			
E	121	141		F	120		G	143		H	124		I	133	170	256	138
J	133	138	145	147	175		K	134	141	171	175		M	133	139	147	175
N	133	139	172	175		P	101	138	147	175	191	(3)					
Q	133	145	147	175		R	109	173	176		S	134	174	175			
U	133	138	170	175		Z	133	140	174	175							
T	133	138	172	175		V	999										

Agriculture/Natural Vegetation

adjacent to the road edge; in roadside verges wider than 2 m, a second, parallel, Verge plot was recorded immediately adjacent to the first one (see Wide Verges in Results section); two of the Verge plots were located at random and three were placed to sample different road types.

2.3.12 Table 2.1 shows the numbers of vegetation plots that were recorded during the survey.

2.3.13 Because the Main plots were placed at random within the 1 km squares, the numbers were directly proportional to the extent of the cover types present; this was also true of those linear plots that were placed at random. By contrast, the additional linear plots (placed to sample different types of linear feature) only gave information on the characteristics of the resource, as they were placed along linear features regardless of the length present. The absence of the features within some squares meant that the numbers had a relationship with length, but it was not exact. The Habitat plots were targetted (at semi-natural habitats) and, whilst able to give a measure of the relative abundance of the habitats concerned, they could not be used in a statistical sense to estimate relative frequency.

2.3.14 The field survey was completed between June and October 1990. The work was carried out by ITE staff working with specially recruited field botanists in teams of two. Each site took between two and six days to survey depending on its remoteness, intrinsic heterogeneity and other independent factors such as access restrictions and weather.

2.3.15 A Quality Assurance Exercise was completed which gives an independent measure of the accuracy and efficiency of the field surveyors. This is discussed in section 2.4.

2.3.16 All of the field data were handled and processed at ITE Merlewood. There were three major activities:

i. digitising of the mapped linework using ARC/INFO GIS,
ii. computer entry of the codes which describe the mapped features, and storage in a proprietary data base system (ORACLE),
iii. computer entry of the coded vegetation data from the plots (also stored in ORACLE).

Table 2.1 Types and numbers of vegetation plots

Plot type	Max per square	Total
Main plots (200 m²)	5	2 531
Habitat plots (4 m²)	5	2 529
Hedge plots (10 m x 1 m)	2	564
Boundary plots (10 m x 1 m)	5	1 807
Verge plots (10 m x 1 m) – random	2	789
Additional Verge plots (10 m x 1 m)	3	1 165
Streamside plots (10 m x 1 m) – random	2	885
Additional Streamside plots (10 m x 1 m)	3	1 287
Total		11 557

2.3.17 Data validation was carried out by double-punching of data, routine logical checks and on-screen visual checks. In addition, rule-based checks have been completed to ensure consistency in the use of mapped data. For the purposes of reporting, the combinations of codes which describe land cover and landscape features have been aggregated into 58 categories. These are the same as the 59 categories identified in the Land Cover Definitions (LCD) project (see Figure 2.2), except for minor differences in the classification of coppice woodland and built categories.

2.3.18 Analysis of the mapped information has been completed using the overlay facilities of the ARC/INFO GIS, and its links with the ORACLE data bases. Such methods have been used to generate the extent and frequencies of features in each of the sample squares, which were combined to estimate the average amounts of each feature in each ITE Land Class.

2.3.19 The ways in which sample data have been used to make national and regional estimates have been described elsewhere (eg Bunce & Heal 1984). Simply, the ITE Land Class means for any feature are multiplied by the number of squares of that class in the region. The totals for each class are then summed to give a final total for the feature.

2.3.20 Statistical errors are given for all estimates. Full discussion of the procedures, including those estimating change between surveys, and choice of error terms is given in Appendix 3.

2.3.21 Plant species nomenclature follows Clapham, Tutin and Moore (1987). To ensure that any recording differences associated with difficult taxa, rarity and non-native introductions are minimised, the species were classified according to the following descriptions (analyses of the vegetation data being undertaken with different levels of confidence, depending on which classes are included):

- species which can confidently be regarded as consistently recorded;
- species complexes, aggregates or where known problems occur;
- naturalised species;
- planted species;
- species that were recorded at only one survey date.

2.3.22 Analysis of the vegetation data has been carried out at different levels:

- individual species:
- classification of plots according to species present (plot classes):
- groups of species that occur frequently together and which are characteristic of different habitats (species groups).

2.3.23 Vegetation is composed of different combinations of **individual species**, reflecting the local habitat conditions. Some vegetation is very simple in this respect, as in a uniform ploughed field, and contains few species from a restricted range of environmental conditions. Other vegetation may be complex and, within one sample unit, may contain species with differing micro-habitat requirements (eg local variation in nutrient levels and moisture).

2.3.24 Within Britain, there are some 250 vascular species that form the main vegetation cover, and the assemblages in which they are found are continuously variable. The objective of a classification technique such as TWINSPAN (Hill 1979) is to use mathematical procedures to divide the vegetation continuum into classes which can then be defined in terms of the species present. These are termed **plot classes** and their characteristics can be summarised by convenient names which help the user to recognise them (eg grass leys, moorland). Each set of plots, as shown in Table 2.1 (eg Main plots, Hedge plots), has been classified separately using TWINSPAN to give a unique set of plot classes (eg Main plot classes, Hedge plot classes).

2.3.25 The species present, within all of the plot classes, can be divided into groups of species (**species groups**) which have a similar distribution throughout the vegetation plots. These groups can be defined using a variety of mathematical techniques but, in the present study, minimal variance clustering of the DECORANA ordination was used. Each species occurs in only one group and the species within a given group have similar habitat requirements (eg field margin plants, bog pool plants).

2.4 Quality control and assessment – field survey

2.4.1 The field survey element of CS1990 was carried out by about 40 field surveyors and took place over a five-month time span which included a period of drought in parts of GB. Inevitably there was some variation in the way data were recorded, associated with different observers, times of year, geographical and ecological zones, and types of information.

2.4.2 Within the project, quality control has remained an important consideration and every effort has been made to ensure consistent field recording. However, it is important that a proper assessment is made of the remaining differences and this can only be achieved through some form of quality assurance measurement, or quality assessment (an approach which has often been overlooked within other surveys of this type).

2.4.3 A Quality Assurance Exercise was undertaken late in 1990. A preliminary examination of the results suggested that a significant cause of differences in species recording may have been due to mis-location of plots and to variations in the times of year of the recording. To examine these points more thoroughly, a further study included a re-survey in 1991, visiting sites on or about the same time of year as they were surveyed during the main survey.

2.4.4 The four aims of the quality assessment were:

i. to quantify the accuracy of field recording in CS1990 and hence to comment on the accuracy of change statistics;
ii. to explain any differences in recording in terms of observer error, time of year, plot location, type of information, geographical region and special

factors such as drought;

iii. to relate the conclusions from (i) and (ii) to previous comparative work done on ITE survey methods

iv. to recommend modifications to survey methodology for future surveys which would improve the accuracy and confidence of the resulting statistics.

2.4.5 The work was carried out by Ecological Surveys (Bangor) and is summarised in Appendix 4.

2.4.6 The main points to note from the quality assurance work are given below.

- The permanent marking of plots was of sufficiently high standard to suggest that detailed changes in vegetation may be followed using the present survey methods, but that plot re-location may be time-consuming, especially in the uplands.
- The initial recording accuracy was between 74% and 83%, depending on such factors as weather, seasonal variation and relocation of plots. This level of accuracy is close to the maximum attainable efficiency that can be expected.
- Estimation of species cover values as part of field mapping was variable and needs to be improved in further surveys.
- Trends in vegetation change have been related to environmental change, using correspondence analysis. The consistent directions of change between 1990 and 1991 indicated that 1990 plot data are sufficiently reliable to demonstrate environmental change.
- Land cover mapping was more reliable at the primary code level (84% agreement) rather than at more detailed levels (78% agreement for objective qualifying codes; 49% for subjective qualifiers). Recording was more reliable in the lowlands (95% agreement at primary code level) than in the uplands (71%).

2.4.7 The steps that were taken to ensure reliability are shown in Figure 2.5. Recommendations on modifications to survey methodology have been made and these will be taken into account in the planning of future surveys of this type.

2.5 Freshwater studies

2.5.1 The data bases analysed in the freshwater component of this study were of aquatic macro-invertebrate assemblages in streams, rivers, drains and canals. Complementary environmental data were compiled from contemporary field measurements and from cartographic sources. Separate data bases were used to relate faunal information and water quality to ITE Land Class and land cover:

- CS1990 field survey
- environmental quality
- other related surveys and data bases

Countryside Survey 1990 – field survey

2.5.2 Where present and suitable, a single running watercourse was sampled in each of the 508 1 km squares surveyed as part of CS1990. In this context, a suitable stream was one of first, second or third stream order. A first-order stream is one with no tributaries, a second-order stream is one formed by the confluence of two first-order streams and a third-order stream results from the merger of two second orders.

2.5.3 Fourth- and higher-order streams were regarded as unsuitable for sampling for three reasons.

i. They could be deep and silty and therefore potentially dangerous to sample in remote locations.

ii. Deep sites would have required additional, cumbersome equipment to sample adequately and this could not easily be carried in the field.

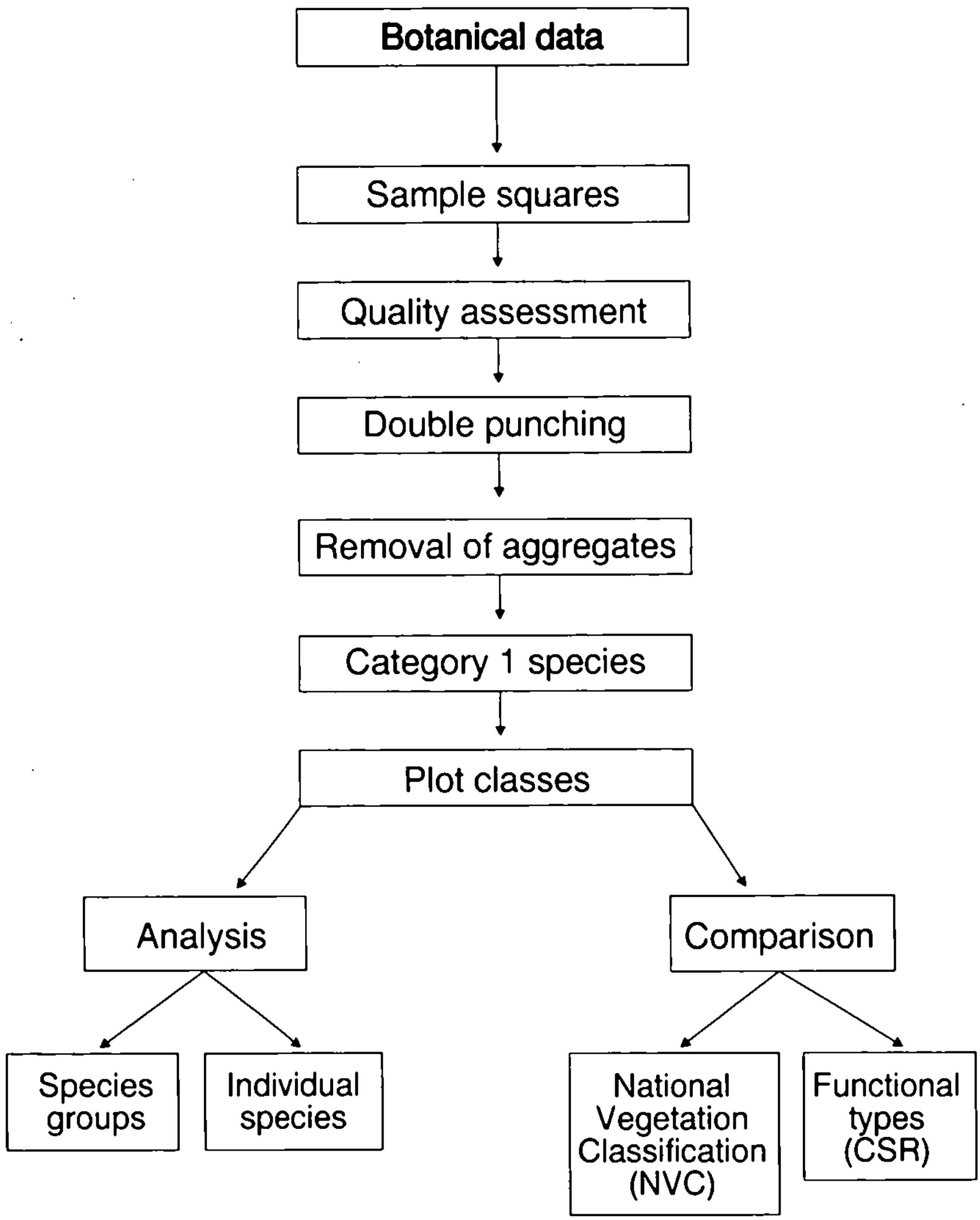
iii. Higher-order watercourses occurred so infrequently in the survey squares that they were too few to allow meaningful comparisons between ITE Land Classes and might even distort any attempt to do so.

2.5.4 Higher-order streams were well represented in the other data bases available for analysis.

2.5.5 A set of rules was established to select the watercourse and site location in each survey square.

- Rivers were given preference over canals which, in turn, were preferred to drains.
- Third-order streams were given preference over second-order and second-order over first-order. This procedure tended to equalise the number of sites sampled in each category.
- In the absence of rivers, the largest canal (or drain) judged to be wadable was

Figure 2.5 The processes involved in the collection, manipulation and analysis of the Countryside Survey botanical data



selected.

- Where possible, the site on the chosen watercourse was located near the point where it flowed out of the 1 km square. This tended to maximise the proportion of its catchment which lay within the square and was therefore surveyed for land cover and use.
- Reaches just downstream of possible point sources of pollution or near human artefacts (eg just downstream of a sewage treatment works or close to a weir) were avoided. No other criteria were established to ensure that the selected stream was necessarily the least polluted of those available within the square. This strategy ensured that, in future surveys, the opportunity to record improvements in quality, as well as deterioration, was available within the data set.
- Given the above criteria, the sites were selected to be reasonably close to roads and tracks in order to limit the distance sampling equipment had to be carried.

2.5.6 Site selection was made in the laboratory prior to sampling. Field surveyors were permitted to modify the sampling point in the field, under certain defined conditions:

- if the selected watercourse was dry;
- if the entire width of the selected watercourse was too deep to wade with safety;
- if the chosen site was physically inaccessible with safety;
- if permission to sample was withheld by the landowner.

Field selection of a replacement site was to follow the same criteria as had been employed in the original selection procedures. (Field surveyors were instructed not to alter the location of sampling sites purely for their own convenience.)

2.5.7 Samples were collected by use of a hand net. The preferred sampling procedure was to hold the mouth of the net downstream of an area of stream substratum being vigorously disturbed by the surveyor's foot. Where aquatic macrophytes were present, these were also sampled by 'sweeping' the net through the vegetation. If these techniques were impossible (eg some very shallow streams), the surveyors were asked to improvise using the most appropriate strategy to collect animals.

2.5.8 The preferred and several alternative sampling strategies were demonstrated to all surveyors during a pre-survey training course.

2.5.9 Whichever sampling strategy was used, the active sampling duration was to be three minutes and the underlying objective of sampling was to collect the widest possible variety of species within this period.

2.5.10 In general, drains and canals were only sampled where wadable in thigh waders, although some such watercourses were only sampled from the margins where the nature of the substratum rendered them potentially dangerous to enter.

2.5.11 Samples were preserved in formalin and identified to the best achievable level, normally species. Most identifications were made by two highly trained staff who worked together to identify difficult or contentious specimens. Specialist help was enlisted to identify or confirm identifications of difficult groups or problematic specimens.

2.5.12 As a further safeguard against mis-identification, the lists of taxa identified at each site were scrutinised by other, experienced IFE staff members. Any unusual specimens, or specimens thought to be at or beyond their perceived ecological range, were re-examined in case of error.

2.5.13 A standardised level of identification was used in all statistical analyses and presentation of analyses. This meant that any small or damaged specimens which could not be identified to the usual detailed level, for their taxonomic group, were deleted from the analytical data set.

2.5.14 At each sampling site, field surveyors recorded environmental data associated with the site on a standard recording sheet. Bankside vegetation and land use, channel management and pollution were recorded for a 25 m length of watercourse either side of the sampling site. Watercourse size characteristics, current velocity and substratum were recorded for the sampling site; locational and the remaining geographical and hydrological data were read from maps. Further details of how these categories were recorded are available in the Field Handbook (Barr 1990).

Environmental quality

2.5.15 Each site was assigned to a biological quality class using procedures devised and recommended by IFE. These were associated with their classification and prediction software package RIVPACS (Wright *et al.* 1988, 1991; Clarke *et al.* 1992; Sweeting *et al.* 1992; Furse *et al.* 1987; Moss *et al.* 1987).

2.5.16 RIVPACS assessments are based upon biotic index values of sites derived from the taxa present. The method used is the Biological Monitoring Working Party (BMWP) score system (Armitage *et al.* 1983). Each family of invertebrate present is allocated a score according to its tolerance of organic pollution. Intolerant taxa are assigned high scores because their presence indicates a lack of pollution. Conversely, pollution-tolerant taxa have low scores. The BMWP site score for the site is the sum of the scores of the individual taxa present.

2.5.17 A criticism of the scoring system is that it is effort- and efficiency-related. The BMWP score is likely to increase with the duration of sampling or improved efficiency of the person sampling. A much less performance-related derivative of the scoring system is the average score per taxon (ASPT). This is the total site score divided by the number of taxa contributing to that score. The ASPT is thus the average pollution tolerance of the taxa captured.

2.5.18 The ratio of the observed score or ASPT of a sample collected from a site and that predicted for it by RIVPACS is termed the Environmental Quality Index (EQI) and is an expression of the extent to which the fauna of a site matches that to be expected in the absence of environmental stress (Wright *et al.* 1988). A perfect match provides an EQI of 1, whilst a site without taxa will have an EQI of zero. Using this procedure, sites of entirely different environmental character in different parts of the country may be compared on a common basis.

2.5.19 A quality banding system has been derived by dividing EQIs into four value ranges for single- or multiple-season sampling (Clarke *et al.* 1992). Different but complementary value ranges apply to score and ASPT. A site may be banded according to score or ASPT alone or an overall band may be ascribed which is an integration of the separate bands derived from score and ASPT (Wright *et al.* 1991). The integration is weighted more heavily towards the ASPT band because this derivative of the system is least effort-dependent.

2.5.20 All sites in the CS1990 data set, for which RIVPACS is operative, were assigned to an ASPT quality band using this methodology. This excluded sites with National Grid References beginning with the letter 'H', for which the requisite climatic data were not incorporated in the software package, and any other site with missing environmental data. A total of 339 sites remained. It should be noted that, even where theoretically operative, the RIVPACS predictions are based on comparing the sites to be banded with those of similar environmental characteristics held in its data base. If no directly comparable sites are held, then those most similar to the site to be banded are used. In this case, the system provides a warning that the prediction must be treated with some caution.

Related surveys and data bases

2.5.21 Prior to the incorporation of running water studies in CS1990, DOE funded a feasibility study. In 1988 a pilot study of running-water macro-invertebrate assemblages was undertaken in 156 of the 1 km squares studied by ITE in their 1978 field survey. In four squares a second sample was also collected, making a total of 160 samples available for analysis. The seasons and methods of biological and environmental sampling were the same as the full 1990 survey. The same level of identification was achieved by the same personnel and the same methods of data validation were applied.

2.5.22 The IFE scientists collaborating in CS1990 have also worked on a wide range of other studies involving the collection and identification of running-water macro-invertebrate assemblages. Almost all sampling was undertaken at sites believed to be unpolluted and in the highest chemical and biological quality class, as assessed by the standard procedures adopted by the water industry. In addition to the two sets of sites referred to above, approximately 700 other sites were available for analysis. Each had been sampled using the standard procedures used in the CS1990 and subject to the same identification procedures. Each was supported by information on the same suite of environmental variables.

2.5.23 CS1990 coincided with the most extensive biological survey of river quality ever undertaken in the United Kingdom. The survey continued the cycle of quinquennial and largely chemistry-based surveys of water quality undertaken on the behalf of DOE since 1970. The 1990 biological survey was organised and implemented by the National Rivers Authority (England and Wales), River Purification Boards (Scotland) and Department of the Environment (Northern Ireland). IFE were regularly consulted by the organisers before, during and after the survey. The macro-invertebrate sampling procedures were those used by IFE in accumulating the data sets referred to above. A similar set of environmental variables was measured and recorded.

2.5.24 All biological and environmental data resulting from the surveys, together with the vast majority of the original samples, are held by IFE and available to them for analysis. Only the results from the main CS1990 field survey are presented in detail here. Further analysis will be given in a separate thematic report.

2.6 Soil surveys

2.6.1 During the CS1990 project there have been two important developments with respect to the linking and integration of soil data with the ITE Land Classification. The first has involved the provision of soil data for each of the c 240 000 1 km squares in GB from the data bases of the Soil Survey and Land Research Centre (SSLRC) and the Macaulay Land Use Research Institute (MLURI). The second has involved the detailed mapping of the soils of each of the 508 1 km sample squares surveyed during CS1990. These additional data present considerable opportunities for the increased and enhanced incorporation of soil information into studies based on the ITE Land Classification or the field survey squares.

Characterisation of ITE Land Classes – 1978 field survey

2.6.2 At the time of the development of the initial ITE Land Classification and the first countryside survey carried out by ITE, there was no uniform national soil data set covering England, Wales and Scotland. Major surveys were in progress by the Soil Surveys of England and Wales, and of Scotland to fill in the gaps between the existing, published soil maps with the aim of producing a national coverage at the 1:250 000 scale.

2.6.3 In the absence of uniform soil data, it was not possible to incorporate soils into the initial classification or to extract data on the soils of the survey squares from available data bases. As a result, soil data were collected from each survey square during the 1978 ITE field survey. A soil pit was dug adjacent to each of the five random vegetation quadrats recorded in each 1 km sample square; the soil profile was described using a simple proforma and soil samples were collected from the surface horizons. The soils were later allocated to one of a number of soil types, essentially soil groups, on the basis of the profile description and field notes.

2.6.4 The resultant soil data were used to determine the distribution of soils in the ITE Land Classes and have been used in a number of subsequent studies based on the ITE Land Classification. However, it was always intended that improved data would be linked to the classification as and when they became available.

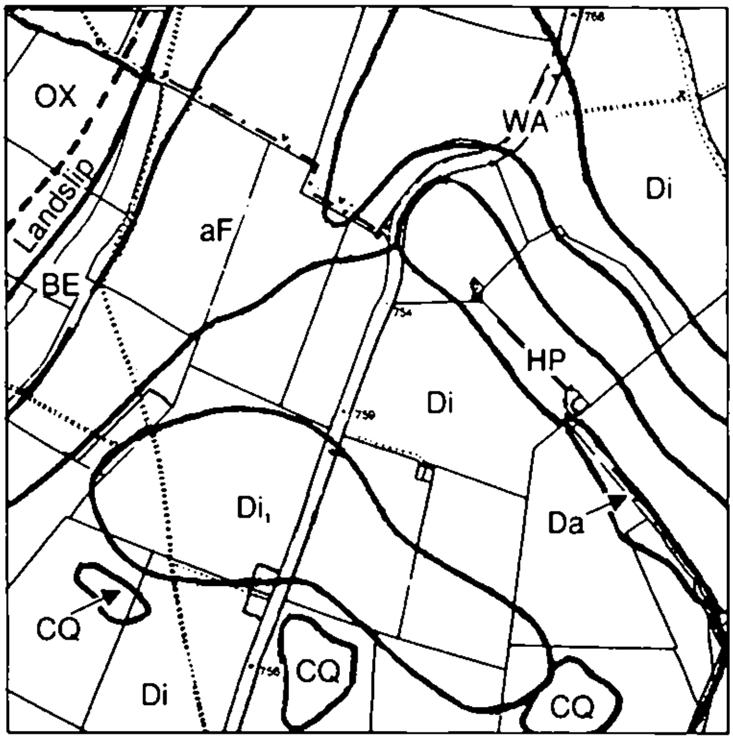
Characterisation of ITE Land Classes – data from soil maps

2.6.5 In 1983 a series of 1:250 000 scale soil maps were published which provided complete coverage of GB. During CS1990, SSLRC and MLURI were commissioned to develop a soil data set, in machine-readable form, based on the national maps and providing information on the soil subgroups occurring in each 1 km square in GB using a uniform classification.

2.6.6 The data were presented as the dominant and a series of subdominant soil subgroups occurring in each 1 km square. Separate data files were produced by the

Figure 2.6 An example of a soil survey map

SSLRC – ITE Countryside Survey



Scale: 1:10,560

ITE No: 11/301
Grid ref:
Location:

Surveyed by:

Date:

Symbol	Soil series	Subgroup	Complexity
aF	Aberford	5.11	Varying stone content
BE	Bearsted	5.41	Some more silty areas giving Atrim series
CQ	Cranwell	5.11	
Di_1	Dinorben (sandy variant)	5.51	Less stony than Di, topsoils often stoneless. Soil readily blows
Di	Dinorben	5.41	Stone content varies from stoneless to slightly stony
Da	Denchworth	7.12	
HP	Hopsford	5.43	Variable degree of wetness. Marginal to well drained
OX	Oxpasture	5.72	Area includes patch of landslip
WA	Waltham	5.41	

Comments:

SSLRC and the MLURI based on the respective national maps and using the respective national classifications. The SSLRC produced software to facilitate the conversion of the MLURI classificationary units into the equivalent units in the SSLRC classification.

2.6.7 The merged data sets, with all soils classified in terms of the SSLRC classification have been analysed to determine the distribution of soils between ITE Land Classes, the most common soils in each ITE Land Class, and the distribution of soils in the four landscape types. The numbers of 1 km squares in each ITE Land Class in which given soil subgroups occur as the dominant or subdominant soil were calculated. The numbers recorded were then expressed as a percentage of the total 1 km squares within the given ITE Land Class; the five most commonly occurring soil units in each ITE Land Class were listed.

Soil surveys in CS1990

2.6.8 During CS1990, SSLRC and MLURI were commissioned to carry out detailed soil surveys of each of the 508 1 km field survey squares. The mapping was done at the 1:10 000 scale and at the series level, wherever possible. Figure 2.6 provides an example of the completed maps.

2.7 Summary of Chapter 2

2.7.1 One of the primary objectives of CS1990 was that information on a variety of topics, related to rural land use, should be integrated to provide a holistic view of the British countryside in 1990. To do this, there had to be a common framework within which the different parts of the survey could function. This was provided by the ITE Land Classification, and its use of a 1 km square grid, which allowed information to be integrated and summarised on a common spatial basis.

2.7.2 Census land cover mapping of GB was completed by the interpretation and classification of Landsat satellite imagery. Although undertaken at a pixel size of 25 m x 25 m, the results of the classification were also summarised at the 1 km square level.

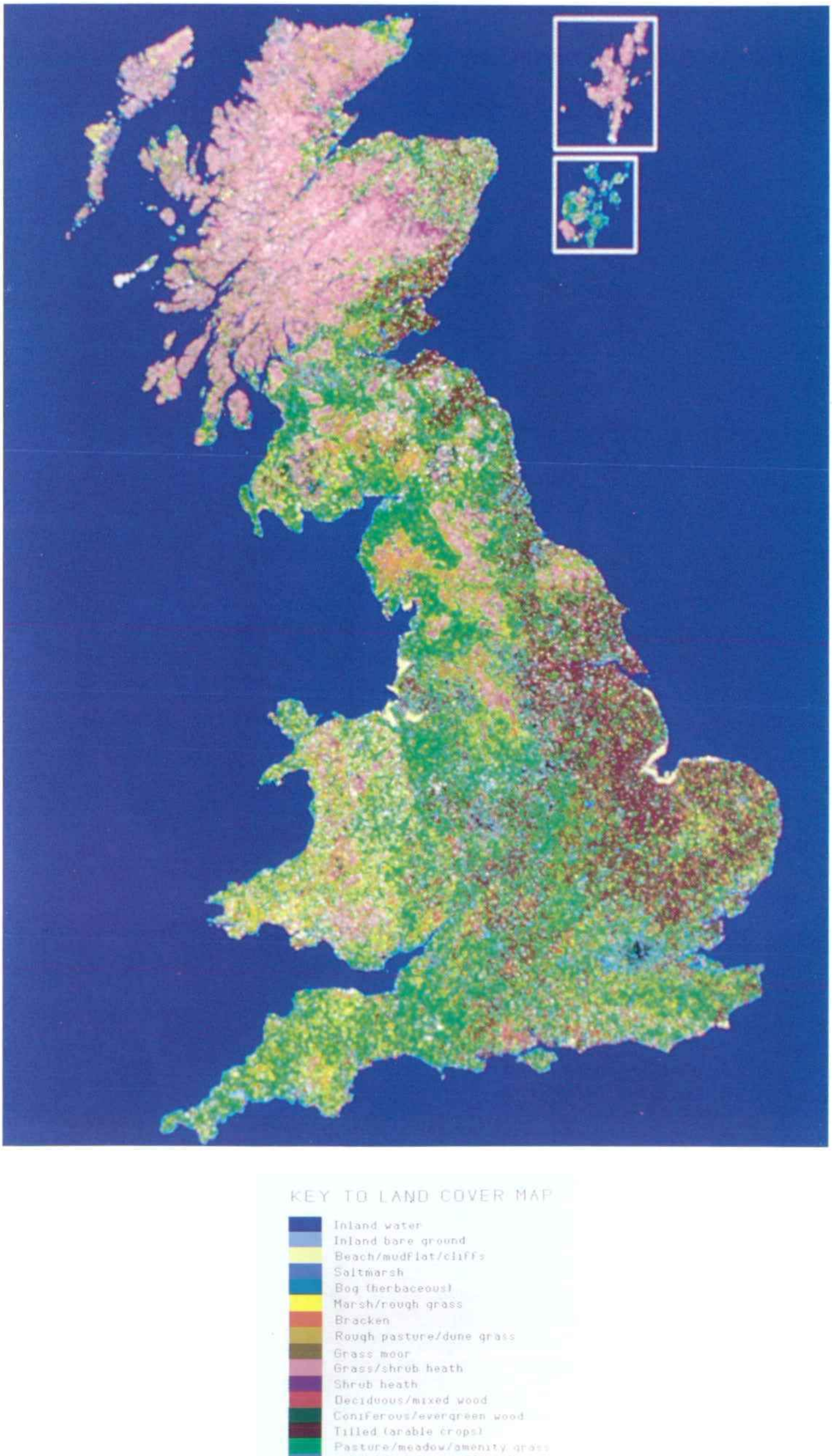
2.7.3 Sample survey information on land cover, land use, landscape features, habitats and vegetation in quadrats was collected in 508 1 km squares in GB, stratified by ITE Land Class. Data were summarised using the ITE Land Classification.

2.7.4 Although quality control was carried out at all stages and in all parts of the project, a special Quality Assurance Exercise was completed in relation to the field survey. The results suggested that recording accuracy was as 'close to the maximum attainable efficiency that can be expected'.

2.7.5 Information on freshwater biota, and water quality, was collected from a variety of sources, including sampling the 508 1 km squares. Results have been expressed at the 1 km square level and by ITE Land Class.

2.7.6 Soil information has been assembled from existing maps and, at a greater level of spatial accuracy, by survey in 1990 of the 508 1 km sample squares. Results have been expressed at the 1 km square level and by ITE Land Class.

Plate 1 The Land Cover Map of Great Britain



Chapter 3 THE RESULTS (I): LAND COVER

3.1 Interpretation of results

While the outputs from this study provide the most up-to-date figures available on the stock and change of land cover, landscape features and vegetation, caution should be used in their interpretation, as follows.

- Figures resulting from the land cover map, produced by interpretation of satellite imagery, provide census data (land cover summaries are given for every 1 km square in Great Britain (GB)). Because they are census data, they do not need to carry expressions of statistical accuracy (in contrast to sample-based systems). However, the results have been obtained using computer-aided interpretation of satellite data and there will inevitably be a proportion of instances where incorrect classification takes place. Validation of the satellite data is discussed in section 3.6. onwards.

- The field survey estimates of stock and change are derived from a sample-based survey. As with any such system, there are statistical errors associated with extrapolation from a sample to national estimates. These error terms are given where possible and should be taken into account when interpreting results, especially in considering change. A full account of the choice of error terms, and how they were calculated, is given in Appendix 3.

- Although every effort was made to standardise recording procedures in the field (including an extensive training course; use of a field handbook (Barr 1990), use of aerial photographs; field supervision and checks; mixing of field teams), there are likely to be some differences in the way that the data have been recorded by different observers. There is no reason to expect estimates of field recording to be biased in any particular direction and it is likely that any differences will 'balance out' over the whole data set. (See also quality assurance in section 2.4.)

3.2 1990 stock figures from satellite imagery

Land cover mapping

3.2.1 The land cover has been fully mapped, except where very small pockets of cloud cover obscured the land surface. The main output is called the Land Cover Map of Great Britain, and is shown in Plate 1. Out of 3% which remains unclassified, perhaps one-fifth is unclassified due to cloud. Elsewhere, unusual cover types are the most likely cause. The only other exceptions to this observation are Tiree, part of Coll and the northern and southern tips of Shetland which did not fall within suitable Landsat scenes of GB. These areas, totalling perhaps 200 km^2, represent just 0.1% of GB. They will be added to the land cover map after classification of alternative images, eg Landsat Multispectral Scanner.

3.2.2 In all, 46 different scenes were required to make up full cover of GB: 88% of GB was classified from combined summer/winter images, and 12% from single-date, mostly summer, data.

3.2.3 Geometric correction was to subpixel level: this means that the polynomial model for correction placed ground control points within 1 pixel of their Ordnance Survey (OS) mapped position. Co-registration of vector field maps of 143 Countryside Survey 1990 (CS1990) squares with Landsat raster equivalents showed that an average displacement throughout was 0.8 pixels (20 m), 75 out of 143 squares needed no shift to achieve correspondence, 43 squares a one pixel shift, 15 squares 2 pixels movement and only 10 squares required more than 2 pixels movement.

3.2.4 Classification of the satellite imagery produced 25 target classes (cf section 2.2.13 and Table 2.1), aggregated to 17 key cover types with correspondence to CS1990 field and other surveys. The classes were further simplified to nine major cover types for pattern analysis.

3.2.5 A new suite of image analysis procedures was developed for this project, including some novel approaches to contextual and knowledge-based corrections of class maps.

3.2.6 The results take the form of computer files of raster data, stored as 100 km x 100 km sections. Various hard-copy products have been demonstrated and it is intended to publish generalised land cover maps. Maps at full detail can be made to order, though it is expected that the major uses of the data will be in Geographical Information Systems (GIS).

The land cover of Great Britain

3.2.7 Table 3.1 gives land cover statistics for GB and the breakdown of land cover within England, Scotland and Wales. In this discussion, urban land includes continuous urban and suburban land, and semi-natural vegetation includes rough grass/marsh, bracken, heath/moor grass, open shrub heath/moor, dense shrub heath/moor, bog, deciduous woodland and saltmarsh, but not managed grass.

3.2.8 In GB as a whole, managed grassland is the most extensive land cover type (27%), followed by tilled land (21%) and open shrub heath moor (12%). Urban land amounts to 7% and semi-natural vegetation covers one-third of GB.

3.2.9 In England the predominance of tilled land and managed grass is notable, together covering 66% of the land surface. Urban land in England amounts to 10%, a higher proportion than in Scotland or Wales. Woodlands cover 8% and heath/moorland/bog categories add to 9%. Semi-natural vegetation covers about 17% of England.

3.2.10 In Scotland, there is a much higher cover of heath/moor/bog (52%), with managed grasslands important at 15%; arable land covers just 8% of Scotland and urban areas amount to under 2%. Established coniferous forestry now covers 6% of Scotland, but, in addition, there will be some new planting which will have been classified as moorland. Semi-natural vegetation covers over 57% of Scotland

3.2.11 In Wales, managed grasslands dominate with 38% cover; arable covers just 5% Woodlands are important with 16% cover and heath/moor/bog areas cover 20% of the country. Urban areas only cover 3% Bracken, the only species given a cover class of its own, is at its most prevalent in Wales (5%). Semi-natural vegetation covers more than 39% of the country

Table 3.1 Land cover (km²) in England, Scotland, Wales and GB from the satellite land cover map - 1990

	England		Scotland		Wales		GB	
Land cover class	Area	%	Area	%	Area	%	Area	%
Continuous urban	2 446	1.8	103	0.1	55	0.3	2 603	1.1
Suburban	11 243	8.4	1 312	1.5	614	2.8	13 169	5.5
Tilled land	43 311	32.4	6 921	8.1	1 082	5.0	51 313	21.4
Managed grassland	44 489	33.3	13 001	15.3	8 181	37.9	65 672	27.3
Rough grass/marsh	1 988	1.5	1 659	2.0	660	3.1	4 307	1.8
Bracken	1 296	1.0	1 153	1.4	1 154	5.3	3 603	1.5
Heath/moor grass	7 570	5.7	10 672	12.6	1 961	9.1	20 203	8.4
Open shrub heath/moor	2 349	1.8	23 980	28.2	1 539	7.1	27 868	11.6
Dense shrub heath/moor	1 236	0.9	5 410	6.4	574	2.7	7 220	3.0
Bog	271	0.2	3 807	4.5	231	1.1	4 309	1.8
Deciduous/mixed woodland	7 873	5.9	1 934	2.3	2 523	11.7	12 329	5.1
Coniferous woodland	2 184	1.6	4 659	5.5	879	4.1	7 722	3.2
Inland bare	1 013	0.8	1 408	1.7	144	0.7	2 566	1.1
Saltmarsh	293	0.2	54	0.1	43	0.2	389	0.2
Coastal bare	681	0.5	596	0.6	144	0.7	1 421	0.6
Inland water	392	0.3	1 249	1.3	73	0.3	1 714	0.7
Sea/estuary	1 867	1.4	5 203	4.7	613	2.8	7 683	3.2
Unclassified	3 149	2.4	1 868	3.9	1 116	5.2	6 133	2.6
Total	**133 651**	**100.0**	**84 987**	**100.0**	**21 584**	**100.0**	**240 222**	**100.0**

Table 3.2 Land cover (km²) in the arable landscapes of England, Scotland, Wales and GB from the satellite land cover map – 1990

Land cover class	England Area	England %	Scotland Area	Scotland %	Wales Area	Wales %	GB Area	GB %
Continuous urban	1 194	1.8	62	0.4	4	0.4	1 259	1.5
Suburban	6 100	9.2	834	5.7	26	3.0	6 960	8.5
Tilled land	29 228	44.3	4 071	27.9	81	9.1	33 380	41.0
Managed grassland	19 119	28.9	4 376	30.0	455	51.4	23 950	29.4
Rough grass/marsh	1 226	1.9	393	2.7	18	2.0	1 637	2.0
Bracken	177	0.3	86	0.6	27	3.1	290	0.4
Heath/moor grass	1 121	1.7	686	4.7	24	2.8	1 831	2.2
Open shrub heath/moor	349	0.5	1 338	9.2	43	4.8	1 730	2.1
Dense shrub heath/moor	172	0.3	363	2.5	3	0.3	537	0.7
Bog	46	0.1	130	0.9	2	0.2	177	0.2
Deciduous/mixed woodland	4 026	6.1	548	3.8	120	13.5	4 693	5.8
Coniferous woodland	941	1.4	879	6.0	13	1.5	1 834	2.2
Inland bare	545	0.8	65	0.4	3	0.3	613	0.8
Saltmarsh	85	0.1	11	0.1	1	0.1	97	0.1
Coastal bare	135	0.2	54	0.4	2	0.3	192	0.2
Inland water	175	0.3	162	1.1	0	0.0	337	0.4
Sea/estuary	420	0.6	229	1.6	5	0.5	653	0.8
Unclassified	986	1.5	292	2.0	58	6.6	1 337	1.6
Total	**66 043**	**100**	**14 579**	**100**	**885**	**100**	**81 507**	**100**

Arable landscapes

3.2.12 In the arable landscape of GB, tilled land forms 41% of the land area, occupying 44% of land in arable landscapes of England, 28% in Scotland and 9% in Wales (Table 3.2). Managed grasslands are nearly as extensive, occupying up to 30% of arable landscapes in both England and Scotland and over 50% in the Welsh arable landscapes. About half of all urban land falls in the arable landscapes, with 11% of England's arable landscape under urban cover types, a corresponding value of 6% in Scotland and 3% in Wales. Not surprisingly, heaths, moors and bogs are relatively scarce at 5% cover: although these only form 3% of English arable landscapes, they extend to 17% of Scottish and 8% of Welsh arable landscapes. Deciduous woodlands occupy 6% of arable landscapes in England and in GB as a whole, but this includes values as low as 4% in Scotland and as high as 14% in Wales. Less than 14% of this landscape type comprises semi-natural vegetation.

Pastural landscapes

3.2.13 In pastural landscapes, managed grasslands dominate with 39% of the land cover of pastural Britain, including 39% of England 35% of Scotland and 42% of Welsh pastural landscapes (Table 3.3). Tilled land occupies 22% of pastural Britain, occurring in 25% of English, 20% of Scottish and 8% of

Table 3.3 Land cover (km²) in the pastural landscapes of England, Scotland, Wales and GB from the satellite land cover map – 1990

Land cover class	England Area	England %	Scotland Area	Scotland %	Wales Area	Wales %	GB Area	GB %
Continuous urban	1 172	2.3	16	0.2	47	0.4	1 238	1.8
Suburban	4 911	9.5	205	2.4	454	4.4	5 582	7.9
Tilled land	13 160	25.4	1 682	19.8	833	8.0	15 720	22.2
Managed grassland	20 335	39.3	3 001	35.3	4 370	41.9	27 781	39.3
Rough grass/marsh	595	1.1	333	3.9	378	3.6	1 310	1.9
Bracken	334	0.6	75	0.9	661	6.3	1 072	1.5
Heath/moor grass	2 227	4.3	640	7.5	435	4.2	3 314	4.7
Open shrub heath/moor	462	0.9	816	9.6	328	3.2	1 617	2.3
Dense shrub heath/moor	243	0.5	199	2.3	54	0.5	498	0.7
Bog	53	0.1	90	1.1	40	0.4	185	0.3
Deciduous/mixed woodland	3 128	6.0	267	3.1	1 098	10.5	4 503	6.4
Coniferous woodland	615	1.2	445	5.2	194	1.9	1 262	1.8
Inland bare	409	0.8	40	0.5	61	0.6	511	0.7
Saltmarsh	208	0.4	13	0.2	42	0.4	264	0.4
Coastal bare	546	1.1	71	0.8	141	1.4	760	1.1
Inland water	141	0.3	67	0.8	20	0.2	229	0.3
Sea/estuary	1 447	2.8	362	4.3	609	5.8	2 425	3.4
Unclassified	1 734	3.4	184	2.2	662	6.3	2 385	3.4
Total	**51 720**	**100.0**	**8 506**	**100.0**	**10 427**	**100.0**	**70 653**	**100.0**

Table 3.4 Land cover (km^2) in the marginal upland landscapes of England, Scotland, Wales and GB from satellite land cover map – 1990

Land cover class	England Area	England %	Scotland Area	Scotland %	Wales Area	Wales %	GB Area	GB %
Continuous urban	58	0.5	10	0.1	5	<0.0	72	0.2
Suburban	208	1.8	128	0.8	133	1.3	469	1.2
Tilled land	777	6.7	714	4.4	167	1.6	1 658	4.3
Managed grassland	4 464	38.7	2 874	17.6	3 353	32.8	10 691	28.0
Rough grass/marsh	118	1.0	335	2.0	262	2.6	715	1.9
Bracken	540	4.7	238	1.5	465	4.5	1 243	3.3
Heath/moor grass	2 707	23.4	2 514	15.4	1 487	14.5	6 708	17.6
Open shrub heath/moor	727	6.3	4 262	26.0	1 161	11.4	6 150	16.1
Dense shrub heath/moor	522	4.5	1 020	6.2	510	5.0	2 052	5.4
Bog	53	0.5	658	4.0	189	1.8	900	2.4
Deciduous/mixed woodland	682	5.9	332	2.0	1303	12.7	2 317	6.1
Coniferous woodland	275	2.4	1 190	7.3	670	6.6	2 135	5.6
Inland bare	50	0.4	248	1.5	78	0.8	376	1.0
Saltmarsh	0	0.0	6	<0.0	0	0.0	6	<0.0
Coastal bare	0	0.0	120	0.7	0	0.0	120	0.3
Inland water	57	0.5	145	0.9	52	0.5	254	0.7
Sea/estuary	0	0.0	1 307	8.0	0	0.0	1 307	3.4
Unclassified	309	2.7	265	1.6	393	3.8	968	2.5
Total	**11 546**	**100.0**	**16 366**	**100.0**	**10 228**	**100.0**	**38 140**	**100.0**

Welsh pastural landscapes. In England, urban land occupies 12% of pastural landscapes, but the corresponding figures for Scotland and Wales are 3% and 5% respectively, giving a GB average of 10%. Deciduous woodlands occupy 6% of GB with figures for England, Scotland and Wales showing 6%, 3% and 11% respectively. Conifers in English pastural landscapes cover just over 1% while in Scotland cover reaches over 5% and in Wales 2%. Thus, tree cover in Welsh pastural landscapes reaches 12%, while in England it is 7% and in Scotland 8%. About 16% of pastural landscapes in Britain comprise semi-natural vegetation

Marginal upland landscapes

3.2.14 In marginal landscapes, managed grass dominates at 28% of the total (Table 3.4). In England a higher proportion is managed at 39%, while in Scotland and Wales the amounts are less at 18% and 33% respectively. Tillage only covers about 4% of marginal landscapes. Heath and moorland grass take second place in cover terms at 18% of GB. In England the heath/moor grass cover is 23%, in Scotland it is 15%, and in Wales 15%. Total heath, moor and bog cover for GB is over 41%, occupying 35% of marginal landscapes in England, 52% in Scotland and 33% in Wales. Bracken in marginal landscapes occupies 3% of land, reaching 5% cover in England and Wales. Only 1–2% of Britain's marginal landscapes are urban. The result is a landscape comprising over 52% semi-natural vegetation.

Upland landscapes

3.2.15 The upland landscapes are dominated by dwarf shrub heath: combined totals for open and dense shrub heaths/moors in GB show cover to be 45% (Table 3.5). In England the figure is as low as 26%, in Wales (where the upland landscape is restricted mainly to Snowdonia) it reaches 32%, and in Scotland it extends to 47%. Total heath, moor and bog cover in GB uplands is 68%. Mature conifers cover 5% of uplands. Urban land covers just 0.4% of uplands. The 7% cover of sea/estuary shows that this landscape type is one that is defined as being generally characteristic of the uplands, but which extends to coastal regions in the extreme north and west of Britain. Total semi-natural vegetation covers over 73% of upland landscapes in GB.

Conclusions

3.2.16 The land cover mapping project has successfully recorded the land cover of all GB. It is the first such survey since the 1960s (Coleman 1961) and only the second this century (see also Stamp 1962).

3.2.17 The most important development has been the provision of land cover data for GB at a single point in time. The availability of land cover data in digital form greatly facilitates access to the map

Table 3.5 Land cover (km²) in the upland landscapes of England, Scotland, Wales and GB from satellite land cover map – 1990

Land cover class	England Area	England %	Scotland Area	Scotland %	Wales Area	Wales %	GB Area	GB %
Continuous urban	22	0.5	15	<0.0	0	0.0	37	0.1
Suburban	25	0.6	145	0.3	0	0.2	170	0.3
Tilled land	146	3.4	454	1.0	1	1.5	600	1.2
Managed grassland	571	13.2	2 750	6.0	3	7.8	3 325	6.7
Rough grass/marsh	50	1.2	598	1.3	2	4.4	650	1.3
Bracken	245	5.6	754	1.7	1	2.9	1 000	2.0
Heath/moor grass	1 515	34.9	6 832	15.0	14	32.1	8 362	16.7
Open shrub heath/moor	812	18.7	17 564	38.6	6	14.5	18 382	36.8
Dense shrub heath/moor	300	6.9	3 828	8.4	8	17.4	4 135	8.3
Bog	119	2.7	2 928	6.4	1	1.8	3 048	6.1
Deciduous/mixed woodland	37	0.8	787	1.7	1	2.9	825	1.7
Coniferous woodland	353	8.1	2 145	4.7	1	1.2	2 498	5.0
Inland bare	10	0.2	1 055	2.3	3	6.0	1 068	2.1
Saltmarsh	0	0.0	24	0.1	0	0.0	24	0.0
Coastal bare	0	0.0	351	0.8	0	0.1	351	0.7
Inland water	19	0.4	875	1.9	0	0.5	894	1.8
Sea/estuary	0	0.0	3 306	7.3	0	0.1	3 306	6.6
Unclassified	120	2.8	1 126	2.5	3	6.5	1 248	2.5
Total	**4 342**	**100.0**	**45 536**	**100.0**	**44**	**100.0**	**49 922**	**100.0**

information and manipulation for specific applications.

3.2.18 The Countryside Information System (CIS) holds summary data at 1 km square resolution. Although losing the full spatial details of the original survey, this data set offers an enormous quantity of information and is suitable for most analyses where the exact spatial context of land cover units is not needed.

3.2.19 The marriage, in CIS, of a general map of total land cover with the detail of a sample-based field survey offers a great potential in terms of supplying integrated land cover information. Additional information on geology, soils, terrain, climate and administrative boundaries can increase this potential. These data are not only available for scientific enquiry: the relatively simple access to data and analyses within the CIS allows planners, policy-makers and landscape managers to access the data and support their decisions with data and 'tailor-made' analyses.

3.2.20 The land cover data at full resolution show Britain at a field-by-field scale. This allows the provision of paper maps at scales up to about 1:25 000 or overviews at perhaps 1:1 000 000. Such maps can clearly help those concerned with wider issues of land management. The larger-scale products are likely to be specially designed, fitting a user's requirements for scale and details. The small-scale product is likely to be mass-produced for general use.

3.2.21 The most detailed analyses of the land cover data will be in GIS. These will allow users to explore the full resolution of the original data, drawing on detailed maps of topography, climate, terrain and administration.

3.3 1990 stock figures from field survey

3.3.1 As outlined in the earlier sections, a great variety of information has been collected on land cover by field survey. Each distinct parcel of land in the 508 1 km sample squares was described and mapped using combinations of coded descriptors. The descriptors were based on a suggested list of 100 primary codes which could be further qualified with secondary codes either drawn from the 250 suggested or, if necessary, specially created. No limit was placed on the number of codes which could be used and the permutations are too numerous to present. Although the detail allows specific interrogations to follow precise and intricate questions, for this report the data have been aggregated into 58 categories (see section 2.3.17). Further aggregations allow the data to be summarised in categories that correspond to those used in the land cover map (Tables 3.6–3.8).

3.3.2 The predicted areas of land cover classes, with standard errors, are presented in hundreds of km squares (10 000 ha) and are calculated using the methods described

Table 3.6 Land cover for GB (from the CS1990 field survey, by area ('00 km²), standard error (SE) ('00 km²) and percentage (%GB) (+ = presence <50 km² or <0.5%). The subtotals (in bold) correspond approximately to the 17 key cover types obtained from the satellite land cover map

Cover type	GB stock 1990 Area	SE	%
Communications			
Railway	4	1	+
Road	44	2	2
	48	**2**	**2**
Built up			
Agricultural buildings	14	1	1
Residential buildings	68	7	3
Other buildings	30	5	1
Unsurveyed urban land	48	‡	2
	160	**10**	**7**
Tilled land			
Wheat	223	15	10
Barley	115	10	5
Oats	9	2	+
Mixed and other cereals	3	2	+
Maize	4	2	+
Turnips/swedes	7	1	+
Kale	5	2	+
Oil-seed rape (OSR)	41	6	2
Crucifer crops (other than OSR)	3	1	+
Peas	11	3	+
Field beans	10	3	+
Legumes (not peas/field beans)	+	+	+
Sugar beet	22	4	1
Root crops (not turnips/swedes/potatoes)	1	+	+
Potatoes	14	3	1
Other field crops	10	2	+
Horticulture	4	3	+
	481	**23**	**21**
Managed grass			
Recreational (mown) grass	25	5	1
Recently sown grass	71	6	3
Pure rye-grass	203	14	9
Well-managed grass	193	13	8
Weedy swards with >25% rye grass	99	8	4
Non-agriculturally improved grass	20	4	1
Calcareous grass	7	3	+
Upland grass	61	7	3
Maritime vegetation	3	1	+
	682	**23**	**29**
Rough grass/marsh			
Non-cropped arable (ploughed and fallow)	35	8	2
Unmanaged grassland and tall herb	27	2	1
Felled woodland	4	2	+
Wetland	37	5	2
Waste and derelict land	4	1	+
	107	**9**	**5**
Dense bracken	**37**	**6**	**2**
Moorland grass			
Purple moor grass-dominated moorland	37	8	2
Moorland grass (other than Purple moor grass)	81	11	3
Dune	2	1	+
	120	**14**	**5**
Open heath			
Open-canopy heath	82	10	4
Berry-bush heath	12	3	1
Drier northern bogs	52	8	2
	146	**13**	**6**
Dense heath	**45**	**8**	**2**
Wet heaths and saturated bogs	**166**	**15**	**7**
Broadleaved/mixed woodland			
Perennial crops	7	3	+
Mixed woodland	22	4	1
Broadleaved woodland	92	7	4
Shrub	9	1	+
	130	**9**	**6**
Conifers	**137**	**16**	**6**
Inland bare			
Inland rocks and screes	2	1	+
Hard areas without buildings	2	+	+
Quarries and extractive industries	3	1	+
	6	**1**	**+**
Saltmarsh	**4**	**2**	**+**
Coastal bare			
Intertidal soft coast without vegetation	12	4	1
Hard coast with no vegetation	6	1	+
	18	**4**	**1**
Inland water			
Still water	21	7	1
Running water	8	1	+
	29	**7**	**1**
Total	**2318**		

‡ Unsurveyed urban land is a census estimate from all 1 km squares not surveyed and consequently has no SE. The area is included in the built up category and percentage area but the SE is for the built up categories without unsurveyed urban land

in Appendix 3. The surveys were of rural land and excluded areas covered by more than 75% built land or curtilage. The figures presented include a total for these excluded urban areas ('unsurveyed urban land'), and a prediction for the rural part of those squares.

3.3.3 The results (which are held in the CIS) are presented here for GB, England, Scotland and Wales, and for the four landscape types.

Great Britain in 1990

3.3.4 The results for GB are presented in Table 3.6 and show general agreement with the land cover map (Table 3.1). Tilled land covers 21% of the land surface and is dominated by wheat (10%) then barley (5%) and oil-seed rape (2%). These figures differ from the 1990 Ministry of Agriculture, Fisheries and Food (MAFF) June census, which shows a similar total for wheat and barley combined, but with a different breakdown (wheat – 20 100 km² from MAFF and 22 300 km² from CS1990; barley – 15 200 km² from MAFF and 11 500 km² from CS1990).

3.3.5 The GB data are broken down by country in Table 3.7. This shows that 31% of England is tilled (33% if non-cropped arable is included), compared with only 9% of Wales and 7% of Scotland. In both Scotland and Wales the barley area exceeds that for wheat. Oil-seed rape accounts for 9% of the tilled land in England, 6% in Scotland and 5% in Wales, while sugar beet accounts for 5% in England and less than 1% in both Scotland and Wales.

Table 3.7 National land cover from the CS1990 field survey, by area ('00 km²), standard error (SE) ('00 km²) and percentage (%GB) (+ = presence <50 km² or <0.5%). The subtotals (in bold) correspond approximately to the 17 key cover types obtained from the satellite land cover map

	Stock 1990								
	England			Wales			Scotland		
Cover type	Area	SE	%	Area	SE	%	Area	SE	%
Communications									
Railway	3	1	+	+	+	+	2	+	+
Road	32	2	2	4	+	2	8	1	1
	35	**2**	**3**	**4**	**+**	**2**	**9**	**1**	**1**
Built up									
Agricultural buildings	10	1	1	1	+	1	2	+	+
Residential buildings	53	6	4	8		4	8	1	1
Other buildings	22	4	2	3	+	1	5	2	1
Unsurveyed urban land	41	‡	3	1	‡	+	4	‡	1
	126	**8**	**9**	**12**	**2**	**5**	**20**	**3**	**3**
Tilled land									
Wheat	202	14	15	6	1	3	15	3	2
Barley	80	8	6	7	1	3	29	5	4
Oats	6	2	+	1	+	+	2	1	+
Mixed and other cereals	3	2	+	+	+	+	+	+	+
Maize	4	1	+	+	+	+	+	+	+
Turnips/swedes	3	1	+	1	+	+	3	1	+
Kale	3	1	+	+	+	+	1	1	+
Oil-seed rape (OSR)	35	6	3	1	+	+	4	1	1
Crucifer crops (other than OSR)	2	1	+	+	+	+	1	1	+
Peas	10	2	1	+	+	+	1	+	+
Field beans	9	2	1	+	+	+	1	+	+
Legumes (not peas/field beans)	+	+	+	+	+	+	0	0	0
Sugar beet	21	4	2	1	+	+	+	+	+
Root crops (not turnips/swedes/potatoes)	1	+	+	+	+	+	+	+	+
Potatoes	11	3	1	1	+	+	2	1	+
Other field crops	9	2	1	+	+	+	+	+	+
Horticulture	4	3	+	+	+	+	+	+	+
	403	**20**	**31**	**19**	**2**	**9**	**59**	**8**	**7**
Managed grass									
Recreational (mown) grass	21	4	2	2	+	1	2	1	+
Recently sown grass	50	5	4	7	1	3	14	3	2
Pure rye-grass	145	10	11	25	3	12	34	5	4
Well-managed grass	112	8	8	34	5	34	48	6	6
Weedy swards with >25% rye-grass	52	5	4	17	2	17	30	4	4
Non-agriculturally improved grass	11	2	1	3	1	3	6	2	1
Calcareous grass	4	2	+	+	+	+	2	1	+
Upland grass	17	3	1	9	2	4	35	5	4
Maritime vegetation	1	+	+	+	+	+	2	1	+
	412	**17**	**31**	**97**	**6**	**46**	**172**	**12**	**22**
Rough grass/marsh									
Non-cropped arable (ploughed and fallow)	32	8	2	1	+	1	2	1	+
Unmanaged grassland and tall herb	17	2	1	2	+	1	8	1	1
Felled woodland	1	+	+	+	+	+	3	1	+
Wetland	12	2	1	5	1	2	20	3	2
Waste and derelict land	3	1	+	+	+	+	1	+	+
	65	**8**	**5**	**8**	**1**	**4**	**34**	**3**	**4**
Dense bracken	**12**	**2**	**1**	**9**	**2**	**4**	**15**	**4**	**2**
Moorland grass									
Purple moor grass-dominated moorland	9	2	1	10	4	5	19	4	2
Moorland grass (other than purple moor grass)	20	4	2	7	3	3	54	7	7
Dune	+	+	+	+	+	+	2	1	+
	29	**5**	**2**	**17**	**5**	**8**	**75**	**8**	**9**
Open heath									
Open-canopy heath	19	3	1	7	2	3	56	7	7
Berry-bush heath	2	+	+	1	+	+	10	2	1
Drier northern bogs	9	2	1	2	1	1	41	6	5
	30	**4**	**2**	**9**	**3**	**4**	**107**	**9**	**13**
Dense heath	**13**	**3**	**1**	**4**	**2**	**2**	**28**	**5**	**3**
Wet heaths and saturated bogs	**15**	**3**	**1**	**3**	**1**	**1**	**149**	**14**	**19**
Broadleaved/mixed woodland									
Perennial crops	7	3	1	+	+	+	+	+	+
Mixed woodland	13	2	1	2	1	1	8	2	1
Broadleaved woodland	68	6	5	10	1	5	13	2	2
Shrub	6	1	+	1	+	1	2	+	+
	94	**8**	**7**	**14**	**1**	**7**	**23**	**4**	**3**
Coniferous woodland	**45**	**6**	**3**	**7**	**2**	**3**	**85**	**12**	**11**
Inland bare									
Inland rocks and screes	+	+	+	+	+	+	1	+	+
Hard areas without buildings	1	+	+	+	+	+	1	+	+
Quarries and extractive industries	2	1	+	+	+	+	1	+	+
	3	**1**	**+**	**+**	**+**	**+**	**3**	**1**	**+**
Saltmarsh	**3**	**1**	**+**	**1**	**+**	**+**	**1**	**+**	**+**
Coastal bare									
Intertidal soft coast without vegetation	9	4	1	1	+	1	2	+	+
Hard coast with no vegetation	2	+	+	1	+	+	4	1	+
	11	**4**	**1**	**2**	**+**	**1**	**6**	**1**	**1**
Inland water									
Still water	10	6	1	1	+	+	10	3	1
Running water	5	1	+	1	+	+	2	+	+
	15	**6**	**1**	**2**	**+**	**1**	**12**	**3**	**1**
Total	**1311**			**208**			**790**		

‡ Unsurveyed urban land is a census estimate from all 1 km squares not surveyed and consequently has no SE. The area is included in the built up category and percentage area but the SE is for the built up categories without unsurveyed urban land

3.3.6 Of the 31% of GB covered by managed grass, about 40% is intensively managed as short term ley or pure rye-grass. England again has the dominant share of this type of grassland, both in terms of area and proportion of all grassland. The converse of this can be seen in the larger proportion of more natural managed grasslands in Scotland and Wales.

3.3.7 The total area of land managed for agriculture in England is 81 500 km^2 (or 84 700 km^2 if non-cropped arable is included), which compares with 84 730 km^2 from the MAFF June census for 1990. This area is equivalent to 62% of the land surface of England; figures for Scotland and Wales are 29% and 56% respectively.

3.3.8 The field survey data show that 21% of GB is occupied by heaths, bogs and moorland grass, compared with the figure of 25% derived from the land cover map (Table 3.1). The areas for individual countries show similar differences; thus, the satellite land cover map data showed that these categories cover 57% of the land area of Scotland, compared to the 49% derived from field survey. These variations almost certainly derive from differences in data capture methods and definitions of cover categories (see section 3.6).

3.3.9 A more detailed examination of the data on the heath/bog cover categories from the field survey showed, for example, that purple moor grass-dominated moorland occupied 4% of the land area of Wales, 2% in Scotland and less than 1% in England. Drier northern bogs cover 5% of Scotland, but less than 1% of England and Wales.

3.3.10 The urban area of GB (including all built-up areas and communications) covers about 9% of the land area, when the non-surveyed urban land is included. Urban land is predominantly in England (12% of land area) and is dominated, in rural areas, by residential building and curtilage.

3.3.11 Forest/woodland covers around 12% of GB and 11% of England, which is higher than the Forestry Commission (1990) estimate, but in part may be explained by the inclusion of small woodlots, orchards (included in perennial crops) and shrub.

Arable landscapes

3.3.12 As with the satellite land cover map (Table 3.2), the field data showed that the arable landscapes are dominated by tilled land (43%) (Table 3.8). The field survey gives detailed estimates of different crop types. A number of crops are grown predominantly in this type of landscape and this includes wheat, oil-seed rape, mixed and other cereals, sugar beet and peas. Approximately 78% of the land under wheat in GB occurred in this landscape, 60% of the barley and 80% of the oil-seed rape. The arable landscapes contain the lowest proportion of semi-natural vegetation of the four landscape types. A large proportion (45%) of the managed grass is short term or intensively managed, and may be part of a crop rotation.

3.3.13 About 12% of the arable landscapes is urbanised and 10% forested/wooded (predominantly broadleaved).

Pastural landscapes

3.3.14 The pastural landscapes are dominated by managed grasslands which cover 45% of the area. Approximately 50% of these grasslands are short term or intensively managed (ie recently sown or pure rye-grass). Only 18% of the area is tilled and wheat and barley are about equally dominant in cover. However, 34% of the total land area of GB under barley occurred in this landscape, but only 20% of the GB under wheat. Some 5% of the area is under minor arable crops, compared with 13% of the arable landscapes. Forest/woodland forms 10%, of which 70% is broadleaved woodland. Urban land forms 14% of the pastural landscapes, a slightly higher proportion than the arable landscapes.

Marginal upland landscapes

3.3.15 Although these landscapes may be considered to be transitional between the predominantly agricultural lowland landscapes and the more open and natural uplands, they are more similar to the latter in character. Only 3% of the area is tilled land, which is mostly under barley and only 22% of the grassland is intensively managed. Heath, moorland and bog occupied 35% of the landscapes, with 11% of this area dominated by purple moor grass, 17% by wet bogs and 15% by dense shrub heath. Some 44% of the total area of dense bracken in GB occurs in this landscape.

3.3.16 Forestry/woodland occupied 13% of the landscapes and over 75% of this forest land

Table 3.8 Land cover for landscape types of GB from the CS1990 field survey by area ('00 km²) and standard error (SE) ('00 km²) (+ = presence <50 km² or <0.5%) The subtotals (in bold) correspond approximately to the 17 key cover types obtained from the satellite land cover map

	Stock 1990							
	Arable		Pastural		Marginal		Upland	
Cover type	Area	SE	Area	SE	Area	SE	Area	SE
Communications								
Railway	2	0	2	+	+	+	+	+
Road	20	1	18	1	4	1	2	0
	22	**1**	**19**	**1**	**5**	**1**	**2**	**+**
Built up								
Agricultural buildings	7	1	6	1	1	+	+	+
Residential buildings	28	5	36	6	3	1	1	+
Other buildings	15	4	14	3	+	+	+	+
Unsurveyed urban land	25	‡	20	‡	1	‡	+	‡
	75	**7**	**76**	**7**	**5**	**1**	**1**	**+**
Tilled land								
Wheat	175	13	46	6	2	1	0	0
Barley	67	8	40	6	7	3	1	+
Oats	5	2	3	1	1	1	+	+
Mixed and other cereals	3	2	+	+	0	0	+	+
Maize	3	1	1	1	0	0	0	0
Turnips/swedes	3	1	3	1	1	1	+	+
Kale	2	1	3	1	+	+	+	+
Oil-seed rape (OSR)	32	6	8	3	+	+	0	0
Crucifer crops (other than OSR)	2	1	+	+	0	0	0	0
Peas	9	2	2	1	+	+	0	0
Field beans	9	2	2	1	0	0	0	0
Legumes (not peas /field beans)	+	+	0	0	0	0	0	0
Sugar beet	16	3	6	3	0	0	0	0
Root crops (not turnips/swedes/potatoes)	+	+	+	+	0	0	+	+
Potatoes	9	3	5	1	+	+	+	+
Other field crops	8	2	2	1	+	+	+	+
Horticulture	4	3	+	+	0	0	0	0
	348	**19**	**121**	**12**	**11**	**5**	**1**	**1**
Managed grass								
Recreational (mown) grass	14	4	10	3	1	+	+	+
Recently sown grass	30	4	32	4	6	2	3	2
Pure rye-grass	60	8	118	9	22	6	3	2
Well-managed grass	57	7	83	7	47	8	5	3
Weedy swards with >25% rye-grass	23	5	43	5	24	4	9	3
Non-agriculturally improved grass	9	3	5	2	5	2	1	1
Calcareous grass	3	2	1	1	1	1	1	1
Upland grass	6	2	11	3	22	4	22	4
Maritime vegetation	+	+	1	+	1	+	1	1
	202	**15**	**305**	**14**	**126**	**128**	**46**	**8**
Rough grass/marsh								
Non-cropped arable	30	8	5	1	+	+	0	0
Unmanaged grassland and tall herb	15	2	10	1	2	1	+	+
Felled woodland	1	+	+	+	1	1	2	1
Wetland	3	1	12	3	11	3	11	2
Waste and derelict land	2	1	2	1	+	+	0	0
	50	**8**	**29**	**4**	**14**	**3**	**13**	**2**
Dense bracken	**2**	**1**	**6**	**2**	**16**	**4**	**12**	**4**
Moorland grass								
Purple moor grass-dominated moorland	1	+	4	2	15	6	17	4
Moorland grass (other than purple moor grass)	1	+	3	1	29	8	48	7
Dune	1	+	+	+	1	1	+	+
	2	**1**	**8**	**2**	**46**	**10**	**65**	**8**
Open heath								
Open-canopy heath	2	1	6	2	26	6	48	8
Berry-bush heath	0	0	+	+	2	1	10	3
Drier northern bogs	1	1	1	1	15	5	35	6
	3	**2**	**7**	**2**	**43**	**8**	**92**	**10**
Dense heath	**4**	**3**	**2**	**1**	**19**	**6**	**20**	**5**
Wet heaths and saturated bogs	**2**	**2**	**13**	**6**	**22**	**8**	**130**	**12**
Broadleaved/mixed woodland								
Perennial crops	5	2	3	2	+	+	+	+
Mixed woodland	10	2	6	1	3	1	3	2
Broadleaved woodland	40	6	36	4	10	2	6	2
Shrub	4	1	4	1	1	0	+	+
	59	**7**	**49**	**5**	**13**	**2**	**9**	**3**
Coniferous woodland	**20**	**5**	**21**	**5**	**37**	**9**	**59**	**11**
Inland bare								
Inland rocks and screes	+	+	+	+	+	+	1	1
Hard areas without buildings	1	+	+	+	1	0	+	+
Quarries and extractive industries	2	1	+	+	+	+	+	+
	2	**1**	**1**	**+**	**1**	**1**	**2**	**1**
Saltmarsh	**+**	**+**	**4**	**2**	**0**	**0**	**+**	**+**
Coastal bare								
Intertidal soft coast without vegetation	5	4	6	2	+	+	1	+
Hard coast with no vegetation	+	+	2	1	1	+	3	1
	5	**4**	**9**	**1**	**1**	**+**	**4**	**1**
Inland water								
Still water	8	6	2	+	4	3	8	3
Running water	2	+	3	1	1	+	1	+
	10	**6**	**5**	**1**	**5**	**3**	**8**	**3**
Total	**807**		**675**			**368**		**460**

‡ Unsurveyed urban land is a census estimate from all 1 km squares not surveyed and consequently has no SE. The area is included in the built up category and percentage area but the SE is for the built up categories without unsurveyed urban land

is under coniferous plantations. Urban land occupied only 3% of the area.

Upland landscapes

3.3.17 Over 70% of the uplands are covered by semi-natural vegetation and of that nearly 40% is wet heaths or saturated bogs. Tilled land has only a small cover and managed grassland only covers 10% (mostly with upland grass). Bracken is still widespread, occupying over 2% of the landscapes. Some 78% of the woodland in this landscape type is coniferous.

3.4 Net change between 1978, 1984 and 1990

3.4.1 Data collected during the countryside surveys in 1978, 1984 and 1990 can be used in two ways to estimate change in land cover. The sample size was increased for each survey (256 sites in 1978, 384 sites for 1984 and 508 sites for 1990), but the original 256 sites were revisited on each subsequent occasion. Only three of the sites visited in 1984 could not be re-surveyed in 1990 due to access being denied. By using the data collected from all the squares surveyed in each year, separate population estimates can be produced and these are the best estimates of land cover in each year. Change can be estimated by subtracting the totals. However, a better estimate, especially for small changes, can be obtained by using only the repeated sites, which focuses on the actual changes that have occurred, rather than comparing the estimates based on different samples.

3.4.2 The figures presented in Tables 3.9 and 3.10 show the best estimates for the individual years, 1978 and 1984. Table 3.9, which shows 1984 figures, also provides the net change between 1984 and 1990 for each of the 58 cover types; here the values are derived from the repeated squares only and so do not match exactly those produced by subtracting 1984 estimates, derived from 384 squares, from those for 1990, derived from 508 squares. Thus, Table 3.9 provides the most reliable estimate of change.

3.4.3 No equivalent comparison has been made for the 1978 survey, for a number of reasons. Primarily, the information collected in 1978 was recorded in a slightly different way, using a more stringent code list of 68 codes. The codes, listed in Bunce *et al.* (1984), are only broadly comparable with those devised in the Land Cover Definitions (LCD) project (Wyatt *et al.* in prep.). The flexibility of the current ITE system allows comparisons to be made by matching codes, but this has already been reported for the changes between 1978 and 1984 (Barr *et al.* 1986).

3.4.4 The differences between 1978 and the two more recent surveys make interpretation difficult without referring simply to the 1978 categories. The definition of urban land was broader, including recreational areas, the grasslands were divided more sharply on species, and different semi-natural habitats were recorded.

3.4.5 Since the countryside surveys of 1978 and 1984, the ITE Land Classification has been extended to cover every 1 km square in GB. The consequence is a more refined estimate, but with some slight differences. The results presented in this report match those previously published and show no major discrepancies (eg compare Bunce & Heal 1984).

3.4.6 In broad terms, the changes recorded show good agreement with other published figures. Tilled land has shown a decline, losing 4% of its area (or 1% of GB). Within the tilled land shifts between crops can be seen; barley shows an unexpectedly high decline, while wheat, oil-seed rape and maize have all increased. Some of these shifts may reflect changes in environmental conditions, such as climate, but changes in crop varieties, economic incentives and farming traditions are likely to have important roles – further research is in progress (see section 8.2.8) to elucidate the socio-economic pressures leading to land cover change.

3.4.7 Managed grass also shows an overall reduction in area of 2%, but the internal movements between different intensities of management are also important. A decrease in short-term grassland management with reseeding and an increase in more extensive pasture management can both be seen.

3.4.8 There was a small overall gain in semi-natural cover types, though some types have declined, including moorland grass

Table 3.9 Land cover for GB from the 1984 field survey and change to 1990, by area ('00 km²) and standard error (SE) ('00 km²) (+ = presence <50 km² or <0 5%). Change is the area change between 1984 and 1990, positive values are gains, negative losses. The subtotals (in bold) correspond approximately to the 17 key cover types obtained from the satellite land cover map

Cover type	Stock 1984			Change 1984–90		
	Area	SE	% GB	Area	SE	% change
Communications						
Railway	4	1	+	0	+	1
Road	45	2	2	+	+	1
	49	**3**	**2**	**+**	**+**	**1**
Built up						
Agricultural buildings	15	1	1	+	+	2
Residential buildings	56	9	3	5	1	8
Other buildings	30	6	1	2	1	7
Unsurveyed urban land	48	‡	2			
	159	**12**	**7**	**8**	**2**	**4**
Tilled land						
Wheat	213	18	9	14	13	6
Barley	178	13	8	-59	12	-33
Oats	7	2	+	1	3	13
Mixed and other cereals	7	4	+	-6	4	-92
Maize	1	+	+	3	3	355
Turnips/swedes	10	2	+	-4	2	-36
Kale	2	1	+	1	2	53
Oil-seed rape (OSR)	25	5	1	14	8	57
Crucifer crops (other than OSR)	+	+	+	3	2	1220
Peas	9	2	+	3	4	31
Field beans	8	3	+	3	4	33
Legumes (not peas/field beans)	2	2	+	-2	2	-100
Sugar beet	16	4	1	7	6	43
Root crops (not turnips/swedes/potatoes)	1	1	+	+	+	66
Potatoes	20	3	1	-5	3	-23
Other field crops	1	1	+	8	4	581
Horticulture	10	6	+	-2	2	-24
	510	**27**	**22**	**-21**	**13**	**-4**
Managed grass						
Recreational (mown) grass	33	7	1	-	1	0
Recently sown grass	108	12	5	-36	12	-33
Pure rye-grass	190	18	8	-7	16	-4
Well-managed grass	237	18	10	-36	15	-15
Weedy swards with >25% rye-grass	49	6	2	62	10	127
Non-agriculturally improved grass	16	4	1	3	2	18
Calcareous grass	6	3	+	+	1	8
Upland grass	65	8	3	-3	3	-5
Maritime vegetation	3	1	+	-	+	-4
	708	**31**	**31**	**-17**	**11**	**-2**
Rough grass/marsh						
Non-cropped arable (ploughed and fallow)	8	2	+	18	8	226
Unmanaged grassland and tall herb	23	3	1	7	3	29
Felled woodland	2	1	+	2	1	136
Wetland	30	5	1	2	1	6
Waste and derelict land	4	1	+	+	1	11
	66	**6**	**3**	**29**	**9**	**45**
Dense bracken	**42**	**12**	**2**	**-5**	**4**	**-11**
Moorland grass						
Purple moor grass-dominated moorland	39	10	2	-1	2	-2
Moorland grass (other than purple moor grass)	86	12	4	-3	2	-4
Dune	2	1	+	0	0	0
	128	**16**	**6**	**-4**	**3**	**-3**
Open heath						
Open-canopy heath	65	10	3	3	3	5
Berry-bush heath	12	3	1	0	+	-1
Drier northern bogs	51	9	2	-4	3	-7
	128	**14**	**6**	**-**	**5**	**-**
Dense heath	**47**	**10**	**2**	**+**	**1**	**1**
Wet heaths and saturated bogs	**159**	**17**	**7**	**1**	**+**	**1**
Broadleaved/mixed woodland						
Perennial crops	8	4	+	-2	2	-23
Mixed woodland	20	4	1	1	1	6
Broadleaved woodland	89	9	4	3	2	3
Shrub	10	2	+	-1	1	-10
	128	**12**	**6**	**1**	**3**	**1**
Coniferous woodland	**126**	**18**	**5**	**7**	**5**	**5**
Inland bare						
Inland rocks and screes	2	1	+	0	0	0
Hard areas without buildings	1	1	+	+	+	39
Quarries and extractive industries	1	1	+	1	1	105
	4	**1**	**+**	**2**	**1**	**42**
Saltmarsh	**4**	**1**	**+**	**-**	**+**	**-9**
Coastal bare						
Intertidal soft coast without vegetation	14	7	+	-	+	-1
Hard coast with no vegetation	7	1	+	+	+	2
	21	**7**	**+**	**0**	**+**	**0**
Inland Water						
Still water	28	11	+	-	+	-1
Running water	8	1	+	0	0	0
	36	**11**	**+**	**-**	**+**	**-1**
Total	**2318**					

‡ Unsurveyed urban land is a census estimate from all 1 km squares not surveyed and consequently has no SE or change estimates The area is included in the built up category and percentage area but the SE is for the built up categories without unsurveyed urban land

Table 3.10 Land cover for GB from the 1978 field survey, by area ('00 km²) and standard error (SE) ('00 km²) (+ = presence <50 km² or <0.5%) (There were some differences in the land cover categories recorded in the 1978 field survey to those used in 1984 and 1990, but these have been reclassified to allow comparison between survey results.)

Cover type	Area	Stock 1978 SE	% GB
Communications			
Railway	6	1	+
Road	33	3	1
	39	**3**	**2**
Built up			
Built up	198	18	9
Non-surveyed urban land	48	‡	2
	246	**18**	**11**
Tilled			
Wheat	109	15	5
Barley	206	19	9
Oats	17	5	0
Mixed and other cereals	3	2	+
Maize	4	2	+
Kale	4	2	+
Oil-seed rape (OSR)	5	3	+
Peas and beans	20	7	0
Sugar beet	15	4	0
Potatoes	19	4	0
Root crops (not potatoes)	13	3	0
Other field crops	2	1	+
Horticulture	8	3	+
	425	**28**	**19**
Managed grass			
Formal recreational areas	24	6	1
Perennial rye-grass ley	269	24	12
Other leys	20	5	0
Well-managed grass	105	12	5
Neglected pasture	51	8	2
Non-agriculturally improved grass	201	20	9
Calcareous grass	3	1	+
Upland grass	98	15	4
Maritime vegetation	2	0	+
	774	**41**	**34**
Rough grass/marsh			
Non-cropped arable (ploughed and fallow)	18	4	0
Wetland	22	4	0
Waste and derelict land	9	3	+
	49	**6**	**2**
Dense bracken	**29**	**7**	**1**
Moorland grass			
Purple moor grass-dominated moorland	106	17	5
Moorland grass (other than purple moor grass)	49	12	2
	155	**17**	**7**
Open heath			
Open-canopy heath	20	7	0
Berry-bush heath	10	3	+
Drier northern bogs	7	2	+
	37	**9**	**2**
Dense heath	**115**	**27**	**5**
Wet heaths & saturated bogs	**81**	**14**	**4**
Broadleaved/mixed woodland			
Perennial crops	10	7	+
Mixed woodland	20	8	0
Broadleaved woodland	60	9	3
Shrub	18	6	0
	108	**16**	**5**
Conifer woodland	**141**	**25**	**6**
Inland bare			
Rock	17	3	0
Quarry/pit	5	2	+
	22	**4**	**0**
Saltmarsh	**4**	**1**	**+**
Coastal bare (Rocks/sand/mud)	**27**	**9**	**1**
Water			
Lake	35	12	2
Running water	11	3	+
	45	**12**	**2**
Total	**2297**		

‡ Unsurveyed urban land is a census estimate from all 1 km squares not surveyed and consequently has no SE. The area is included in the built land and percentage area but the SE is for the urban cover type without unsurveyed urban land

(by about 3%), whereas others, such as open-canopy heath, have increased (by about 5%). Non-cropped arable land increased three-fold, perhaps due to the introduction of set-aside schemes in 1988 (including unsurveyed urban land). It was assumed that the 'unsurveyed urban land' area remained unchanged between 1984 and 1990, and so the change figures are composed of changes in built land occurring in rural areas only. This change was 800 km² and is much smaller than the error terms associated with the 1984 and 1990 estimates (11 100 km² and 11 200 km² respectively).

3.4.9 A small decline in the area of waterbodies may reflect, in part, the dry summer experienced in the south and east of GB in 1990. Other physical features, such as bare rocks and screes, have remained constant over the survey periods, as would be expected.

3.4.10 Both broadleaf and coniferous woodland have shown increases of 1% and 5%, respectively. Within the overall broadleaf category there was a decline in shrub and perennial crops which includes a decline in orchards.

3.5 The matrix of change between 1984 and 1990

3.5.1 The matrix of change in land cover between 1984 and 1990 (Figure 3.1) identifies not only the quantity of change, but also what has changed into what. Most of the largest changes are between the agricultural land uses, including tilled land, managed grass and rough grass/marsh. Some of the changes are equally balanced, such as the tilled land to managed grass which equals the managed grass to tilled land, while the tilled land to rough grass/marsh may be due to introduction of set-aside schemes.

3.5.2 Built-up land and communications can be seen to have increased at the expense mainly of agriculture, while forestry shows a split between agriculture (mainly broadleaf) and more semi-natural habitats such as moorland grass and heath (conifers). The increase in rough grass/marsh can be seen to be mainly at the expense of managed grass, and tilled land.

3.6 Relationship between satellite and field survey data

3.6.1 There is broadly a good agreement between the estimates of area from field mapping and those derived from the satellite land cover map, as indicated in Table 3.11 and reported in the LCD project (Wyatt *et al* in prep.). Differences can be explained by different definitions and resolution of mapping.

Table 3.11 Comparison of estimates of area ('00 km²) and standard error (SE) ('00 km²) of key cover types in 1990 in GB by satellite and by field survey

	Satellite land cover map		Field survey		
Key cover type	Area	%	Area	%	SE
Urban	158	7	208	9	*
Tilled land	513	21	481	21	23
Managed grass	657	27	682	29	23
Rough grass/marsh	43	2	107	5	9
Bracken	36	1	37	2	6
Heath/moor grass	202	8	120	5	14
Open shrub heath/moor	279	12	146	6	13
Dense shrub heath/moor	72	3	45	2	8
Bog	43	2	166	7	15
Deciduous/mixed woodland	123	5	130	6	9
Coniferous woodland	77	3	137	6	16
Inland bare	26	1	6	<1	1
Saltmarsh	4	<1	4	<1	2
Coastal bare	14	1	18	1	4
Inland water	17	1	29	1	7
Sea/estuary	77	3	–	–	–
Unclassified	61	3	–	–	–
Total	**2402**		**2318**		

* Unsurveyed urban land is a census estimate from all 1 km squares not surveyed and consequently has no SE

3.6.2 Correspondence between field and satellite surveys was quantified by inter-comparing the maps in a GIS. Correspondence results are available for each of the 32 ITE Land Classes, and hence for each landscape and for all of Britain (and for any combination of squares). Allowing for interpretation differences, overall correspondence is 67%, or 71% if boundary pixels are excluded.

3.6.3 There are undoubtedly time-dependent differences between the two surveys. For example, the field survey would have used the low tide line shown on OS maps, while the satellite survey could only depict beaches as they appeared at the time of imaging. The use of crop rotations is prevalent in some areas: field reconnaissance showed that a one-year lag might redistribute half of the arable and grass fields in areas of mixed farming and that a two-year lag between imaging and field work might mean an almost total switch in the distributions of arable and grass. The summary of the field data for newly planted conifers used a method which classified the cover as coniferous woodland, even if the trees were just 0.5 m saplings with scarcely 5% cover. Allowing for such likely changes, agreement between surveys is increased to 81%.

3.6.4 Other reasons for differences are many and varied. First, there is straightforward misclassification by the image analysis procedure. Second, there are discrepancies in field recording: the Quality

Figure 3.1 Matrix of land cover change for Great Britain between 1984 and 1990. Figures are in '00s km^2.
A plus (+) signifies less than 50 km^2 and a stop (.) less than 5 km^2

Land cover in 1984	Land cover in 1990											
	Built up	Inland bare	Tilled land	Managed grass	Rough grass/marsh	Bracken	Moorland grass	Bogs	Shrub heath	Broadleaves	Conifers	Total
Built up	156	+	+	2	1	·	·		+	+	·	161
Inland bare	·	4	·	+	+	·			+	·		4
Tilled land	2	+	406	73	26	·	·			3	+	510
Managed grass	6	1	76	591	17	4	3	+	2	5	2	707
Rough grass/marsh	3	1	4	11	45	+	+	+	+	2	+	66
Bracken	·	·	+	4	+	32	1	·	5	+	+	42
Moorland grass	·	+	+	3	1	1	119	+	1	+	3	128
Bogs							·	159	+			159
Shrub heath	·		·	+	1	1	1	+	167	+	5	176
Broadleaves	1		2	4	2	+	+	·	·	117	1	128
Conifers	+	·		1	3	+	·	·	+	1	121	126
Total	169	6	489	691	95	38	124	160	175	129	132	

Assurance Exercise gave an average 84% correspondence in primary coding of land cover, with 95% correspondence in lowlands and 71% in uplands. There may be minor geometric discrepancies, where a feature is correctly classified but displaced in its exact map position: in a dissected landscape, this can have a major impact on the measure of agreement (on average 40% of 25 m pixels fall across a vector boundary).

3.6.5 A large part of the differences relate to the impossibility of perfectly subdividing a continuously variable landscape into discrete units of uniform cover. Generalisation, hence distortion of 'the truth', plays a necessary part; both procedures are forced to generalise according to different rules. The field survey makes considerable use of physical boundaries (fences, walls, ditches) to map the land cover types. The satellite study takes no account of boundaries but simply attempts to allocate a 25 m square patch on the ground to the nearest cover type. Although integration of approaches is an objective of the project, technical constraints and historical precedent mean that, for some elements, the two surveys operate within different rules and with different objectives. They can, therefore, give different results with neither being wrong. Such complexities are discussed in the report on the LCD project (Wyatt *et al.* in prep.).

3.6.6 Urban land provides an example of a cover class that is difficult to compare between satellite and field survey. The satellite land cover map has two straightforward urban classes (continuous urban and suburban). The field survey, however, was based on a sample of rural GB 1 km squares and included classes such as agricultural buildings, other buildings, roads and railways. In addition, the field survey estimate is supplemented by a census figure, from independent mapped information, for non-countryside areas (referred to as unsurveyed urban land, see Appendix 3). Thus, the larger estimate of urban land from field survey may be due to the incorporation of more rural features, including roads, railways and curtilage around properties.

3.6.7 With reference to reasons for differences between surveys, it is perhaps sufficient to say that, if the field survey correctly recorded 90–95% of the landscape (thus overlapping about 85% with an equivalent quality assurance survey), and if the satellite survey achieved its target 80–85% success, then the overlap would be around 75%, a figure which is typical if we allow for the obvious interpretation differences, perhaps with an element of change.

3.6.8 A fuller analysis of correspondence between field and satellite surveys is given in LCD project (Wyatt *et al.* in prep.). This includes the vector analyses in full spatial mode and the more generalised but more detailed analyses of cover types as made in the point-scoring and summary 1 km square cover data. The latter are particularly important as they represent the correspondences which are relevant to all analyses at 1 km square level, especially those in the CIS.

3.7 Integrated use of field survey and satellite data

3.7.1 Field and satellite data have also been integrated into the 1 km square CIS data base. An example helps to demonstrate how it is possible to combine the spatial information of the satellite-based study with the specific details of the field survey. The satellite study cannot estimate the proportion of, say, oak (*Quercus* spp.) woodland: it makes no distinction between different deciduous tree species. The field survey can examine the study area in terms of the extent of the individual ITE Land Classes. By reference to Land Class mean figures for oak woodland, it can estimate a cover value for oak based on a weighting of the extent of the different cover types.

3.7.2 However, the field survey data cannot take site-specific circumstances into account; for example, in areas where woodland is particularly extensive or perhaps completely absent, it could not predict the continuous variability of woodlands across a region, except insofar as these related to Land Class. By examining the deciduous woodland area according to the cover map, and referring to the 1 km square pattern of Land Classes, it is possible to estimate oak cover as a proportion of the known deciduous woodland cover.

3.7.3 Wherever there is a correlation between a satellite cover type and a specific variable of interest, the land cover map can help predict the specific details. Insofar as the extent of crops can be related to the area of tilled land through the field data, so a map of tillage can refine local crop estimates. If hedges are positively correlated with managed grasslands, the land cover map can be used to improve local and regional hedgerow estimates. The procedure is not limited to CS1990 field data: the British Trust for Ornithology had correlated breeding bird species diversity with land cover diversity (Gates *et al.* in press). Correlative predictions could be further improved by use of soils, altitude and other thematic data in the CIS.

3.7.4 The CS1990 project aimed to inter-compare the results obtained by field survey of the 508 squares with the equivalent areas as surveyed by satellite automated image classification. One stage which involved full GIS integration compared vector field map overlays with the raster, satellite, map. The vector data were simplified to the equivalent 25 cover types of the satellite maps, for full co-registration and inter-comparison. Exact correspondence was achieved by moving the raster back-drop, as necessary, to line up with the vectors. Results showed that more than half of all squares registered without any shift, and that mean displacement was 0.8 pixels, equivalent to 20 m average error.

3.8 Pattern analysis

3.8.1 Various trials were attempted in early assessments of the use of vector GIS for pattern analyses. Demonstration work started on a 75 km x 50 km test area centred on the Thames estuary. This area was converted from raster data to vector format. Such conversion highlighted the problems of dealing with large data bases; this relatively small area, one-sixtieth of all Britain, contained 80 000 polygons. On this basis, GB would probably contain five million polygons in total. There is currently no commercial GIS which could realistically handle such detailed vector information for all of Britain.

3.8.2 Basic analysis of the derived polygon data involved the separation of single land cover classes from the main vector file: this was necessary because initial trials showed that measuring polygon boundary length and areas was an extremely lengthy process with such large files. For instance, the GIS counted 1908 deciduous woodland polygons within the Thames test area. These had a total area of 76 km^2 and a total boundary length of 1597 km, with an average woodland size of 0.04 km^2 and average boundary length of 0.8 km. Further statistics can be extracted from these figures, such as the area/boundary ratio.

3.8.3 Data on cover have been summarised per 1 km square for inclusion in the CIS. The data take the form of an array 700 x 1300 pixels representing all GB x 17 layers (one per key cover type). The 1 km square summary data have provided complex information which cannot be adequately displayed in tabular form. Tabular results do not give any impression of the details which remain, even after simplification from 25 m x 25 m data to 1 km square summaries. For these reasons, hard-copy examples are given in the report on Pattern Analysis (Fuller *et al.* 1993).

3.8.4 Pattern analyses have similarly been completed for all of GB. Boundary lengths per key cover type add 17 layers to the GB array in the CIS. Pairwise combinations add a further 44 layers. The total CIS input is therefore an array 700 x 1300 x 70 byte values, representing 64 Mbytes of data.

3.8.5 Raster analyses of the boundary data show variability in proportion of boundary pixels in different landscapes. On average, pixels which adjoin or cross cover boundaries represent 44% of all GB pixels. This figure was confirmed by vector analyses of 128 1 km squares which showed that 40% of pixels were overlaid by field-surveyed vector boundaries. The minor difference reflects a small proportion of 'noise' in the raster satellite data (4% out of 44% is equivalent to just 10% of boundary pixels being 'noise'); in practice, the results are close. The variability in contents of boundary pixels has been calculated down to the individual ITE Land Class level. Because the sample size is so large (thousands of squares), standard errors are very small and significant differences are found between many Land Classes (Fuller *et al.* 1993).

3.8.6 The assessment of neighbouring cover within a fixed distance of each individual cover class generates enormous quantities of output data: 17 classes with 16 possible 'neighbours' and buffer zones with steps of, say, 100 m, 200 m, 300 m, 500 m and 1000 m, would generate 1360 extra layers of 1300 km x 700 km data for the CIS. The choice of buffer zones should depend upon the objectives. Thus, in studying a songbird's feeding range a user might require cover within tens of metres of woodland nest sites, but a study of buzzard habitats may require buffer zones covering many kilometres. The processing is time-consuming (eg 100 hours of continuous computer-processing for 17 classes and four different zones in a 100 km square, ie nearly a year for all GB) so it is necessary to be highly selective, and to design analyses to specific objectives.

3.8.7 The pattern analysis study therefore investigated the potential for proximity analyses, assessed the feasibility of various analyses, and presented preliminary results to demonstrate the capabilities to users. Four 50 km squares were selected, one from each landscape type. The areas of deciduous woodland, moor and bracken were each in turn buffered by 100 m, 200 m and 300 m.

3.9 Summary of Chapter 3

3.9.1 A land cover map of GB was produced by interpretation and classification of Landsat Thematic Mapper satellite imagery. Although information is gathered at the 25 m pixel level, it has been summarised in this project to give the coverage of 17 key cover types in each 1 km square in GB. This data set has been incorporated into the CIS.

3.9.2 Satellite data showed that, in 1990, managed grass covered the largest area in Britain (27%), followed by tilled land (21%) and open shrub heath moor (11%). England was predominantly tilled land and managed grass (65% together), whereas in Scotland and Wales semi-natural vegetation and managed grass together covered more than two-thirds of the land.

3.9.3 Regional comparisons have been made showing a strong relationship between the four landscape types and the land cover classes present.

3.9.4 Although in the arable landscapes tilled land comprised 41% of the land cover, managed grasslands were significant at 29%. The pattern was reversed in the pastural landscapes, with 39% managed grasslands and 22% tilled land, and there was more land covered by semi-natural vegetation categories. In the marginal upland landscapes, managed grasslands covered 28%, with heath and moorland at 38%. The upland landscapes were dominated by dwarf shrub heath and bog, with the combined totals for open and dense heaths, moors and bogs being over 65%.

3.9.5 Stock information on land cover in GB has also been obtained by extrapolating from a sample of 1 km squares which have been surveyed in the field. The field survey recorded land cover in considerable detail, using combinations from a code list of over 300 categories to describe the individual parcels. These have been aggregated to give 58 land cover types and these, in turn, have been summarised to more or less match the 17 categories from the satellite land cover map.

3.9.6 The results from the sample field survey of 508 1 km squares show good general agreement with the satellite-derived land cover map for most classes. For example, for tilled land, both figures were 21%, and managed grass covered 27% (satellite) compared with 29% (field survey). Some categories, for example rough grass/marsh (2% – satellite; 5% – field survey) differed due to inherent differences in the methods used to identify them and in the ways they have been defined. However, to integrate the two sources of information, the field survey data can be broken down into more detailed categories. For example, the field survey data showed that 40% of the well-managed grass was actually intensively managed. Most figures for crops correspond to MAFF and Department of Agriculture and Fisheries for Scotland statistics; for example, for oil-seed rape, both figures were 410 000 ha.

3.9.7 The exact relationship between the two estimates of land cover stock has been examined from two perspectives. First, the degree of correspondence between them has been examined, both in terms of comparison of the overall estimates, and by comparing results directly in a number of sample squares. The correspondence is reasonable in both cases and reasons for any differences are examined. They relate to spatial arrangements, scale and feature definition, and also reflect the historical and technical differences between the approaches.

3.9.8 Differences between data from field survey and satellite imagery were quantified by inter-comparison of digital maps using GIS. Direct correspondence was 67%, though this increased to at least 71% if boundary pixels were excluded from the comparison (and was better for some cover types than others). Differences were due to the image analysis procedures, discrepancies in field recording, and minor geometric registration errors. The CIS can be used to compare summaries of regions using the two procedures. The information from the field survey can also be used in conjunction with the satellite land cover map categories to estimate species composition in vegetated cover categories, such as woodland or moorland.

3.9.9 Data on land cover have been estimated for 1978, 1984 and 1990 using the field-based sampling approach. Figures for change in cover types, between 1984 and 1990, were obtained from 381 squares visited in the field on both occasions. Tilled land in GB had declined by 4% of its area and within this category there were increases in non-traditional crops such as maize, which increased three-fold. Within the grasslands category, there was a shift within the managed grasslands towards weedy grasslands and away from less weedy types. Within the semi-natural habitats some changes can be seen and, although there is a small overall decline, the previously reported large losses to development are not evident. Reductions were recorded for moorland grass and bracken, while bogs, tall herb and wetland all increased, albeit by small amounts. The increase in set-aside was also recorded within the non-cropped arable figure.

3.9.10 A matrix of change shows the movements between cover types between 1984 and 1990 as well as the overall net change which, on its own, can mask the degree of change taking place. Most of the large changes were due to the shifts between the major agricultural categories, principally tilled land and managed grass. The built-up category has expanded at the expense of managed grass and tilled land, whereas broadleaved woodlands have come from managed grass. Conifer forest expanded in area, mainly at the expense of open shrub. At this level of aggregation, there was a high degree of stability with little or no movement between most cells in the matrix.

3.9.11 Using the satellite data, pattern analysis was also carried out for the whole of GB to determine, for example, boundary lengths between the 17 land cover classes. Pixels which adjoin or cross over boundaries represented 44% of the total, and their distributions were compared within landscapes.

Chapter 4 THE RESULTS (II): BOUNDARY FEATURES

4.1 Introduction

4.1.1 The field survey component of Countryside Survey 1990 (CS1990) recorded linear features such as streams, footpaths, field boundaries, lines of trees, as well as features recorded as areas but which had a strong linear arrangement (eg roads, rivers, belts of trees). In this report, the stock and change statistics for one category of linear feature, physical boundaries, are presented.

4.1.2 ITE has produced a contract report to the Department of the Environment (DOE) which includes an analysis of some of the boundary data set ('Changes in Hedgerows in Britain between 1984 and 1990', Barr *et al.* 1991). This report showed that, in net terms, about 23% of 1984 hedgerows in Great Britain (GB) had changed by 1990. Most of this change was due to the linear boundaries altering in character so that they were re-classified as different boundary types (eg a hedge becoming a line of trees) and it was assumed that this was largely due to changes in hedgerow management regimes.

4.1.3 Field boundaries are often composed of several different elements, eg a hedge with a wall and a fence, on top of an earth bank. These features were recorded together as a single feature and coded in terms of their constituent parts. In the report on changes in hedgerows (Barr *et al.* 1991), data were presented for any boundary that contained a hedgerow element (but which may also have included a fence and a bank, for example – resulting in a 'hedge-fence-bank' boundary).

4.1.4 In the present report, data are summarised according to all boundary elements present, resulting in a list of some 25 'multiple' classes. Such a list can be simplified

Table 4.1 Length ('000 km), standard error (SE) ('000 km) and percentage (%) of boundaries in GB in 1990, by country and by boundary type (B = Bank, F = Fence, G = Grass strip, H = Hedge, R = Relict hedge, W = Wall) and combinations based on 508 sample squares (+ = presence <500 km or <0.5%)

	England			Scotland			Wales			GB		
Boundary type	Length	SE	%	Length	SE	%	Length	SE	%	Length	SE	%
Bank (B)	14	3	1	2	1	1	5	1	3	21	4	1
Fence (F)	385	17	41	221	13	61	70	6	38	676	25	45
FB	18	3	2	2	1	1	11	2	6	30	5	2
Grass strip (G)	8	2	1	1	1	+	+	+	+	9	2	1
Hedge (H)	153	11	16	8	1	2	13	2	7	174	12	12
HB	35	6	4	2	1	1	10	2	5	47	8	3
HF	142	11	15	21	4	6	18	3	10	181	13	12
HFB	42	6	4	1	1	+	11	2	6	54	8	4
HW	3	2	+	+	+	+	1	1	1	4	3	+
HWF	3	2	+	1	+	+	1	1	1	4	2	+
HWFB	+	+	+	0	0	0	+	+	+	+	+	+
Relict hedge (R)	23	2	2	2	+	1	2	+	1	27	3	2
RB	4	1	+	+	+	+	2	1	1	6	1	+
RF	30	3	3	6	2	2	6	1	3	42	5	3
RFB	4	2	+	+	+	+	2	1	1	7	2	+
RW	1	+	+	+	+	+	1	+	1	2	1	+
RWF	+	+	+	+	+	+	+	+	+	1	+	+
Wall (W)	46	7	5	52	7	14	17	6	9	115	15	8
WB	+	+	+	1	+	+	+	+	+	1	1	+
WF	27	4	3	38	6	10	10	2	5	74	10	5
WFB	+	+	+	+	+	+	+	+	+	+	+	+
Unclassified	5	1	1	3	1	1	2	1	1	10	2	+
Total	**943**	**27**	**100**	**361**	**18**	**100**	**182**	**11**	**100**	**1486**	**40**	**100**

according to 'dominant' boundary types but, since there is no logical way of prioritising these (eg determining whether a hedge-with-a-wall should be classified as a hedge, or a wall), the user is invited to summarise the data according to specific requirements. It should be noted that, if all boundaries are summarised according to dominant types, there is a danger of double-accounting, resulting in a total length which is greater than 100%.

4.1.5 Boundary type was also recorded in vegetation plots (see Chapter 5) and these data confirm results (stock and change) from the mapping exercise.

4.2 Boundary stock figures for 1990

4.2.1 Table 4.1 and Figure 4.1 give the breakdown of boundary types in GB, based on analysis of all 508 squares surveyed in 1990, including both single- and multiple-element categories. Relict hedges are those elements of boundaries that were recognised as having once been hedges, but have become, for example, rows of trees or lines of shrubs.

4.2.2 Noting comments made in section 4.1.4 (above) about double-accounting, it is possible to summarise the data in Table 4.1 by dominant boundary element. In Table 4.2, an arbitrary classification is used such that the lengths of boundaries which contained a hedge are presented first; then, of the **remaining** boundaries, the length containing a wall is presented, followed by further boundaries that contained fences. Last, other boundary types (banks, relict hedges and grass strips) are given.

4.2.3 As Table 4.2 shows, boundaries containing hedges formed 31% (464 000 km) of the total length of boundaries in GB in 1990. Of these, 81% (378 000 km) occurred in England, 12% (54 000 km) in Wales and 7% (33 000 km) in Scotland. Relict hedges were an element in only 6% (85 000 km) of the total boundaries (Table 4.1) and nearly three-quarters of them (62 000 km) were in England, with 16% (13 000 km) in Wales and 11% (9000 km) in Scotland.

4.2.4 Boundaries within which walls were dominant formed 13% (193 000 km) of the total boundary length in GB (Table 4.2), most of which occurred in Scotland (47% – 91 000 km) and England (39% – 75 000 km). Relatively few walls were combined with other boundary elements.

4.2.5 Fences were the most widespread boundary component, forming 45% (676 000 km) of the total length (1485 km) when considered as an individual boundary, as shown in Table 4.1. A further 26% (398 000 km) of boundaries contained a fence in conjunction with another boundary feature. Thus, 72% (1 074 000 km) of all boundaries contained a fence. Although most fences were in England, they formed only 41% (385 000 km) of the boundaries there, compared to 61% (221 000 km) of the boundaries in Scotland and 38% (70 000 km) in Wales.

4.2.6 Boundaries containing a bank were infrequent, contributing to less than 11% (167 000 km) of all boundaries and, of these, 70% (117 000 km) occurred in England and 25% (41 000 km) in Wales.

4.2.7 About 70% (1 023 000 km) of all GB boundaries were single-element boundaries. In Scotland, 79% (286 000 km) of all boundaries had only one element (due, perhaps, to the scarcity of hedgerows), compared to 67% (630 000 km) in England and 59% (107 000 km) in Wales. Of the boundaries in England, 24% (153 000 km) of the single-element boundaries were hedges, and 61% (385 000 km) were fences. In Scotland these figures were 2% (7000 km) and 77%

Table 4.2 Length ('000 km), standard error (SE) ('000 km) and percentage (%) of dominant boundary types in GB in 1990, by country (Hedge = any boundary that contains a hedge element, but excluding relict hedge; Wall = any other boundary that contains a wall element, Fence = any remaining boundary that contains a fence element), based on 508 sample squares

	England			Scotland			Wales			GB		
Boundary type	Length	SE	%	Length	SE	%	Length	SE	%	Length	SE	%
Hedge	378	19	40	33	6	9	54	5	30	464	24	31
Wall	75	9	8	91	11	25	28	8	15	193	21	13
Fence	437	19	46	229	14	63	89	7	49	755	28	51
Other	54	5	6	9	1	2	11	2	6	74	6	5
Total	**943**	**27**	**100**	**361**	**18**	**100**	**182**	**11**	**100**	**1486**	**40**	**100**

Figure 4.1 Length of boundaries ('000 km) in GB in 1990, by country and by boundary type (B = Bank, F = Fence, G = Grass strip, H = Hedge, R = Relict hedge, W = Wall, UNC = Unclassified)

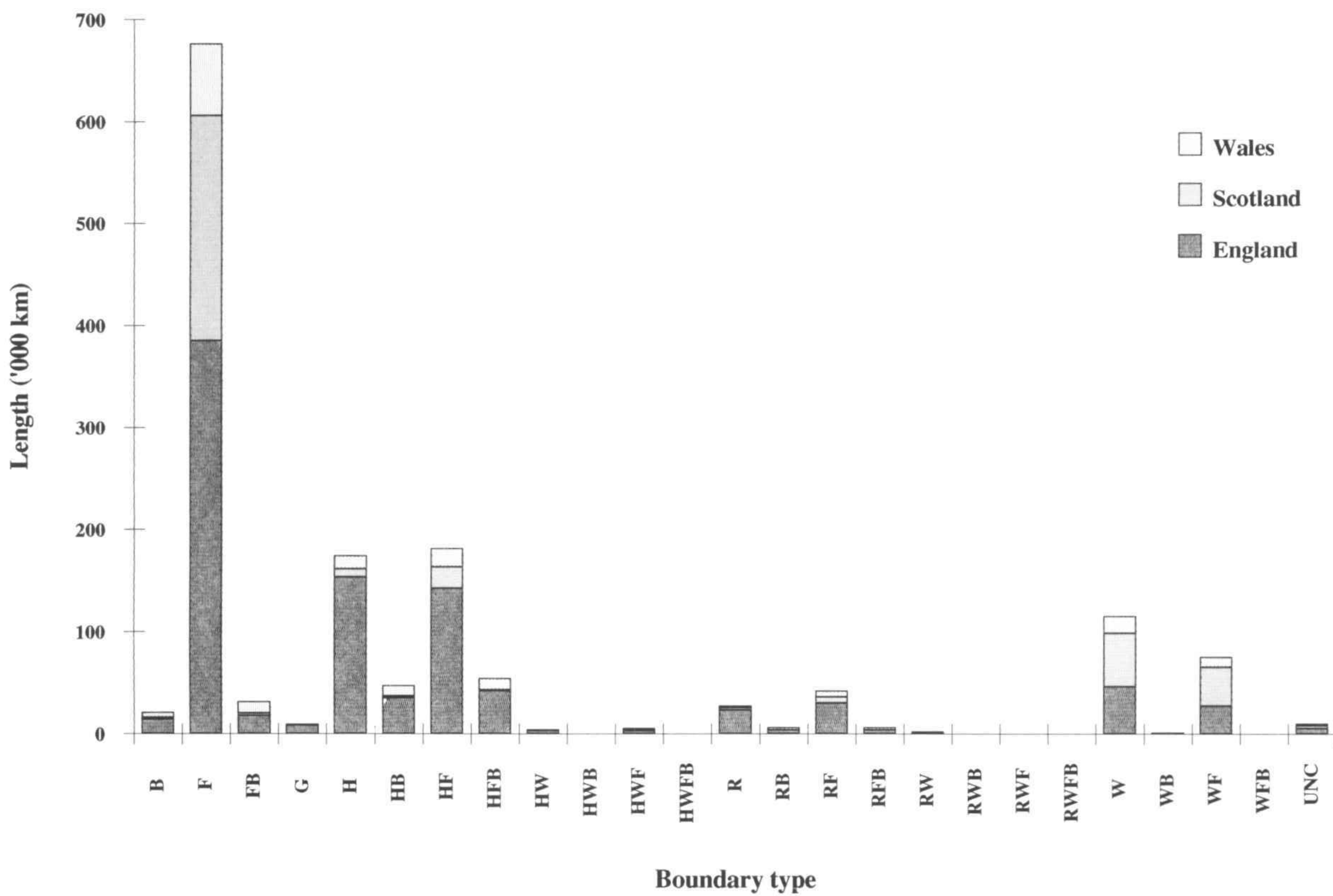


Table 4.3 Length ('000 km), standard error (SE) ('000 km) and percentage (%) of boundaries in GB in 1990, by landscape type and by boundary type (B = Bank, F = Fence, G = Grass strip, H = Hedge, R = Relict hedge; W = Wall) and combinations, based on 508 sample squares (+ = presence <500 km or <0.5%)

	Arable			Pastural			Marginal upland			Upland		
Boundary type	Length	SE	%	Length	SE	%	Length	SE	%	Length	SE	%
Bank (B)	3	2	1	15	4	2	2	1	1	2	1	2
Fence (F)	253	16	47	254	14	40	107	12	47	64	8	67
FB	2	1	+	23	5	4	5	2	2	-	+	.
Grass strip (G)	6	2	1	3	1	+	+	+	-	0	0	0
Hedge (H)	99	8	19	68	9	11	7	2	3	+	+	+
HB	5	2	1	38	7	6	4	2	2	0	0	0
HF	89	9	17	81	9	13	11	3	5	0	0	0
HFB	7	3	1	43	8	7	4	2	2	0	0	0
HW	+	+	-	3	2	+	+	+	+	0	0	0
HWF	1	+	+	3	2	+	+	+	+	+	+	+
HWFB	0	0	0	+	-	+	0	0	0	0	0	0
Relict hedge (R)	16	2	3	9	2	1	2	1	1	0	0	0
RB	1	+	+	3	1	+	2	1	1	0	0	0
RF	14	2	3	17	3	3	11	3	5	0	0	0
RFB	+	-	+	4	2	1	2	1	1	0	0	0
RW	+	-	+	0	0	0	1	1	-	0	0	0
RWF	+	-	+	0	0	0	+	+	-	0	0	0
Wall (W)	17	4	3	35	7	6	44	12	19	18	4	19
WB	+	+	-	0	0	0	1	+	+	+	+	+
WF	18	5	3	17	3	3	27	6	12	12	5	13
WFB	+	+	-	0	0	0	0		0	0	0	0
Unclassified	1	+	.	5	1	1	3	1	1	1	1	1
Total	**534**	**22**	**100**	**628**	**21**	**100**	**230**	**22**	**100**	**95**	**13**	**100**

(221 000 km) respectively, whilst in Wales the figures were 12% (13 000 km) and 65% (70 000 km). Where multiple-element boundaries occurred, the combination of fences with other boundary elements is significant as it may indicate boundaries in need of repair or other management (eg laying of hedges).

4.2.8 Table 4.3 and Figure 4.2 show the characteristics of boundary lengths by landscape type.

4.2.9 Hedges and hedges-with-fences were mainly in the arable landscapes, whereas hedges-with-banks were mainly in the pastural landscapes, being typical of the west of GB. Overall, most hedgerows were in the pastural landscapes (51% – 238 000 km) but the arable landscapes still contained a major hedgerow resource (43% – 201 000 km) as pointed out by Cummins *et al.* (1992). Hedges were present, but more restricted, in the marginal uplands and almost absent from the upland landscapes. Relict hedges occurred in similar proportions in the arable and pastural landscapes but, in the latter, occurred more frequently in boundaries with fences.

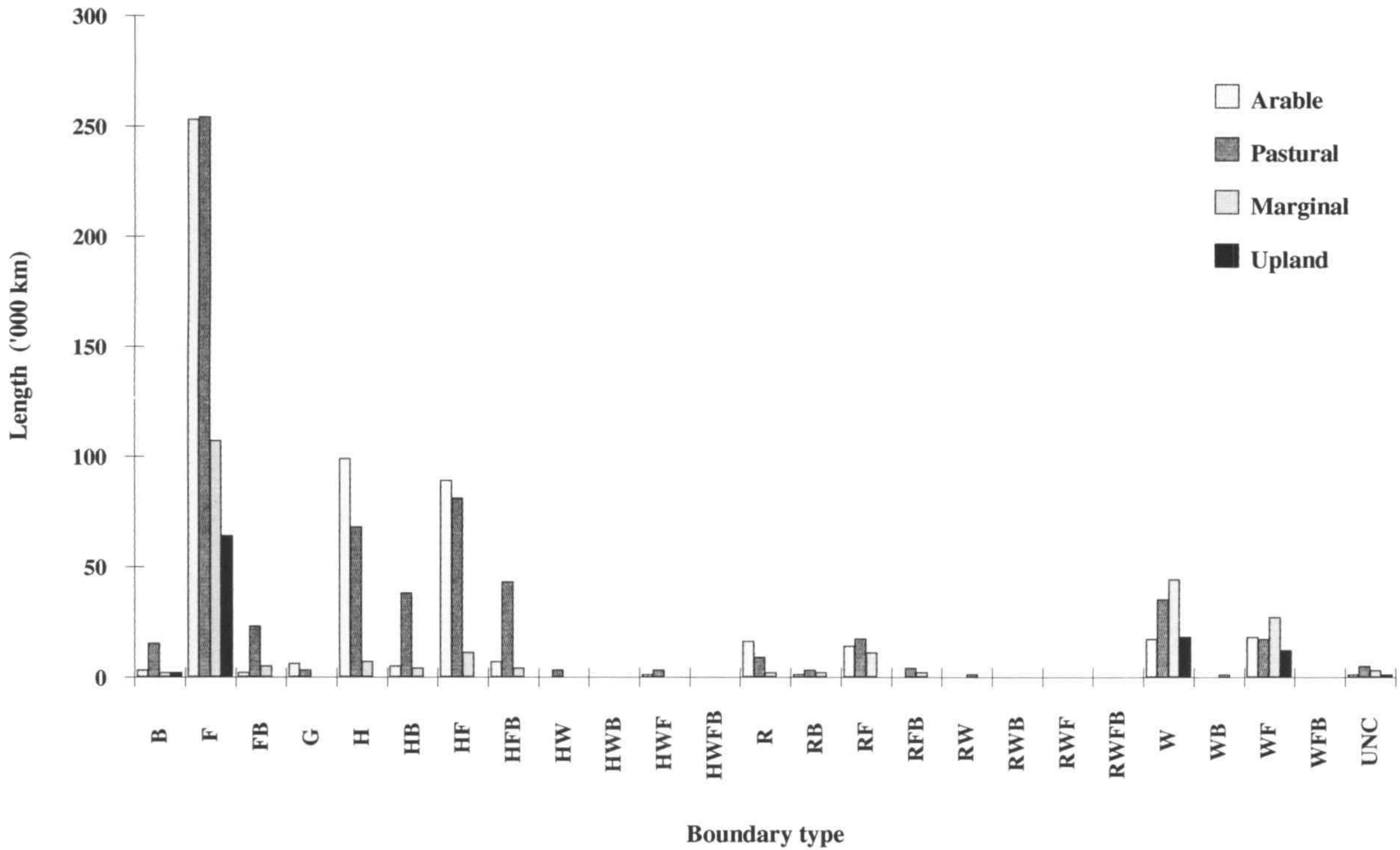
4.2.10 There were more walls in the marginal upland landscapes than elsewhere (38% – 72 000 km), a figure made more significant by the limited extent of this landscape type. The other three landscape types also contained significant lengths of wall with the arable landscapes (19% – 36 000 km) having a greater length, overall, than the uplands (16% – 31 000 km). Nevertheless, in the uplands walls would be regarded as characteristic because they formed 31% of all boundaries compared to only 12% of all boundaries elsewhere.

4.2.11 Fences occurred in similar lengths in the arable (37% – 253 000 km) and pastural landscapes (38% – 254 000 km) with shorter lengths overall in the marginal upland (16% – 107 000 km) and upland (9% – 64 000 km) landscapes. However, fences made up a higher proportion of boundaries in marginal upland and upland landscapes because hedges were less common.

4.2.12 A higher proportion of boundaries containing banks were in the pastural landscapes (76% – 127 000 km), with 11% (19 000 km) in the arable and 12% (18 000 km) in the marginal upland landscapes. Only 2% (2000 km) of upland boundaries contained banks.

4.2.13 Upland areas had the highest percentage of single-element boundaries, with 87% (83 000 km) of the boundaries taking this form, compared to 74% (394 000 km) in arable landscapes, 70% (162 000 km) in

Figure 4.2 Length of boundary types ('000 km) present in GB in 1990, by landscape type and boundary type (B= Bank, F = Fence, G = Grass strip, H = Hedge, R = Relict hedge, W = Wall, UNC = Unclassified)



marginal upland landscapes and 62% (384 000 km) in pastural areas. Fences were the most common single element boundary in all four landscape types.

4.3 Net change between 1984 and 1990

4.3.1 The data for net change between 1984 and 1990, by country, is given in Table 4.4 and in Figure 4.3.

4.3.2 Hedges on their own and hedges-with-fences declined more than hedges associated with other boundary types, in terms of overall length, although, as there was a higher initial stock of these types in 1984, the percentage change is less than for other hedge boundaries. The high percentage loss of hedge-with-wall and hedge-with-wall-and-bank reflects their limited extent in GB. In general, the length lost was proportional to the initial stock, suggesting that no one type had been lost to a greater degree than might be expected. The same applies to the relative losses in the three countries. This agrees with the conclusions of Cummins *et al.* (1992) in relation to the species composition of the hedgerows that have been lost. The relict hedges had the greatest proportional increase (53% – 31 000 km) of any boundary, especially in England and Wales.

4.3.3 Walls had a lower percentage loss than hedgerows. Walls-with-fences declined more than walls on their own, perhaps because the former were already in decline. Although the overall trend was for a decrease of walls throughout GB, there was a small increase in the number of walls in Scotland. By contrast, walls-with-fences declined in England and Scotland but increased in Wales.

4.3.4 Fences increased more in length than any other boundary type with a 12% (75 000 km) increase overall. The increase was mainly in England and to a lesser degree in Scotland.

4.3.5 The characteristics of boundary change by landscape type are shown in Table 4.5 and Figure 4.4.

4.3.6 The greatest length of hedges on their own was lost in the arable landscapes (27 000 km) although, proportionally, similar amounts were lost in pastural landscapes. A higher proportion of hedge-with-banks was lost in the arable landscapes, but, by total length, the greatest loss was in the pastural landscapes. There

Table 4.4 Changes in the length ('000 km) and standard error (SE) ('000 km) of boundaries in GB, between 1984 and 1990, by country and by boundary type (B – Bank; F – Fence, G = Grass strip H = Hedge, R = Relict hedge W = Wall) and combinations based on 381 sample squares (NB ↑ – a gain <500 km, ↓ = a loss <500 km, + – SE <500 km, % = percentage change of 1984)

	England			Scotland			Wales			GB		
Boundary type	Length	SE	%	Length	SE	%	Length	SE	%	Length	SE	%
Bank (B)	−3	3	−17	−3	1	−56	1	1	14	−6	5	−20
Fence (F)	38	14	11	21	5	10	16	4	25	75	17	12
FB	3	5	20	−4	2	−70	1	4	7	↓	9	↓
Grass strip (G)	7	2	>100	1	1	>100	1	+	>100	8	2	>100
Hedge (H)	−42	10	−22	−4	2	−33	−4	2	−20	−49	12	−22
HB	−10	6	−23	↑	1	20	−5	2	−37	−15	8	−25
HF	−36	12	−21	−7	3	−24	↑	2	1	−43	14	−20
HFB	−7	7	−19	−1	2	−38	−11	4	−57	−19	10	−33
HW	−1	1	−65	↓	+	−61	−1	1	−81	−3	1	−70
HWB	↓	+	−100	↓	+	−100	↓	+	−100	↓	+	−100
HWF	−1	1	−37	−1	1	−66	↑	+	27	−2	1	−47
HWFB	↓	+	−7	↓	+	−100	↓	+	−60	↓	+	−33
Relict hedge (R)	8	3	49	↓	1	−20	−1	1	−34	7	3	31
RB	0	2	9	↑	+	>100	1	1	68	2	3	29
RF	12	5	62	3	2	>100	4	2	81	18	6	71
RFB	4	3	>100	↑	+	16	1	1	80	5	4	>100
RW	↓	1	−7	↓	+	−37	−1	1	−83	−1	1	−46
RWB	↓	+	−100	↓	+	−100	↓	+	−100	↓	+	−100
RWF	↑	+	>100	↑	+	>100	↑	+	>100	1	+	>100
RWFB	0		0	0		0	0		0	0		0
Wall (W)	−4	6	−8	4	5	7	−8	4	−35	−8	10	−7
WB	↑	+	>100	↑	+	72	↑	+	>100	1	+	>100
WF	−9	5	−25	−8	4	−18	2	1	31	−14	8	−17
WFB	↑	+	83	↓	+	−99	↓	+	−82	↓	+	−43
Unclassified	−9	3	−59	−2	1	−40	−1	1	−24	−13	4	−49
Total	**−49**	**14**	**−5**	**−3**	**5**	**−1**	**−6**	**3**	**−3**	**−58**	**16**	**−4**

Figure 4.3 Net change in length of boundary ('000 km) in GB from 1984 to 1990, by country and boundary type (B = Bank, F= Fence, G = Grass strip, H = Hedge, R = Relict hedge, W = Wall, UNC = Unclassified)

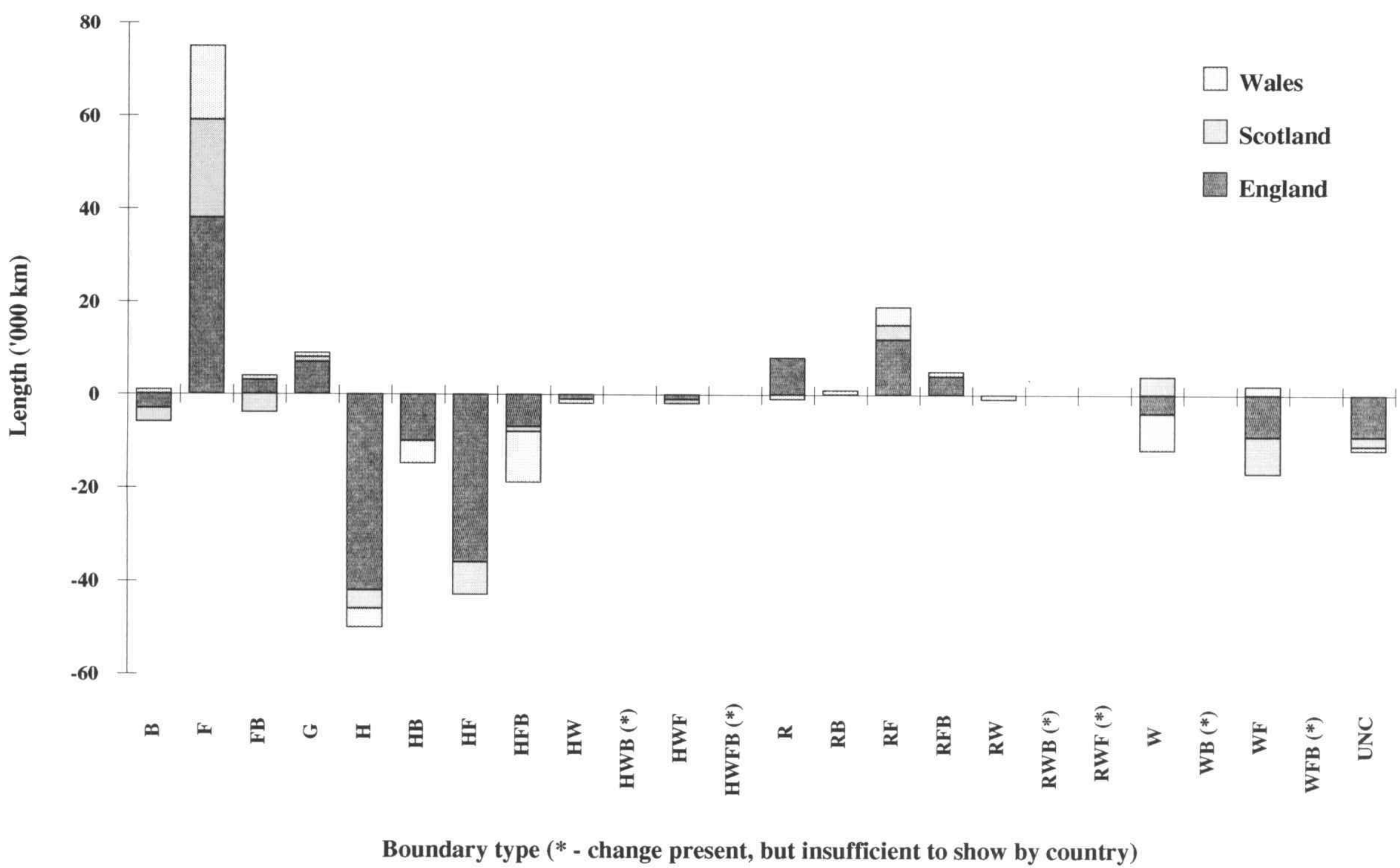


Figure 4.4 Net change in length of boundaries ('000 km) in GB from 1984 to 1990, by landscape type and by boundary type (B = Bank, F = Fence, G = Grass strip, H = Hedge, R = Relict hedge, W = Wall, UNC = Unclassified)

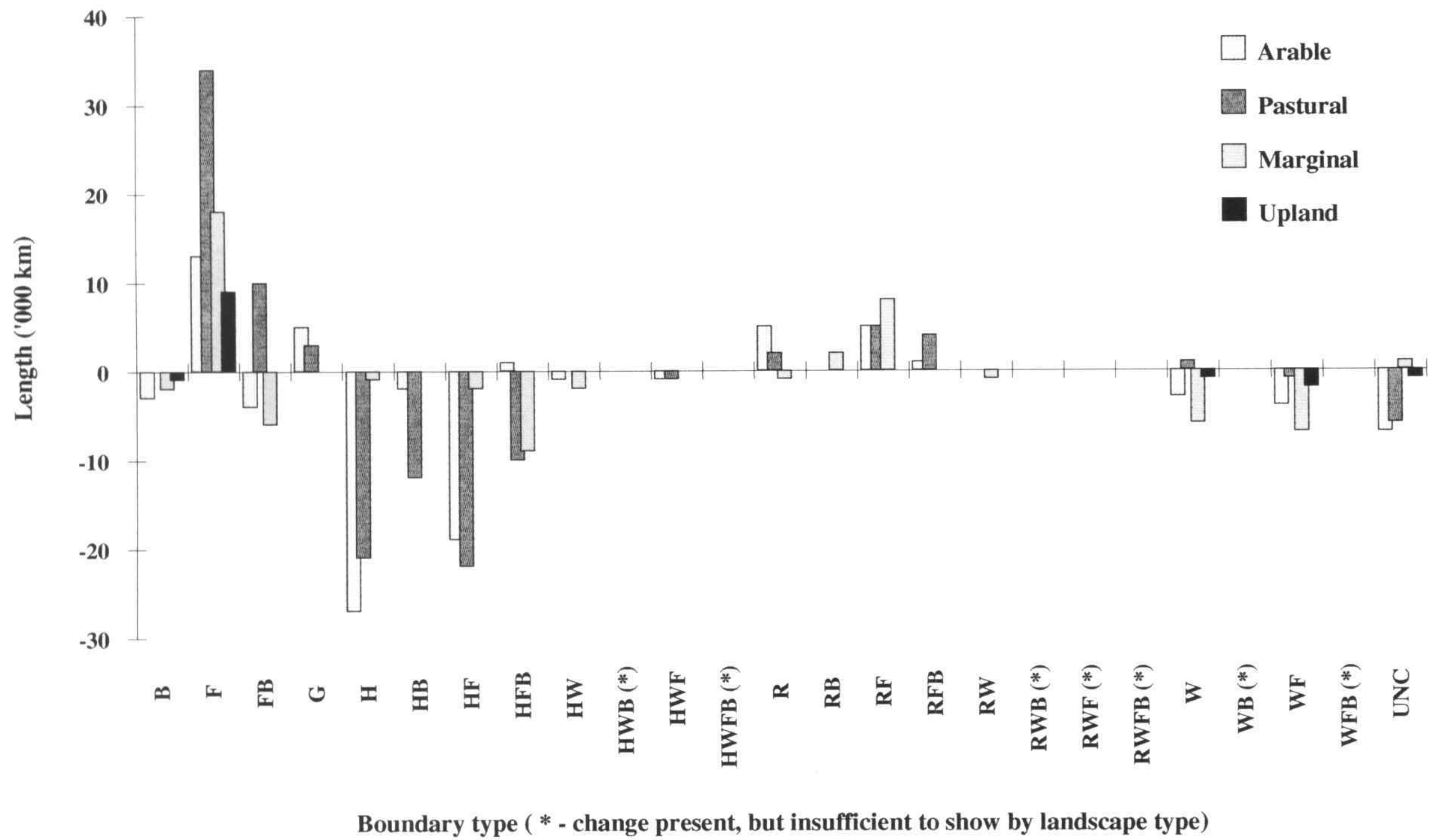


Table 4.5 Changes in the length ('000 km) and standard error (SE) ('000 km) of boundaries in GB, between 1984 and 1990, by landscape type and by boundary type (B = Bank, F = Fence, G = Grass strip, H = Hedge, R = Relict hedge, W = Wall) and combinations, based in 381 sample squares (NB ↑ = a gain <500 km; ↓ = a loss<500 km; + = <500 km, % = percentage change of 1984)

	Arable			Pastural			Marginal upland			Upland		
Boundary type	Length	SE	%	Length	SE	%	Length	SE	%	Length	SE	%
Bank (B)	−3	1	−46	↑	4	1	−2	1	−68	−1	+	−39
Fence (F)	13	13	6	34	9	14	18	7	21	9	3	17
FB	−4	3	−92	10	6	54	−6	5	−59	↓	+	−20
Grass strip (G)	5	1	>100	3	1	>100	↑	+	>100	0		0
Hedge (H)	−27	7	−23	−21	9	−23	−1	4	−7	↑	+	>100
HB	−2	3	−36	−12	7	−27	↓	3	−4	0		0
HF	−19	8	−19	−22	11	−21	−2	3	−12	0		0
HFB	1	2	27	−10	9	−24	−9	5	−68	↓	+	−100
HW	−1	+	−97	↓	1	−26	−2	1	−93	0		0
HWB	0		0	↓	+	−100	↓	+	−100	0		0
HWF	−1	+	−52	−1	1	−51	↑	+	1	↑	+	>100
HWFB	0		0	↓	+	−32	0		0	0		0
Relict hedge (R)	5	3	45	2	1	30	−1	2	−24	0		0
RB	↓	+	−23	↑	2	9	2	2	>100	0		0
RF	5	3	−47	5	4	49	8	4	>100	0		0
RFB	1	+	>100	4	3	>100	↓	+	−11	0		0
RW	↓	+	−100	↑	+	>100	−1	1	−61	0		0
RWB	0		0	0		0	↓	+	−100	0		0
RWF	↑	+	>100	↑	+	29	↑	+	>100	0		0
RWFB	0		0	0		0	0		0	0		0
Wall (W)	−3	3	−18	1	3	3	−6	9	−10	−1	4	−4
WB	↑	+	>100	↑	+	>100	↑	+	>100	0		0
WF	−4	3	−17	−1	3	−8	−7	7	−20	−2	3	−20
WFB	↓	+	−27	↓	+	−81	0		0	0		0
Unclassified	−7	3	−84	−6	3	−43	1	1	42	−1	+	−49
Total	**−43**	**12**	**−8**	**−12**	**9**	**−2**	**−6**	**5**	**−2**	**4**	**3**	**+4**

was no clear pattern of change in relict hedges associated with landscape type.

4.3.7 Although most boundaries with walls were lost in the marginal uplands, proportionally, more walls were lost in the arable landscapes, which had fewer walls overall; there was no change in overall length in the pastural landscapes.

4.3.8 Almost half of the new fences were built in the pastural landscapes although both marginal upland and upland landscapes showed a greater percentage increase. The arable and upland landscapes had relatively few new fences by length.

4.3.9 The upland landscapes were the only type to show a net increase in boundaries - 9000 km of fence.

4.4 The matrix of change between 1984 and 1990

4.4.1 A matrix of change is presented in Figure 4.5. This matrix gives the movement between boundary types, showing how those present in 1984 (left-hand side) had changed by 1990 (top row). The centre diagonal (in bold) represents those boundaries which remained in the same category.

4.4.2 Of the total boundary length in 1990, about 11% (181 000 km) was composed of new boundaries, where there had been no boundary previously. Of this new length, 79% (143 000 km) was composed of fences. Only 7% of new boundaries had a hedge element associated with them, and 5% included a wall.

4.4.3 About 14% (236 000 km) of the 1984 boundary length was removed by 1990. Of this length of removed boundary, over half (123 000 km) was composed of fences and 27% (64 000 km) had a hedge element in the lost boundary.

4.4.4 Nearly 70% (379 000 km) of the boundaries which contained a hedge element in 1984, also had a hedge element in 1990. Of these, only 43% (239 000 km) remained completely unchanged in terms of recorded boundary elements. There were movements in both directions between hedges-with-fences and hedges alone. The major directional shift was from hedges-with-fences, to fences on their own. In addition, both hedges and hedges-with-fences had been removed. There was also movement from hedges-with-fences to relict hedgerows-with-fences.

Figure 4.5 Change in lengths of boundaries ('000 km) in GB, between 1984 and 1990, based on 381 sample squares

1984	1990																								
	B	F	FB	G	H	HB	HF	HFB	HW	HWF	HWFB	R	RB	RF	RFB	RW	RWF	W	WB	WF	WFB	N	UNC	Total 1984	%
B	10			+	1	1	+	1				+	+	+	+			2	+	+		9	+	28	*2*
F	1	430	4	+	4	1	12	1	+	+		3	+	12	1		+	5	+	6	+	123	3	604	*35*
FB	1	14	9		+	1	1	1	+	+			+	1	+			+	+	2		5	+	35	*2*
G				1		+																		1	*0*
H	1	11	2	+	108	10	34	5	+	+		11	1	2	+			1		+		32	1	220	*13*
HB	5	2	4		8	17	4	7	+	+		1	1	+	+			+		+		6	+	58	*3*
HF	+	29	1	+	34	6	99	8	+	+	+	2		16	1	+	+	+		1		21	1	218	*13*
HFB	1	3	7		3	6	11	14	+	+		+	+	2	4		+	+		+		4	+	57	*3*
HW		+	+		1	+	+	+	1	+			+	+		+		+		+		1		4	*0*
HWB		+								+														0	*0*
HWF	+	1			+		1	+	+	1				+			+	+		1	+	+		4	*0*
HWFB		+	+			+	+																	0	*0*
R	+	1			2		1					7	1	+				+				7		21	*1*
RB	1	+	1		+	+	+	+				+	1	+	+					+		1		5	*0*
RF	+	6	+		2	+	6	+		+		1	+	6	+			+		+		3	+	25	*1*
RFB	+	+	1		+	+	1	+				+		+	1							+		3	*0*
RW		+	+		+								+	1		+		+		+		+		2	*0*
RWB		+												+										0	*0*
RWF		+								+				+				+						0	*0*
W	1	8	+	+	1		+	+	+	+		+	+	1	+	+	+	84	+	14		15	+	126	*7*
WB																			1					1	*0*
WF	+	13	1		+		+		+	+		+		1			+	21	+	45	+	4	+	86	*5*
WFB		+	+																	+				0	*0*
N	1	143	3	6	5	1	5	+	+			2	+	1	+	+	+	7	+	1			4	181	*11*
UNC	+	15	+	1	+	+	1	+				+	+	+	+			1		+		5	2	25	*1*
Total 1990	22	678	34	10	171	43	176	38	1	2	0	28	7	44	8	1	1	120	1	72	0	236	13	1706	*100*
%	*1*	*40*	*2*	*1*	*10*	*3*	*10*	*2*	*0*	*0*	*0*	*2*	*0*	*3*	*0*	*0*	*0*	*7*	*0*	*4*	*0*	*14*	*1*	*100*	

(B= Bank, F = Fence, G = Grass strip, H = Hedge, R = Relict hedge, W = Wall, N= Not present, UNC = Unclassified)

4.4.5 The major change in the matrix was from walls-with-fences to walls but, in landscape terms, the conversion of walls-with-fences to fences alone, and from walls to no boundary, is more important.

4.4.6 In terms of proportions of their total length, fences were the most stable boundary type with almost two-thirds (430 000 km) remaining unchanged between the two surveys. Newly built fences were the largest single contributor to the additional length of fences (143 000 km) recorded at the two dates, balanced to a large degree by the removal of other fences (128 000 km) from the landscape.

4.4.7 About half of the boundaries (837 000 km) retained the same characteristics (in terms of boundary element composition) between 1984 and 1990.

4.5 Summary of Chapter 4

4.5.1 Overall, boundaries with fences dominated the British countryside in 1990, although there was still a high proportion of hedges. In GB as a whole, walls were a relatively infrequent type but were proportionally more important in both Scotland and Wales. England contained the majority of hedgerows while most boundaries in Scotland included fences and walls. Wales had the widest diversity of boundary types.

4.5.2 The arable landscapes had the highest percentage of fences and simple hedges. The pastural landscapes had a wider range of hedge types and a significant length of wall. The marginal upland landscapes contained most walls but also had extensive fences and a minor element of hedgerows. Within the uplands, fences occurred in almost 80% of the boundaries and walls in over 30%. As shown elsewhere in this report, the upland landscapes were the most uniform type.

4.5.3 The biggest net loss in length was for boundaries containing hedges, but the largest individual change was an increase in fences. The relict hedgerows showed the biggest percentage change, an increase of 53%. In addition, the loss in walls indicates a simplification in the landscape. The major changes in lengths of boundary types were in England but there was a high proportional loss of hedgerows in Wales.

4.5.4 The biggest changes overall by length were in the pastural landscapes – this agrees with changes in species diversity reported in Chapter 5. The smallest changes were in the uplands which were relatively stable, as is pointed out in Chapters 3 and 5 (on land cover and vegetation). The marginal uplands showed a higher percentage change in a range of different types but their contribution to overall change was small, due to the restricted area occupied by this type. Lastly, the arable landscapes showed hedgerow losses on the one hand, and increases in relict hedges on the other, and a relatively small increase in fences.

Chapter 5 THE RESULTS (III): VEGETATION

5.1 Introduction

5.1.1 This study has focused on two types of change which are occurring in the British countryside, shifts in land cover and more subtle changes in vegetation. The most obvious is the step-wise shift between major land cover types, eg conversion of heath to arable, and results on this type of change have been reported in previous chapters. The second type of change, discussed in this chapter, is the more subtle change in the balance of plant species within a land cover type, eg the gradual change in a field which has been grazed and is then left unmanaged for a few years, leading to fine palatable grasses being slowly replaced by coarse grasses and tall herbs.

5.1.2 The methods and sampling schemes used to record the vegetation, and quality assurance procedures are described in section 2.3, and in more detail in the Field Handbook (Barr 1990).

5.1.3 In order to describe the wide range of vegetation recorded in CS1990, a statistical technique (TWINSPAN) has been used to group together the vegetation plots which are most similar into 29 classes, here called '**plot classes**'. This is an objective and reproducible alternative to assigning plots subjectively to a predetermined list of habitat types (eg calcareous grassland, mesotrophic grassland, acid grassland). Use of this technique means that the assignment of plots to classes takes account of all the species in a plot rather than relying on a few indicator species, as in key-based systems. Another advantage of this approach is that changes in vegetation can be measured empirically in terms of 'movement' from one plot class to another. For example, the gradual transition of an unimproved pasture to a more intensively managed one may be 'measured' as the changing species composition causes the plot to cross a statistically determined 'line' from one plot class to another.

5.1.4 Within a plot class, there will be some species with a high frequency, whilst other species occur in only a few plots. Some plots will have more species than others. With such a large data set (about 11 500 plots were recorded in CS1990), it is not feasible to analyse the plots in terms of the frequency and cover of each individual species. However, by grouping the species which frequently grow together, and therefore have similar environmental requirements, it is possible to describe vegetation in terms of the type of species present, and to identify where there is an ecologically significant shift, eg from a group of plants typical of waterlogged conditions to a group typical of drier situations. In order to produce these groups of species, a statistical technique (Ward's minimum variance clustering of DECORANA ordination scores) has been used to group species which have similar distributions within the data set into 32 '**species groups**' (SG). Investigating the changes in the frequency of these 32 species groups is much more manageable than considering several hundred species individually.

5.1.5 The way in which plot classes and species groups are derived from the raw plot data is illustrated in Figure 5.1a. Because the same species groups have been used to describe the **Main plots** (in fields, woodland and moorland) and **linear plots** (alongside hedges, streams and roads), as shown in Figure 5.1b, it is possible to compare the way in which they have changed across habitats, eg to see whether calcareous meadow

Figure 5.1a **Species groups and plot classes are derived from raw plot data**
(Plot classes are derived from TWINSPAN classification of plots.
Species groups are derived by Ward's Minimum Variance Clustering of DECORANA scores)

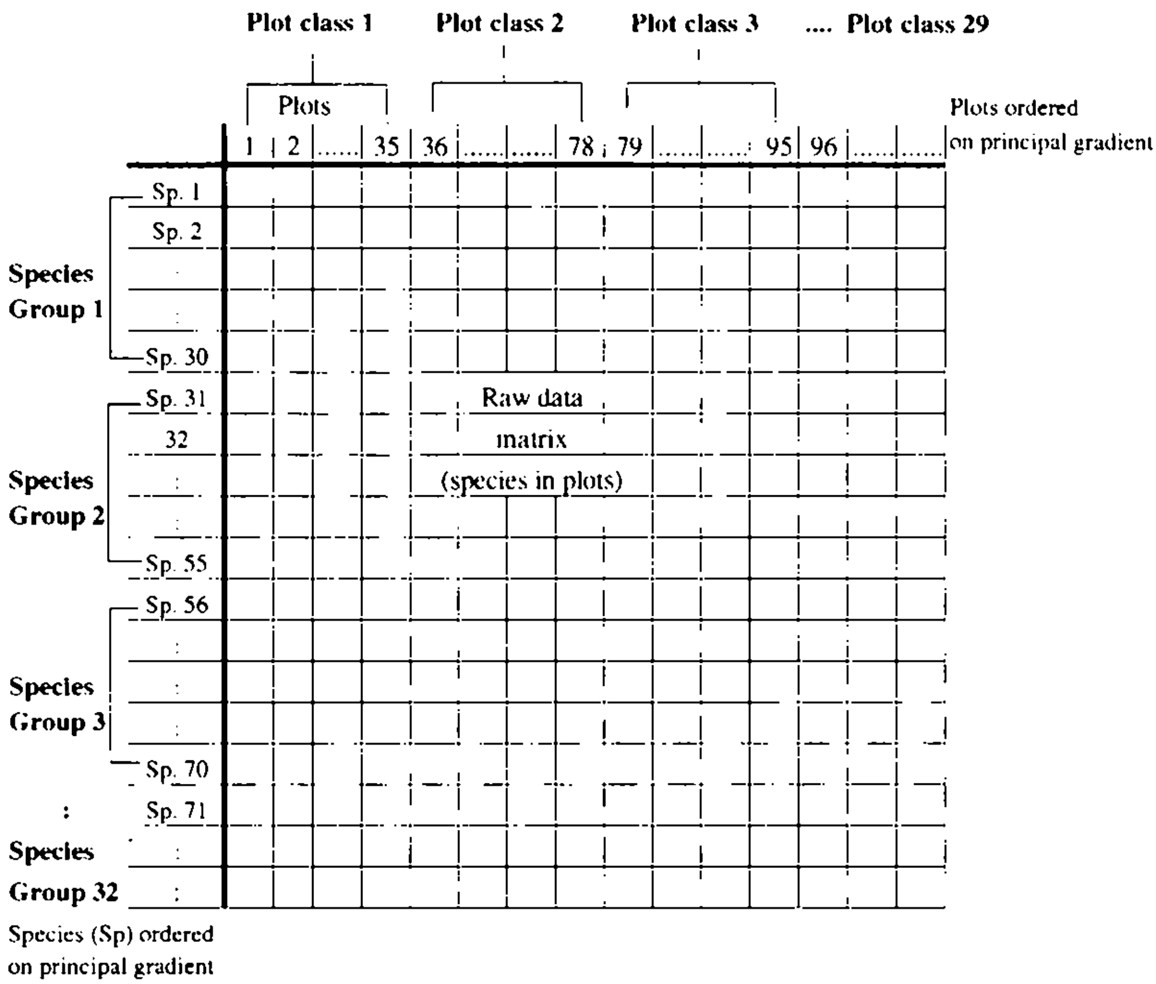
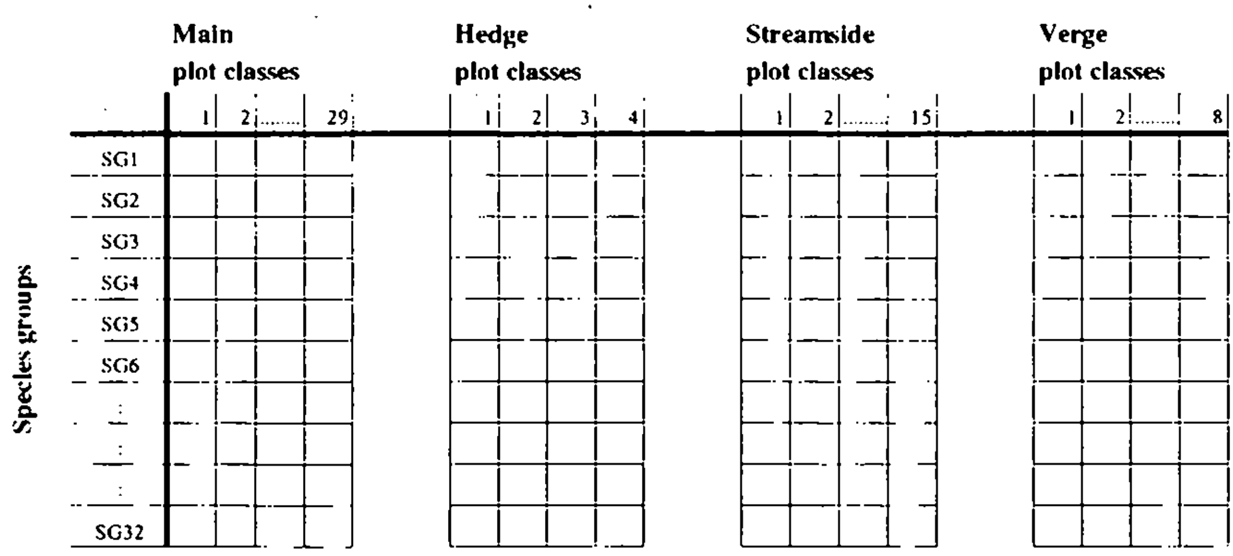


Figure 5.1b **Species groups can be used to describe and compare the species composition of Main, Hedge, Streamside and Verge plot classes**



See Figure 5.4 for data

plants are declining in road verges as well as in the fields (Main plots).

5.1.6 The data have also been analysed to investigate change using mean number of species and mean number of species groups as measures of **diversity**. The number of species in a plot may change for a number of reasons; for example, disturbance may lead to patches of bare ground which allow colonisation by weed species, thus increasing the number of species present. A better understanding can be gained by considering the types of species which are increasing or decreasing, through the analysis of species groups. The use of change in mean species number as a measure of diversity is also much more sensitive to inaccuracies in recording than the use of plot classes or species groups – for this reason, analysis of change in terms of species number considers only those species which can confidently be regarded as consistently recorded – referred to as 'Category 1 species' (see Section 2.3.21 and Appendix 2).

5.2 Main plots

Vegetation classification

5.2.1 Plant species and cover estimates were recorded from five randomly placed, 200 m² plots in each 1 km square. These are referred to as '**Main plots**', to distinguish them from other randomly placed plots in particular situations, eg roadsides. The purpose of the Main plots was to sample the main land cover types, ie agricultural fields, woodland, and moorland. Since these plots were located randomly they are representative of the range of vegetation in the survey squares.

5.2.2 A total of 2534 Main plots were recorded from 507 1 km squares throughout GB (one of the 508 survey squares was completely built up in 1990). In order to describe this

Table 5.1 Brief descriptions of the 29 main plot classes derived from the TWINSPAN analysis of the Main plots recorded in 1978 and 1990, together with the three species which show the greatest degree of preference to each class according to their frequency in that class, as opposed to the frequency in the other classes. (Some classes had fewer than three preferential species). Plot classes (except saltmarsh) are ordered on the principal gradient (derived from DECORANA), from 1, 'intensive – high nutrient status' to 29, 'extensive – low nutrient status'

Main plot class	Description	Characteristic species
MPC1	Saltmarsh	*Aster tripolium, Suaeda maritima, Puccinellia maritima*
ARABLE FIELDS		
MPC2	Arable A (almost weed-free cereals)	None
MPC3	Arable B (scattered weeds in mixed crops)	*Fallopia convolvulus, Polygonum aviculare, Viola arvensis*
MPC4	Arable C (mainly graminaceous weeds in cereals)	*Avena fatua, Alopecurus myosuroides, Bromus sterilis*
MPC5	Arable D (broadleaved weeds in mixed crops)	*Senecio vulgaris, Polygonum aviculare, Stellaria media*
MPC6	Arable E (mixed weeds in cereals)	*Polygonum aviculare, Stellaria media, Poa annua*
MPC7	Arable F (weedy leys/under-sown cereals)	*Capsella bursa-pastoris, Stellaria media, Polygonum aviculare*
LOWLAND IMPROVED GRASSLAND		
MPC8	Leys	*Lolium perenne, Trifolium repens*
MPC9	Intensive grass + weeds	*Lolium perenne, Plantago major, Stellaria media*
MPC10	Rye grassland	*Lolium perenne, Rumex obtusifolius, Trifolium repens*
MPC11	Improved pasture	*Agrostis stolonifera, Cirsium arvense, Dactylis glomerata*
MPC12	Improved grassland + clover	*Lolium perenne, Trifolium repens, Poa annua*
LOWLAND SEMI-IMPROVED GRASSLAND		
MPC13	Semi-improved neutral grassland	*Holcus lanatus, Lolium perenne, Trifolium repens*
MPC14	Neutral grassland	*Cerastium fontanum, Trifolium repens, Lolium perenne*
MPC15	Semi improved pasture	*Plantago lanceolata, Dactylis glomerata, Achillea millefolium*
MPC16	Unimproved neutral/acid pasture	*Cerastium fontanum, Holcus lanatus, Rumex acetosa*
WOODLAND		
MPC17	Open broadleaved secondary woodland	*Urtica dioica, Arrhenatherum elatius, Crataegus monogyna*
MPC18	Basiphilous broadleaved woodland	*Crataegus monogyna, Fraxinus excelsior, Urtica dioica*
MPC19	Acid woodland	*Oxalis acetosella, Pteridium aquilinum, Digitalis purpurea*
MPC20	Acid scrub	*Pteridium aquilinum, Sorbus aucuparia, Ilex aquifolium*
MPC21	Sitka plantation	None
UPLAND GRASS MOSAICS		
MPC22	Upland grassland diverse	*Lotus corniculatus, Plantago lanceolata, Anthoxanthum odoratum*
MPC23	Marshy upland grass	*Juncus effusus, Potentilla erecta, Anthoxanthum odoratum*
MPC24	Acid grass/heath/wood	*Galium saxatile, Potentilla erecta, Blechnum spicant*
MPC25	Upland grass/heath	*Galium saxatile, Festuca ovina, Deschampsia flexuosa*
MOORLAND		
MPC26	Boggy moorland	*Nardus stricta, Erica tetralix, Molinia caerulea*
MPC27	Moorland	*Vaccinium myrtillus, Deschampsia flexuosa*
MPC28	Dwarf shrub heath	*Vaccinium myrtillus, Deschampsia flexuosa, Calluna vulgaris*
MPC29	Bog	*Erica tetralix, Trichophorum cespitosum, Calluna vulgaris*

vegetation, the species data from all these Main plots (plus data from Main plots recorded in 1978) have been classified using the multivariate statistical technique, TWINSPAN, to create 29 '**Main plot classes**' (**MPCs**). These have been given short descriptive names to aid presentation of the results, but it should be remembered that the definition of the plot classes may not correspond entirely with the more general usage of these names. A total of 29 classes was chosen as being a suitable level of detail for the purposes of this report; they could be further subdivided for more detailed analysis.

5.2.3 The plot classes were ordered, as shown in Table 5.1, according to their relative positions on the principal gradient (derived from the multivariate statistical technique, DECORANA). The order has been interpreted in terms of a gradient from high intensity of management (eg in arable fields) to low intensity (eg in upland vegetation). The woodlands, however, occur throughout this gradient and they have been grouped together in Table 5.1 and subsequent Figures (but retaining their respective order, one to another), as an aid to interpretation.

Main plots: stock in 1990

5.2.4 Figure 5.2 shows how the Main plots recorded in 1990 were distributed between these 29 Main plot classes, in the four landscape types.

5.2.5 In the arable landscapes, the most abundant plot classes were those associated with arable fields and improved grass; there was also a small number of plots in woodland. The more upland classes which included moorland and bog were mainly from land immediately adjacent to arable areas in Scotland.

5.2.6 Six classes of vegetation have been identified associated with arable crops. In the arable landscapes, classes 'Arable C' (MPC3 – mainly graminaceous weeds in cereal fields) and 'Arable E' (MPC6 – mixed weeds in cereal fields) were most abundant, compared to the pastural landscapes where there was a more even spread over the six classes.

5.2.7 The pastural landscapes were dominated by grasslands, but also included examples of most other plot classes. Previously the marginal upland landscapes have been thought of as having the most diverse landscapes, but Figure 5.2 shows that, in terms of plot classes, the lowland landscapes have a greater variety; the presence of upland vegetation was largely fragments of acid grass and moorland remaining in lowland classes.

5.2.8 The vegetation of the marginal upland landscapes fell into two distinct groups: the upland grass/moorland and the lowland grassland. The spatial proximity of these two habitats is important, eg in providing bird species with roosting and feeding grounds respectively.

5.2.9 The upland landscapes were dominated by moorland, and were least diverse in that they contain large areas with few plot classes. Woodlands recorded included both conifer plantations and native woods. The small area of improved grassland was largely associated with crofting townships.

Main plots: change between 1978 and 1990

5.2.10 A total of 1203 Main plots, from 248 1 km squares, was recorded in the same position in both 1978 and 1990. Data from these pairs of plots were used here to consider how the vegetation changed over this period.

5.2.11 There are two scales of change observable from the plot data. First, there is the gross change which follows a change in land use, for instance following the ploughing of old pasture. Second, there is a more subtle change in quality within the land cover type, as detected by a gradual loss of species.

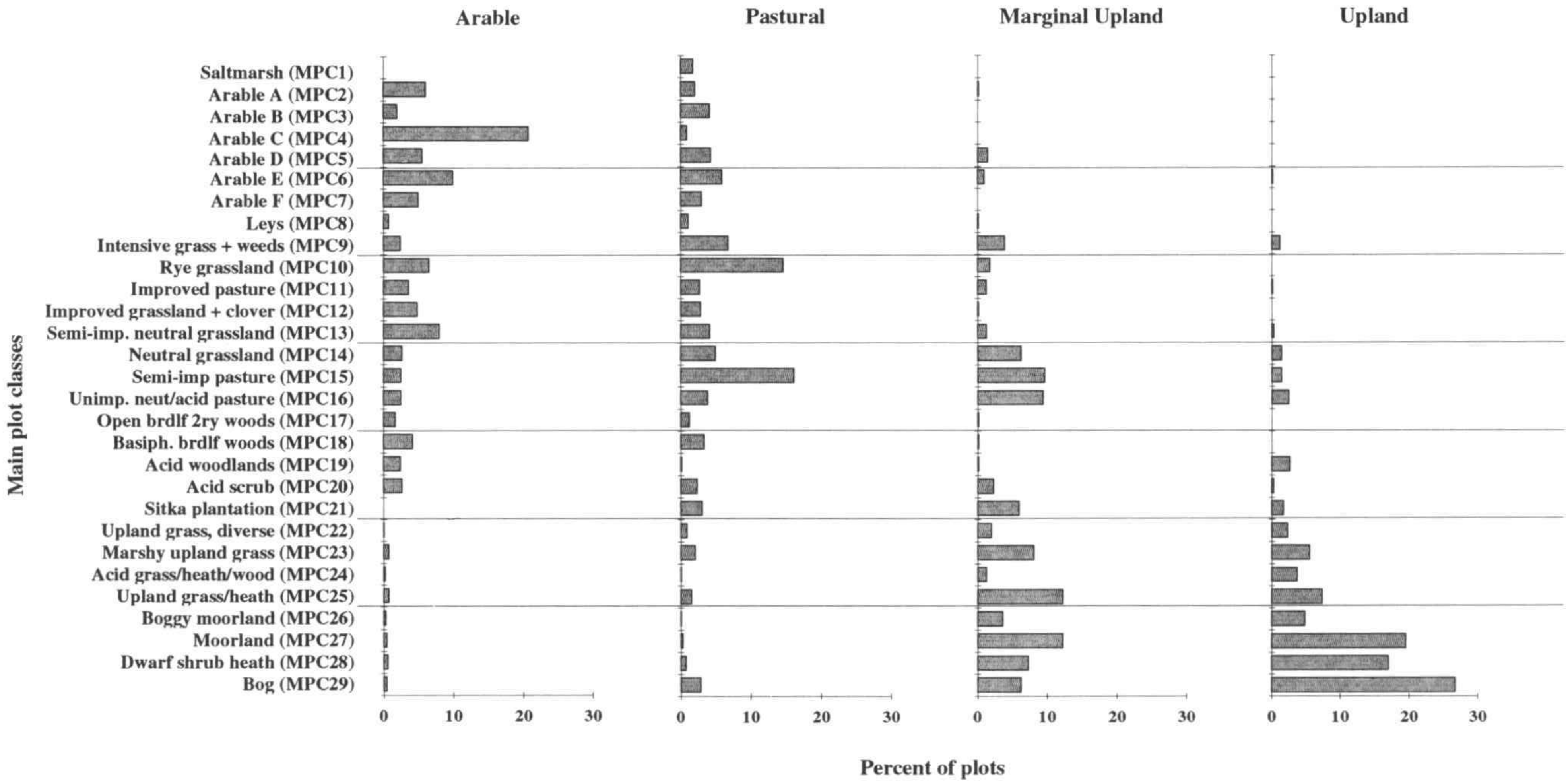
5.2.12 The extent of the gross changes is most reliably derived from the land cover mapping, as presented in Chapter 3, although vegetation plot data may provide additional insights (as discussed briefly below – section 5.2.13 onwards). However, the vegetation plot data alone provide information on more subtle changes in quality (as discussed in 5.2.19).

Main plots: gross change in vegetation

5.2.13 In order to consider gross change, the 29 plot classes have been aggregated into six broad categories: 'arable fields' (classes MPC2–MPC7); 'lowland improved grassland' (MPC8–MPC12); 'lowland semi-improved grassland' (MPC13–MPC16); 'woodland' (MPC17–MPC21); 'upland grass mosaics' (MPC22–MPC25); and 'moorland'

Figure 5.2 MAIN PLOT CLASSES IN GB

Percentage frequency of the 29 Main plot classes (MPC1 - 29), (as shown in Table 5.1), derived from TWINSPAN analysis of the Main plots, recorded in 1990, by landscape type



(MPC26–MPC29). (Saltmarsh – MPC1 – has been excluded from these groupings, because it is an ecologically distinct type.) Change in these six categories has been examined for each of the four landscape types in terms of the proportion of plots which have changed from one category to another, as opposed to those which have remained in the same category. Matrices of change between these categories are shown in Figure 5.3 (many of the changes are small in terms of plot numbers and are not significant).

5.2.14 Figure 5.3(a) shows that in the arable landscapes most of the change involved a rotation between the 'arable fields' and the 'lowland improved grassland' categories, with some intensification of the 'lowland semi-improved grassland' category.

5.2.15 Figure 5.3(b) shows that in the pastural landscapes there was rotation not only between 'arable fields' and 'lowland improved grassland', but also between 'lowland improved grassland' and 'lowland semi-improved grassland'. In addition, there were more examples of 'lowland semi-improved grassland' converted to 'arable fields'. There were also examples of 'upland grass mosaics' and 'moorland' becoming lowland grassland or 'woodland'.

5.2.16 Figure 5.3(c) shows a different situation in the marginal upland landscapes. Here there was interchange between some classes in the 'lowland improved grassland' and 'upland grass mosaics' categories. Some of the 'moorland' classes have also become grassland, and *vice versa*.

5.2.17 Figure 5.3(d) shows that the uplands were stable relative to the other landscapes. The only clear directional change was from some of the 'upland grass mosaics' and 'moorland' classes to 'woodland', mainly through conifer afforestation.

5.2.18 Table 5.2 shows the effect the gross changes have on the average number of species recorded per plot. The data were grouped according to the 1978 occurrence of plots in the six categories, regardless of whether they were in the same category

Table 5.2 Gross change (1978-1990) in species numbers recorded in paired Main plots, within the broad categories of plot classes derived from TWINSPAN analysis by landscape type. Plots are allocated to 1978 plot categories (see 5.2.18)

Landscape type	Plot class categories	No. of plots	% of plots in GB	Mean species no. 1978	Mean species no. 1990	Change in mean species no.	% change	SE of change	P
Arable	Arable fields	130	12.2	6.7	5.0	-1.7	-25.4	0.6	**
	Improved grass	55	5.1	11.0	8.5	-2.5	-22.4	0.8	**
	Semi-improved grass	59	5.5	19.4	17.4	-2.0	-10.4	1.0	*
	Woodland	21	2.0	16.0	17.9	1.9	11.6	3.4	
Pastural	Arable fields	73	6.8	7.4	8.4	1.0	13.4	0.9	
	Improved grass	88	8.2	12.8	12.1	-0.7	-5.5	0.6	
	Semi-improved grass	121	11.3	21.5	16.6	-4.9	-22.7	1.2	***
	Woodland	29	2.7	15.0	11.9	-3.1	20.5	1.1	**
	Upland grass	21	2.0	23.5	20.0	-3.5	-15.0	1.6	*
	Moorland	17	1.6	15.1	11.9	-3.2	-21.4	1.5	*
Marginal upland	Improved grass	14	1.3	16.7	17.0	0.2	1.4	1.3	
	Semi-improved grass	57	5.3	22.7	23.8	1.1	4.8	1.9	
	Woodland	11	1.0	21.8	12.9	-8.9	-40.8	3.7	*
	Upland grass	38	3.6	18.9	17.9	-1.0	-5.0	1.5	
	Moorland	38	3.6	12.6	16.7	4.2	33.2	1.3	**
Upland	Improved grass	5	0.5	8.8	12.3	3.5	39.6	1.5	
	Semi-imroved grass	7	0.7	20.2	20.3	0.2	0.8	2.4	
	Woodland	9	0.8	18.4	16.8	-1.7	-9.0	3.7	
	Upland grass	51	4.8	26.6	23.4	-3.2	-12.0	2.1	
	Moorland	204	19.1	18.7	19.6	0.9	4.7	0.5	
GB	Arable fields	209	19.6	7.0	6.4	-0.6	-9.2	0.5	
	Improved grass	162	15.2	9.9	9.7	-0.2	-2.3	0.5	
	Semi-improved grass	244	22.8	20.7	17.9	-2.8	-13.4	0.6	***
	Woodland	70	6.6	16.8	14.5	-2.3	-13.8	1.4	*
	Upland grass	115	10.8	23.6	21.1	-2.5	-10.6	1.1	*
	Moorland	268	25.1	17.4	18.6	1.2	6.7	0.5	*

(Category 1 species only. Probability (P) is based on paired t-test: * <0.1, ** <0.01, *** <0.001)

Figure 5.3 Matrices of change showing movement of Main plots between the six categories into which the Main plot classes have been grouped. Figures are % of total number of plots in the landscape type (+ = less than 0.5%)

(a) Arable

Total plots = 329

1978 \ 1990	Arable	Improved grassland	Semi-imp.grassland	Woodland	Upland grass	Moorland
Arable	47	8	1	.	.	.
Improved grassland	8	7	1	1	.	.
Semi-imp.grassland	2	3	12	1	+	.
Woodland	.	1	1	5	+	.
Upland grass	.	+	+	1	2	+
Moorland	.	.	.	1	.	.

(b) Pastural

Total plots = 353

1978 \ 1990	Arable	Improved grassland	Semi-imp.grassland	Woodland	Upland grass	Moorland
Arable	13	5	1	.	.	.
Improved grassland	4	15	6	+	.	.
Semi-imp.grassland	4	7	22	1	1	+
Woodland	.	+	1	7	+	.
Upland grass	.	.	1	1	3	1
Moorland	.	.	+	+	+	4

(c) Marginal Upland

Total plots = 160

1978 \ 1990	Arable	Improved grassland	Semi-imp.grassland	Woodland	Upland grass	Moorland
Arable	1	1	1	.	.	.
Improved grassland	.	3	6	.	.	.
Semi-imp.grassland	1	3	29	2	1	.
Woodland	.	.	1	6	1	.
Upland grass	.	.	3	3	14	4
Moorland	.	.	1	.	5	18

(d) Upland

Total plots = 278

1978 \ 1990	Arable	Improved grassland	Semi-imp.grassland	Woodland	Upland grass	Moorland
Arable	.	.	.	.	.	.
Improved grassland	+	1	+	.	.	.
Semi-imp.grassland	.	.	2	.	.	+
Woodland	.	.	.	3	1	+
Upland grass	.	.	1	2	10	5
Moorland	.	.	+	2	5	66

in 1990. The lowland arable and pastural landscapes have experienced the most change, with the uplands remaining relatively stable. Over the country as a whole, 'lowland semi-improved grassland', 'woodland', and 'upland grass mosaics' have all experienced a significant loss of species diversity, whilst only in the 'moorland', an inherently species-poor category, has there been an increase.

Main plots: change in vegetation quality

5.2.19 Subtle changes in quality within vegetation of the same category, eg 'moorland', can only be investigated by field survey involving detailed plant species recording. In this section, vegetation in each of the six categories presented above ('arable fields', 'lowland improved grassland' 'lowland semi-improved grassland', 'woodland', 'upland grass mosaics', 'moorland') is considered in turn. For this analysis three measures of change have been used: change between the plot classes within each category; change in mean species number; and change in species groups, to indicate the sort of species which were increasing or declining. Table 5.3 gives brief descriptions of the species groups with typical species to show their ecological character.

5.2.20 The species groups may be used to interpret the ecological composition of the plot classes. The species groups form different combinations within the plot classes according to the characteristics of the vegetation from which they were drawn. These combinations reflect differences in the characteristics of the habitats which relate to the management and environment with which they are associated.

5.2.21 The occurrence of the species groups in the Main plot classes is shown in Figure 5.4 and emphasises the inherent continuity of vegetation. Within the arable fields category, the species present are mainly from the weed groups (SG28, SG29 and SG30), although groups of grassland species are also represented (eg SG23 and SG24). Within the two lowland grassland categories, species from the weed groups are again represented, as well as flush and grassland species (eg from SG10 and SG12). The 'woodland' category contains more shade-tolerant species than elsewhere (eg SG16 and SG18). The 'upland grass mosaics' category has

Table 5.3 Brief descriptions of the 32 species groups (defined by applying Ward's minimum variance clustering of DECORANA scores). Two examples of the list of species belonging to each group are given in order to provide an overall picture of the composition. The groups are ordered according to their average DECORANA scores

SG1	Bog pool plants	*Menyanthes trifoliata, Drosera rotundifolia*
SG2	Bog plants	*Trichophorum cespitosum, Narthecium ossifragum*
SG3	Wet heath plants	*Calluna vulgaris, Molinia caerulea*
SG4	Acid flush plants	*Succisa pratensis, Potentilla erecta*
SG5	Upland heath plants	*Nardus stricta, Viola palustris*
SG6	Dry heath plants	*Vaccinium myrtillus, Deschampsia flexuosa*
SG7	Upland streamside plants	*Thelypteris limbosperma, Galium saxatile*
SG8	Acid damp scrub plants	*Sorbus aucupana, Solidago virgaurea*
SG9	Dry hillside plants	*Sarothamnus scoparius, Pteridium aquilinum*
SG10	Nutrient-poor grassland plants	*Festuca ovina, Thymus drucei*
SG11	Enriched flush plants	*Achillea ptarmica, Cirsium palustre*
SG12	Neutral/acid grassland plants	*Agrostis canina, Conopodium majus*
SG13	Neutral woodland plants	*Crataegus monogyna, Hyacinthoides non scripta*
SG14	Wet meadow plants	*Lychnis flos-cuculi, Cardamine pratensis*
SG15	Damp woodland edge plants	*Corylus avellana, Ajuga reptans*
SG16	Calcareous woodland plants	*Arum maculatum, Mercurialis perennis*
SG17	Calcareous scrub plants	*Cornus sanguinea, Primula veris*
SG18	Wet shaded streamside plants	*Phalaris canariensis, Lysimachia nemorum*
SG19	Calcareous meadow plants	*Sanguisorba minor, Bromus erectus*
SG20	Base-rich meadow plants	*Achillea millefolium, Briza media*
SG21	Damp neutral meadow plants	*Polygonum bistorta, Veronica chamaedrys*
SG22	Shaded wet meadow plants	*Filipendula ulmaria, Caltha palustris*
SG23	Old permanent pasture plants	*Bellis perennis, Leucanthemum vulgare*
SG24	Field margin plants	*Potentilla anserina, Vicia cracca*
SG25	Improved permanent pasture plants	*Lolium perenne, Cirsium vulgare*
SG26	Overgrown field margin plants	*Anthriscus sylvestris, Heracleum sphondylium*
SG27	Maritime plants	*Armeria maritima, Plantago maritima*
SG28	Weeds, mostly perennial	*Rumex obtusifolius, Sonchus oleraceus*
SG29	Enriched field margin plants	*Conium maculatum, Petasites hybridus*
SG30	Weeds, mostly annual	*Avena fatua, Capsella bursa-pastoris*
SG31	Aquatic plants	*Typha latifolia, Nuphar lutea*
SG32	Wall plants	*Polypodium vulgare, Umbilicus rupestris*

Figure 5.4 The occurrence of species groups (SG1-SG30) in the Main plot classes (MPC1-MPC29)

Main plot classes

Species groups	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1																								+		+	+	+	1
2																					+	1	+	1	+	1	1	1	1
3																			+	+		1	1	1	1	1	1	1	1
4															+	+			+			1	1	1	1	1	1	+	1
5																+						1	1	+	1	1	1	1	+
6																		+	1	1	1	1		1	1	1	1	1	1
7																+			1	+		1	1	1	1	1	1	1	+
8																	+	+	1	1	+	+	+	1		+	+	+	
9																+	+	+	1	1		+	+	1	+	+		+	
10													+	+	1	1			+		+	1	1	1	1	1	+	+	
11													+	+		1	+	+	+			1	1	+	+	+	+		
12							+		+	+	1	+	1	1	1	1	+	+	1			1	1	1	1	1		+	
13																+	1	1	1	1		+		+					
14													+		+	+	+						+	+					
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20									+	+	+	+	1	1	1	1		+	+			1	+	+					
21												+	+	1	+	+	+	+	+	+	+	+	+	+	+		+		
22											+					+	+	+				+	+						
23						+	+		1	1	+	1	1	1	1	1	+		+			1	1	+	+				
24	+					+		1	+	1	1	+	1	1	1	+	+	+	+			+	1	+					
25					+	+	+	1	1	1	1	1	1	1	1	1	+	+	+			+							
26			+	+	+	+		+	+	+	+		+	+	+	+	1	+	+										
27	1							1			+		+	+	1	1	+		+			1	1						
28			+	+	+	1	1		1	1	+	+	+	1	+	1	+	+	+			+	+		+				
29			+	+	+	+	+		+	+	1				+		+												
30		1	1	1	1	1	1		1	+	+	+			+														
Total	2	1	4	4	5	7	6	4	9	9	11	8	12	11	16	19	18	18	21	8	5	20	19	19	13	12	11	11	7
Category	Saltmarsh	Arable fields						Lowland improved grassland					Lowland semi-improved grassland				Woodland					Upland grass mosaic				Moorland			

+ indicates that at least one species from the species group is recorded in at least 10% of plots in the plot class

1 indicates that at least one species from the species group is recorded in at least 30% of plots in the plot class

Total is the number of species groups in each plot class, where at least one species is recorded in at least one plot

NB. SG31 and SG32 are excluded from this analysis because there are too few records

Table 5 4 Change (1978–90) in the relative positions of the paired Main plots on the principal vegetation gradient (derived by TWINSPAN analysis), using only those plots which remained in the **'arable fields'** category of plot classes (MPC2–MPC7), by landscape type

Direction of change in arable fields	Landscape type Arable	Pastural	Marginal upland	Upland
Up[1]	67	47	NA	NA
Down[2]	9	24	NA	NA
Same[3]	24	29	NA	NA

[1]Percentage of plots that have moved up the principal gradient to more intensive plot classes
[2]Percentage of plots that have moved down the principal gradient to less intensive plot classes
[3]Percentage of plots that have remained in the same plot class
NA Not applicable

species from a range of groups, whilst species from the 'moorland' category are restricted to the upland groups SG1–SG7.

5.2.22 Figure 5.4 also shows how species groups can be used as a measure of diversity. The 'arable fields' category has the lowest number of species groups. The 'lowland improved grassland' category is variable but generally has more species groups than does the 'arable fields' category. The 'semi-improved grassland' and 'upland grass mosaics' categories are the most diverse, with 'moorland' being intermediate. The 'woodland' category contains both the most diverse plot class (MPC19, acid woodland with 21 species groups), and plot classes with low diversity (eg MPC21, Sitka plantation with only five species groups).

Arable fields (MPC2–MPC7)

Change between plot classes

5.2.23 Figure 5.5 shows the change in the proportion of plots in each of the six plot classes (MPC2–MPC7) associated with arable fields, for the arable and pastural landscapes. (The sample in the marginal upland and upland landscapes was too small for analysis to be included.) In both cases, there has been a decline in the proportion of 'Arable E' (MPC6) and an increase in 'Arable C'(MPC4), indicating a decline in broadleaved weeds and an increase in graminaceous weeds within cereal crops. The overall direction of changes occurring in each landscape type can be simplified by considering the direction of movement of plots along the principal vegetation gradient (Table 5.4). In both arable and pastural landscapes, more plots moved up the gradient to more intensive classes than moved down.

Change in species number

5.2.24 Table 5.5 shows the change in mean species number from plots which were in 'arable fields' in both 1978 and 1990. In the arable landscapes there has been a 38% decline in species number, whilst in the pastural landscapes there has been a small loss which was not statistically significant. This means that, in 1978, fields in the two landscape types had similar numbers of species, but by 1990 those in the arable landscapes were poorer, with 25% fewer species.

Change in species groups

5.2.25 Figure 5.6 shows the way in which different types of species (species groups) have changed in frequency between 1978 and 1990, for those plots which were in the 'arable fields' category (MPC2–MPC7) in both years. Annual weeds (SG30) and perennial weeds (SG28), in particular, and to a lesser extent grassland species, were recorded less often in 1990 than in 1978. For example, there is on average one fewer annual weed species recorded per plot, in the arable landscape type. This decline of the weed flora may have some implications for invertebrate and bird species, but from the botanical viewpoint the species in decline are widespread elsewhere in the landscape, eg on disturbed ground, and are not themselves likely to be considered of great conservation importance. The rare

Table 5 5 Change (1978–90) in the mean number of species per plot, from those paired plots that remained in the **'arable fields'** category of plot classes (MPC2–MPC7), derived by TWINSPAN analysis, by landscape type and GB

Plot class category	Landscape type	No. of plots	% of plots in GB	Mean species no. 1978	Mean species no. 1990	Change in mean species no.	% change	SE of change	P
Arable fields	Arable	112	10.5	6.7	4.1	-2.5	-37.9	0.5	***
(MPC2–	Pastural	52	4.9	6.8	6.1	-0.7	-10.4	0.8	
MPC7)	GB	165	15.4	6.7	4.8	-1.9	-28.7	0.4	***

(Category 1 species only. Probability (P) is based on paired t-test. * <0.1, ** <0.01, *** <0.001)

Figure 5.5 MAIN PLOT CLASSES IN ARABLE FIELDS

Change in the frequency of the six Main plot classes (MPC2 -7), (derived from TWINSPAN analysis of the Main plots), from the 'arable fields' category, using only those plots which were in the same category in both 1978 and 1990, by landscape type

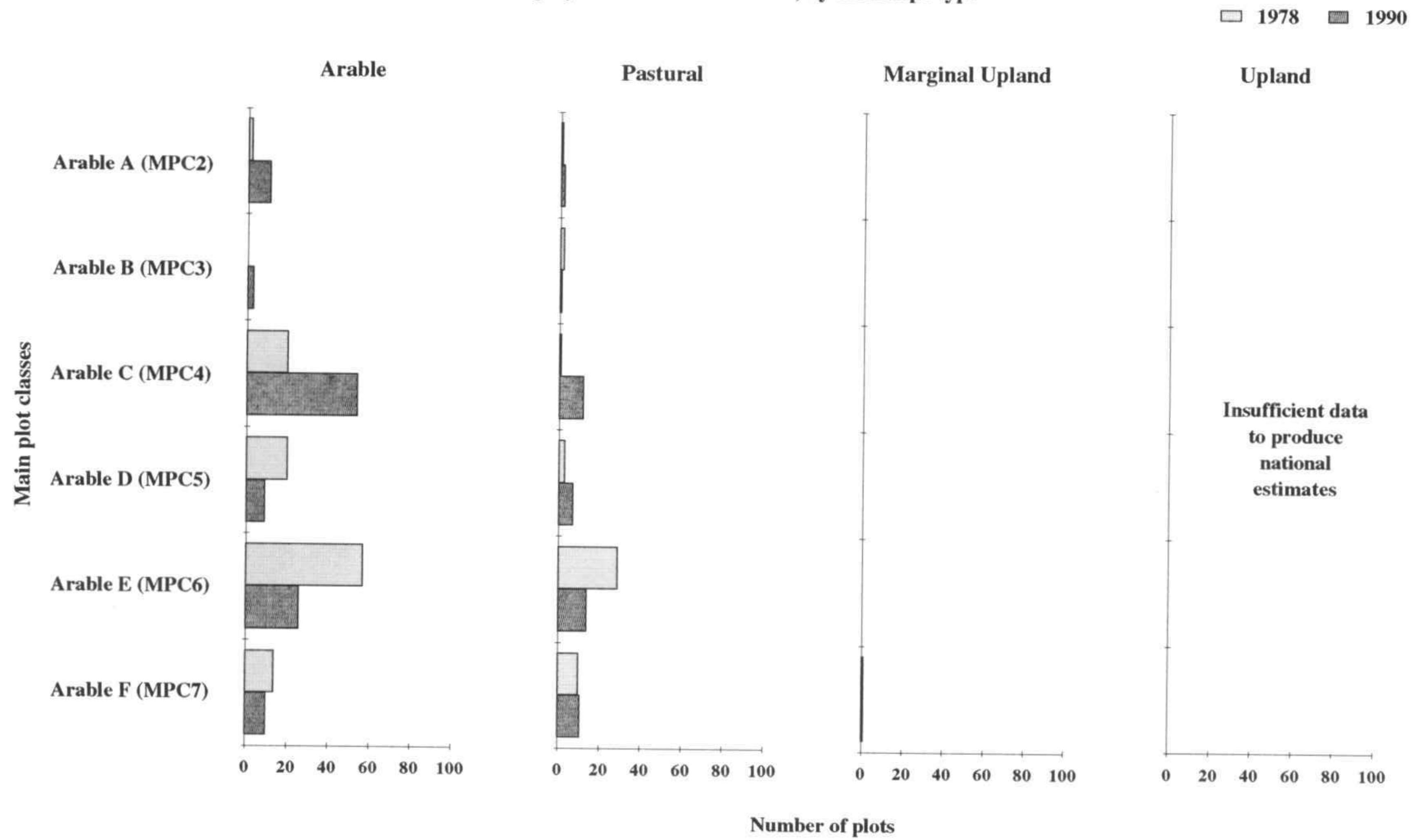


Figure 5.6 SPECIES GROUPS IN ARABLE FIELDS

Change in the mean number of species for each of the 11 species groups (Table 5.3) characteristic of 'arable fields' (MPC2 - 7), by landscape type and using only those plots which were in the same category in both 1978 and 1990

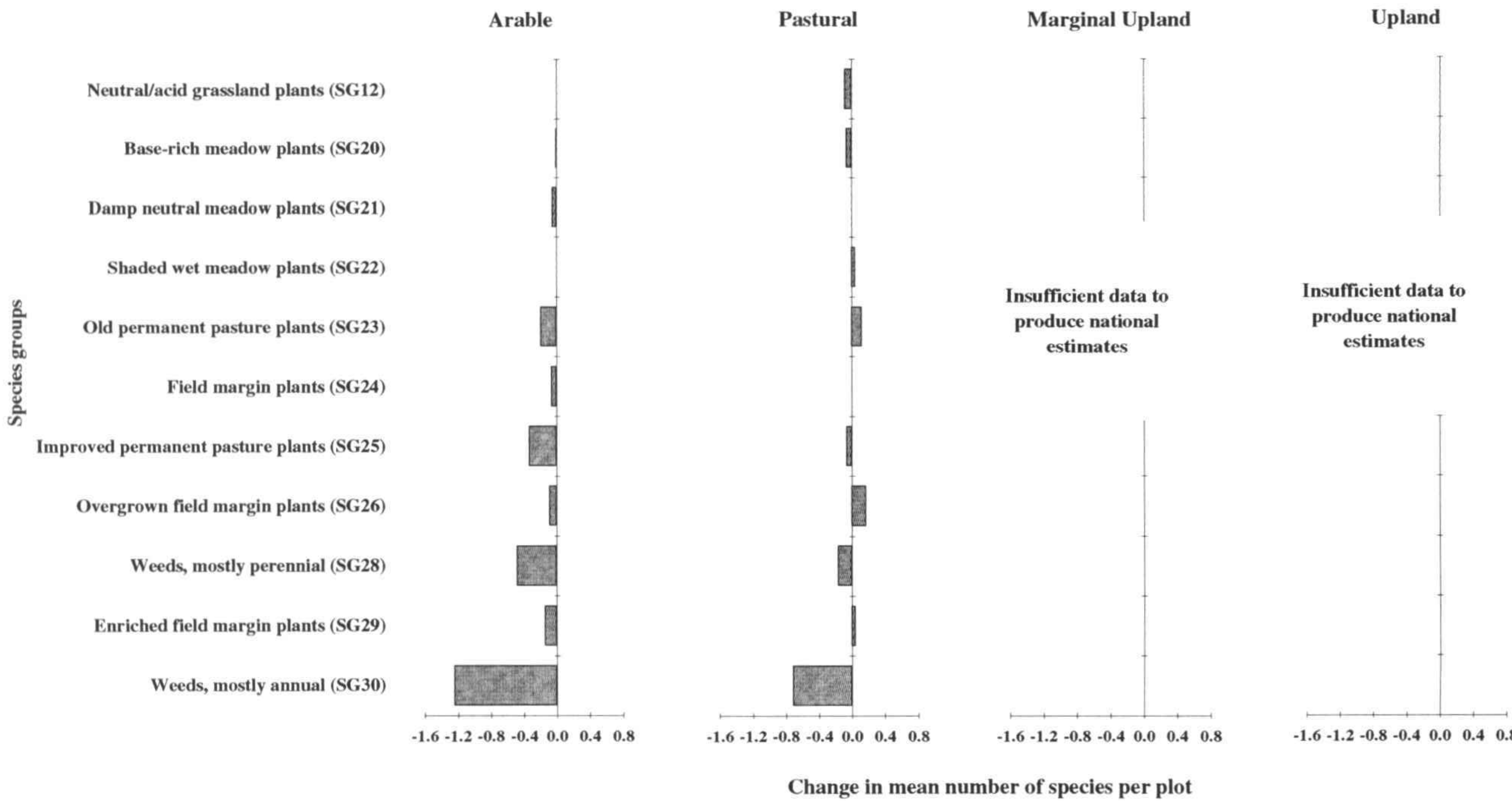


Table 5.6 Change (1978–90) in the relative positions of the paired Main plots on the principal vegetation gradient (derived by TWINSPAN analysis) using only those plots which remained in the **lowland grassland** categories (MPC8–MPC16), by landscape type

Direction of change in lowland grassland	Landscape type Arable	Pastural	Marginal upland	Upland
Up[1]	33	42	23	NA
Down[2]	18	23	31	NA
Same[3]	48	35	45	NA

[1]Percentage of plots that have moved up the principal gradient to more intensive plot classes
[2]Percentage of plots that have moved down the principal gradient to less intensive plot classes
[3]Percentage of plots that have remained in the same plot class
NA Not applicable

species associated with arable fields, such as *Agrostemma githago* (corncockle), had already disappeared from the vast majority of fields by 1978 and so do not occur in this data set.

Lowland grassland (MPC8–MPC16)

Change between plot classes

5.2.26 Figure 5.7 shows the change in the proportion of plots in each of the nine lowland grassland plot classes (improved and semi-improved) (MPC8–MPC16).

5.2.27 The main impact on grasslands in arable landscapes is rotation with arable crops (see Figure 5.3a). In comparison with these fields, permanent pasture shows little significant change.

5.2.28 In the pastural landscapes there have been larger shifts between grassland types in both directions, ie extensification and intensification, with no significant net change. The decrease in the 'intensive grass plus weeds' group (MPC9), and the increase in the 'rye grassland' group (MPC10) may reflect changes in management practice. In these pastural landscapes there are small declines in the least improved groups, MPC15 and MPC16.

5.2.29 In the marginal upland landscape there are small differences but no clear net change. Relatively few plots have changed class compared with the pastural landscape type.

5.2.30 The changes in the distribution of plot classes, as described above, are mostly very small. This could be because a class is gaining and losing plots and so there is no net change, or it could be because changes in species composition are taking place but they are insufficient to cause a shift to another plot class (for example, a plot may be classified into the same class in both years because it has the same 'core' species, but the overall species complement may have declined and fewer species groups may therefore be represented; if this trend continued, and sufficient of the core species were lost, then the plot would change class).

5.2.31 The difference in the direction of the changes occurring in each landscape type can be simplified by considering the proportion of plots which have moved towards the intensive end of the principal gradient, as opposed to those which have moved towards the extensive end (Table 5.6). More plots in the lowland grassland categories have moved up the gradient than have moved down.

Table 5.7 Change (1978–90) in the species number recorded in paired plots that remained in the '**lowland grassland**' categories of plot classes (MPC8–MPC16), derived by TWINSPAN analysis, by landscape type and GB (NB the upland landscape type has very few plots)

Plot class category	Landscape type	No. of plots	% of plots in GB	Mean species no. 1978	Mean species no. 1990	Change in mean species no.	% change	SE of change	P
Improved grassland (MPC8–MPC12)	Arable	26	2.4	9.8	8.7	-1.1	-11.1	1.2	
	Pastural	59	5.5	10.2	10.7	0.5	4.6	0.9	
	Marginal upland	8	0.7	13.9	13.3	-0.6	-4.5	3.3	
	Upland	3	0.3	7.3	8.7	1.3	18.3	2.3	
	GB	96	9.0	10.3	10.3	-0.0	-0.1	0.7	
Semi-improved grassland (MPC13–MPC16)	Arable	28	2.6	21.5	20.3	-1.2	-5.7	1.2	
	Pastural	51	4.8	22.2	19.2	-3.0	-13.5	1.5	*
	Marginal upland	25	2.3	22.2	23.8	1.6	7.2	1.6	
	Upland	5	0.5	19.8	21.2	1.4	7.1	2.5	
	GB	109	10.2	21.9	20.6	-1.3	-5.9	0.9	

(Category 1 species only. Probability (P) is based on paired t-test * <0.1, ** <0.01, *** <0.001)

Figure 5.7 MAIN PLOT CLASSES IN LOWLAND GRASSLAND

Change in the frequency of the nine Main plot classes (MPC8 - 16), (derived from TWINSPAN analysis of the Main plots), from the 'lowland improved grassland' and 'lowland semi-improved grassland' categories, using only those plots which were in the same category in both 1978 and 1990, by landscape type

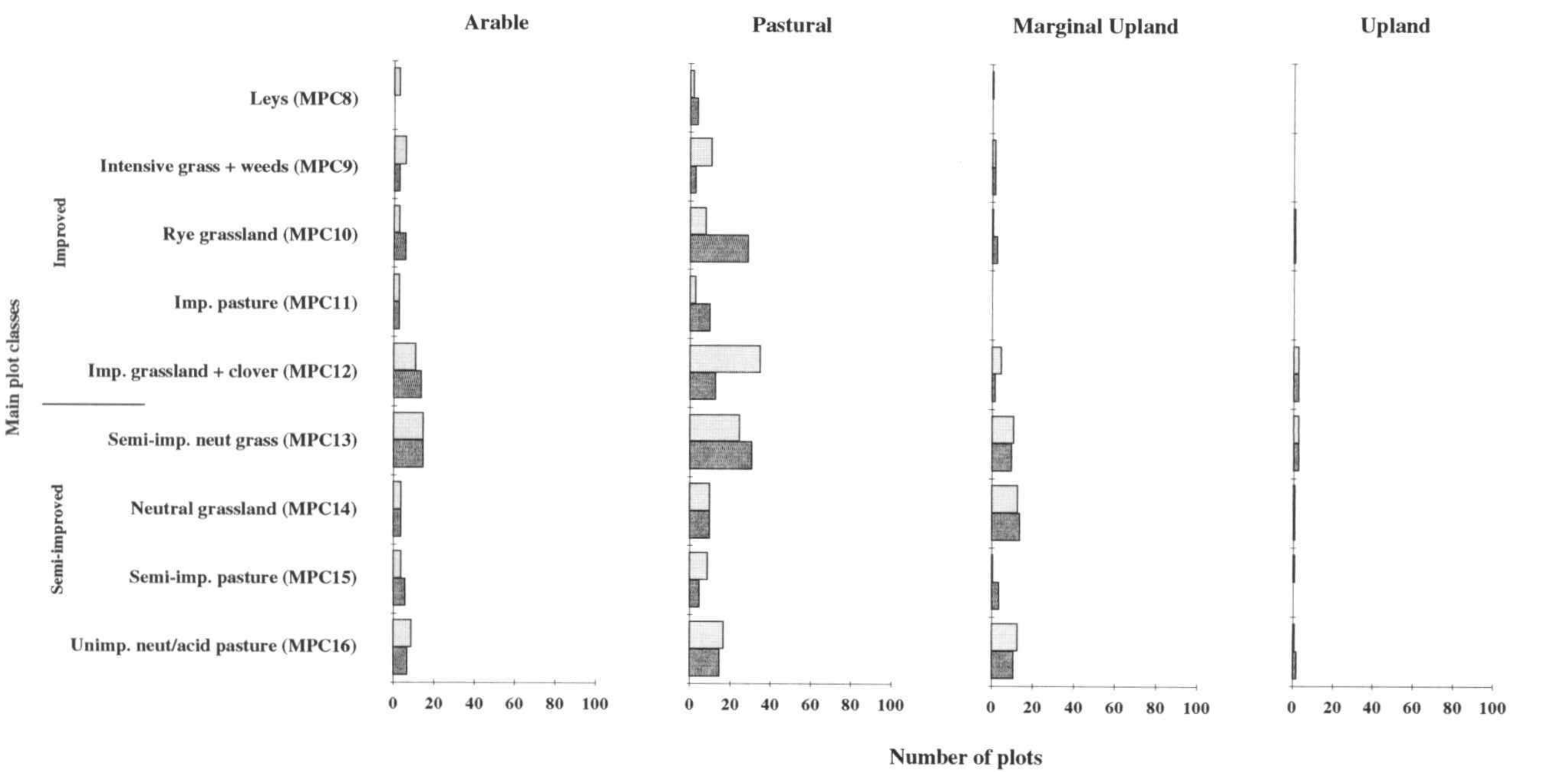


Table 5.8 Mean number of species per plot in **'lowland improved grassland'** (MPC8 - MPC12) and **'lowland semi-improved grassland'** (MPC13 - MPC16) in 1978 and 1990 (these grasslands did not occur in sufficient numbers in the upland landscape type for meaningful comparisons to be made)

Landscape type	Improved grassland 1978	Improved grassland 1990	Semi-improved grassland 1978	Semi-improved grassland 1990
Arable	9 8	8 7	21 5	20 3
Pastural	10 2	10 7	22 2	19 2
Marginal upland	13 9	13 3	22 2	23 8

Change in species number

5.2.32 Table 5 7 shows the change in mean species number from plots which were in 'lowland improved grassland' (MPC8–MPC12) or 'lowland semi-improved grassland' (MPC13–MPC16) categories in both 1978 and 1990 The only statistically significant change was a decline in species number in 'lowland semi-improved grassland' in the pastural landscapes

5.2.33 Table 5.8 shows the different trends in species number in the three landscape types. In 1978 the mean species number in the 'lowland improved grassland' category (MPC8–MPC12) was very similar in the arable and pastural landscapes, and was substantially lower than in the marginal upland landscapes. However, by 1990 the fields in the arable and pastural landscapes had diverged, so that those in arable landscapes were poorer in species. In the 'lowland semi-improved grassland' category (MPC13–MPC16), the fields in all three landscapes had very similar numbers of species in 1978, but by 1990 those in the marginal upland landscapes were nearly 25% richer than those in the pastural landscapes.

Change in species group

5.2.34 Figure 5.8 shows the change in the frequency of species, by species group, between 1978 and 1990, for plots which were in the 'lowland improved grassland' category (MPC8–MPC12) in both years. Annual weeds (SG30) have declined in all three landscape types.

5.2.35 Plots in the pastural landscapes show only small overall changes but data from plots in arable landscapes suggest that simplification has occurred over the period 1978–90, with some loss of 'old permanent pasture plants' (SG23) and 'improved permanent pasture plants' (SG25).

5.2.36 In the marginal upland landscapes there was a marked decline in 'improved permanent pasture plants' (SG25). The small increase in 'neutral/acid grassland plants' (SG12) and 'nutrient-poor grassland plants' (SG10) suggests that some of the fields had declined in fertility between 1978 and 1990.

5.2.37 Figure 5.9 is the equivalent diagram for plots which occurred in 'lowland semi-improved grassland' (MPC13–MPC16) in both years The three landscape types show quite different patterns. In the arable landscapes there were small gains and losses in many groups but there were no clear trends. However, in the pastural landscapes nearly all the species groups have declined, indicating that the loss in diversity has affected most plant species. The most pronounced decline was associated with 'base-rich meadow plants' (SG20) which includes many of the rarer grassland species. The arable and pastural landscape types show a consistent loss of diversity, as measured by the frequency of species groups, with most groups declining.

5.2.38 In the marginal upland landscapes there appear to be two separate trends : in the fields on more fertile soils there was an increase in 'improved permanent pasture plants' (SG25), but also in 'old permanent pasture plants' (SG23) On the less fertile soils and unenclosed areas there were both gains and losses, with an indication of a decline in 'enriched flush plants (SG11) and 'acid flush plants' (SG4).

Table 5.9 Change (1978–90) in the relative positions of the paired Main plots on the principal vegetation gradient (derived by TWINSPAN analysis) using only those plots which remained in the **'woodland'** category (MPC17–MPC21), by landscape type

Direction of change in woodland	Arable	Pastural	Marginal upland	Upland
Up[1]	6	36	33	29
Down[2]	18	28	22	0
Same[3]	77	36	44	71

[1]Percentage of plots that have moved up the principal gradient to more intensive plot classes
[2]Percentage of plots that have moved down the principal gradient to less intensive plot classes
[3]Percentage of plots that have remained in the same plot class

Figure 5.8 SPECIES GROUPS IN LOWLAND IMPROVED GRASSLAND

Change in the mean number of species for each of the 11 species groups (Table 5.3) characteristic of 'lowland improved grassland', (MPC8 - 12), by landscape type and using only those plots which were in the same category in both 1978 and 1990

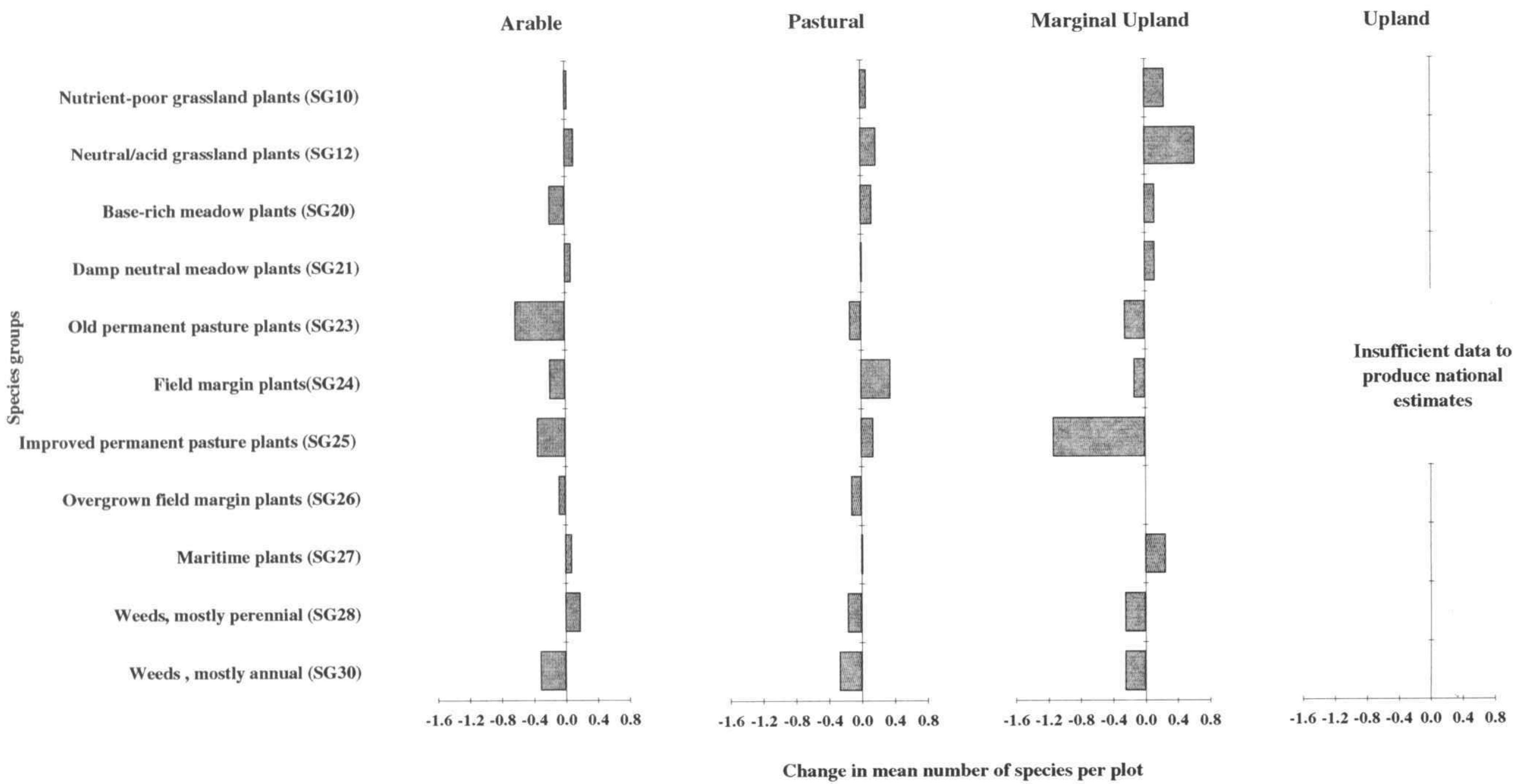


Figure 5.9 SPECIES GROUPS IN LOWLAND SEMI-IMPROVED GRASSLAND

Change in the mean number of species for each of the 27 species groups (Table 5.3) characteristic of 'lowland semi-improved grassland' (MPC13 - 16), by landscape type and using only those plots which were in the same category in both 1978 and 1990

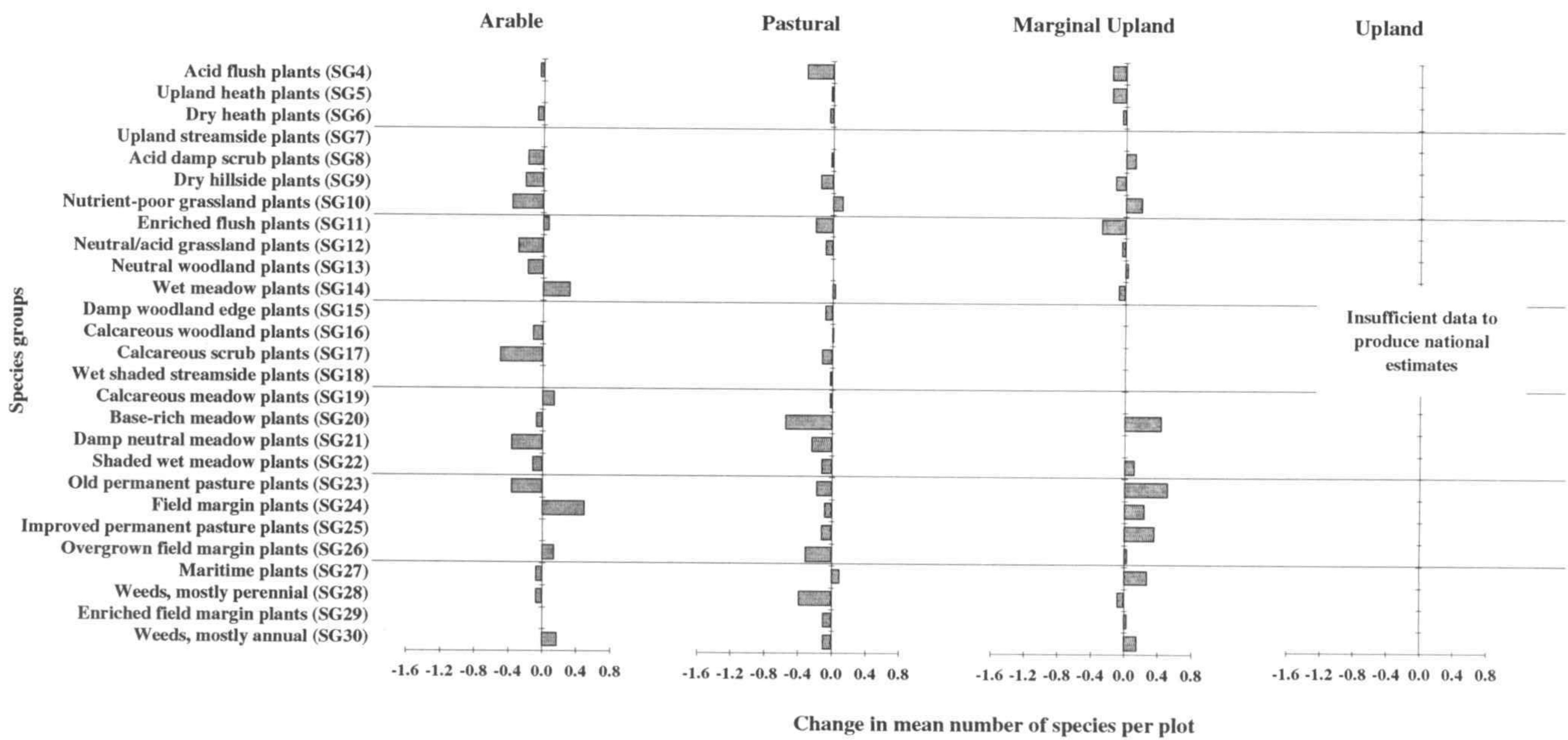


Figure 5.10 MAIN PLOT CLASSES IN WOODLAND

Change in the frequency of the five Main plot classes (MPC17-21), (derived from TWINSPAN analysis of the Main plots), from the 'woodland' category, using only those plots which were in the same category in both 1978 and 1990, by landscape type

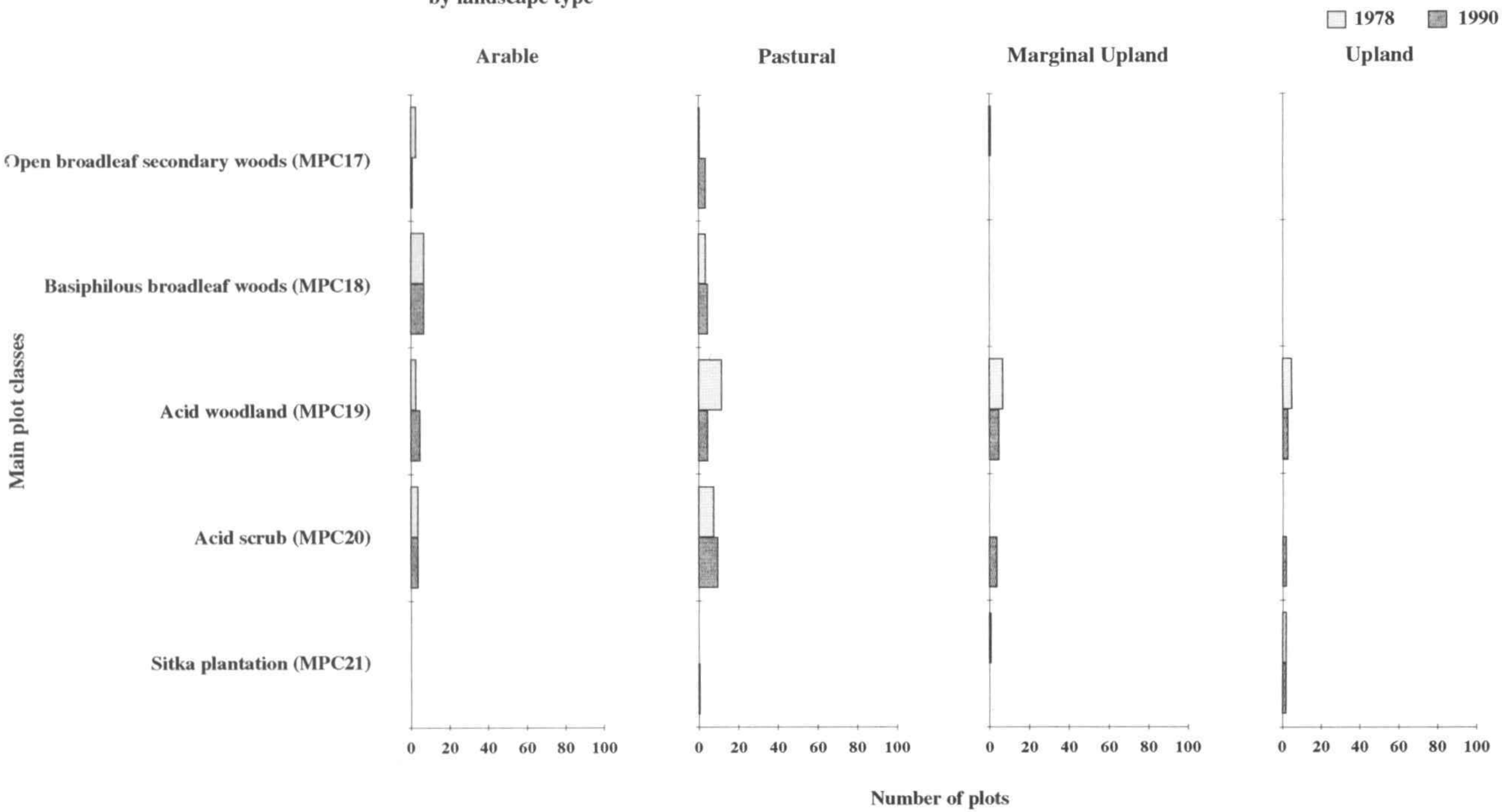


Table 5.10 Change (1978–90) in the species number recorded in paired plots that remained in the '**woodland**' category of plot classes (MPC17–MPC21), derived by TWINSPAN analysis, by the four landscape types and GB

Plot class category	Landscape type	No of plots	% of plots in GB	Mean species no 1978	Mean species no. 1990	Change in mean species no.	% change	SE of change	P
Woodland	Arable	17	1 6	14.9	16 0	1.1	7.1	3.5	
	Pastural	25	2 3	14 9	11 7	-3.2	-21 5	1.0	**
	Marginal upland	9	0 8	19.0	10.6	-8.4	-44.4	3 8	*
	Upland	6	0 6	19 8	12 5	-7.3	-37.0	3 6	*
	GB	57	5 3	16 1	12.9	-3.2	-19.9	1 4	*

(Category 1 species only Probability (P) is based on paired t-test * <0 1, ** <0 01, *** <0 001)

Woodland (MPC17–MPC21)

Changes between plot classes

5.2.39 Figure 5.10 shows the change in the proportion of plots in each of the five woodland classes (MPC17–MPC21). Since the classes were derived from analysis of both canopy species and ground flora data, it is not known whether such change is due to a change in management (leading to changes in canopy composition), or to more subtle changes in the ground flora because of other reasons, or both.

5.2.40 In the arable and pastural landscapes there was little change between the woodland types, although in the latter case there was a small increase in woodland overall In the marginal upland landscapes there were more extensive changes, eg an increase in 'acid scrub' (MPC20).

5.2.41 Table 5.9 shows the change in direction of movement of plots relative to the principal vegetation gradient. Plots in the arable landscapes have moved down this gradient (towards less intensive types), whereas there was movement in both directions in the pastural and marginal upland landscapes and, in the uplands, there was only movement up the gradient.

Change in species number

5.2.42 Table 5.10 shows the change in mean species number for plots which were in woodland in both years. It was expected that woodlands would remain relatively stable, since they are buffered against many processes affecting more open countryside, but the results show changes in species number in three of the four landscape types. Woodlands in arable landscapes show a small but statistically insignificant increase in species, whilst the other three landscapes all show a significant loss of species.

Change in species groups

5.2.43 Figure 5.11 shows the change in the frequency of species, by species group, between 1978 and 1990 for plots that remained as woodland in both years In woods in the arable landscapes, there was no clear pattern, with both gains and losses in species groups. Woods in arable and pastural landscapes showed an increase in 'field margin plants' (SG24) and a decrease in 'calcareous scrub plants' (SG17) and 'neutral woodland plants' (SG13). Woods in the marginal upland landscapes showed the largest losses, with all but one of the species groups represented having declined: this was in line with the overall species loss (Table 5.10). There was a similar situation in the uplands, with a decrease in 'acid damp scrub plants' (SG8) and 'acid flush plants' (SG4).

Upland grass mosaics (MPC22–MPC25)

Change between plot classes

5.2.44 Figure 5.12 shows the change in the proportion of plots in each of the four plot classes in the 'upland grass mosaics'

Table 5.11 Change (1978–90) in the relative positions of the paired Main plots on the principal vegetation gradient (derived by TWINSPAN analysis) using only those plots which remained in the '**upland grass mosaics**' category (MPC22–MPC25), by landscape type

Direction of change in upland grass mosaics	Arable	Pastural	Marginal upland	Upland
Up[1]	NA	0	27	14
Down[2]	NA	27	9	14
Same[3]	NA	73	64	72

[1]Percentage of plots that have moved up the principal gradient to more intensive plot classes
[2]Percentage of plots that have moved down the principal gradient to less intensive plot classes
[3]Percentage of plots that have remained in the same plot class
NA Not applicable

Figure 5.11 SPECIES GROUPS IN WOODLAND

Change in the mean number of species for each of the 23 species groups (Table 5.3) characteristic of 'woodland' (MPC17-21), by landscape type and using only those plots which were in the same category in both 1978 and 1990

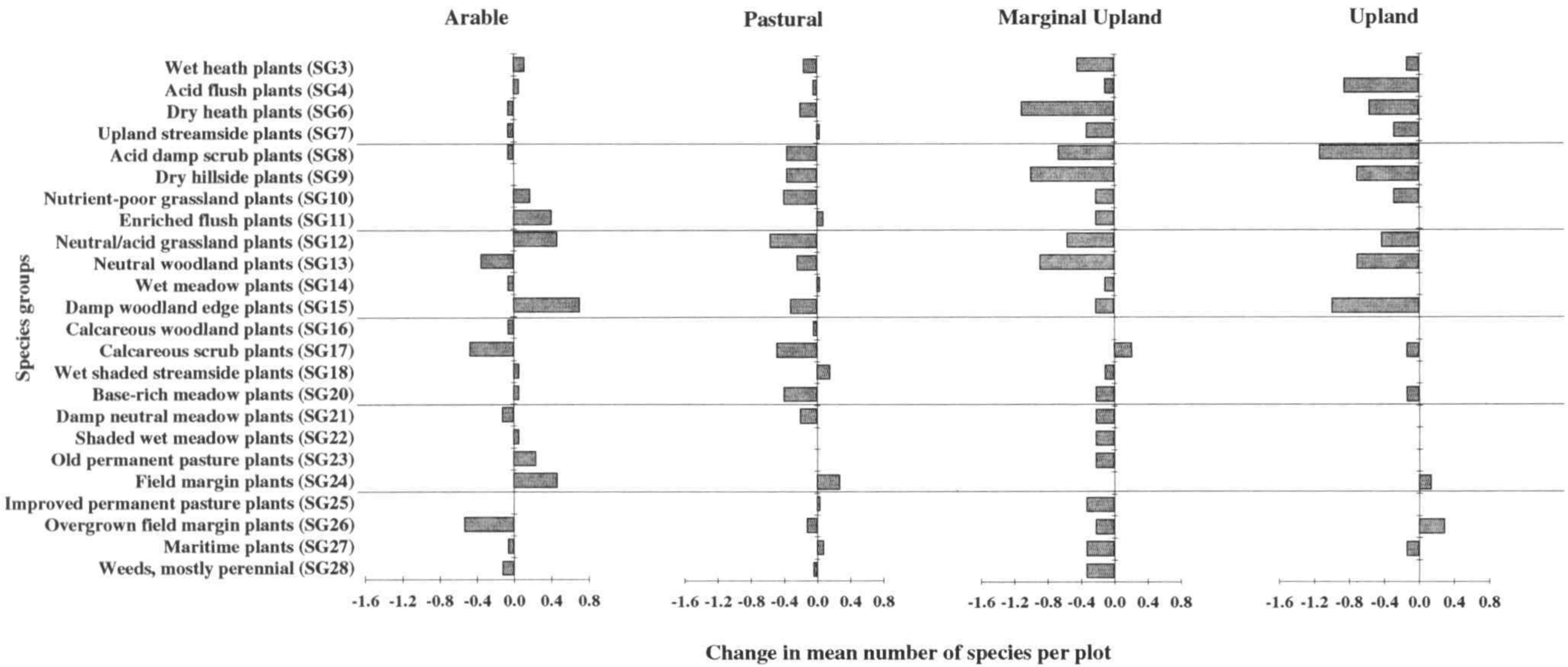


Figure 5.12 MAIN PLOT CLASSES IN UPLAND GRASS MOSAICS

Change in the frequency of the four Main plot classes (MPC22 - 25), (derived from TWINSPAN analysis of the Main plots), from the 'upland grass mosaics' category, using only those plots which were in the same category in both 1978 and 1990, by landscape type

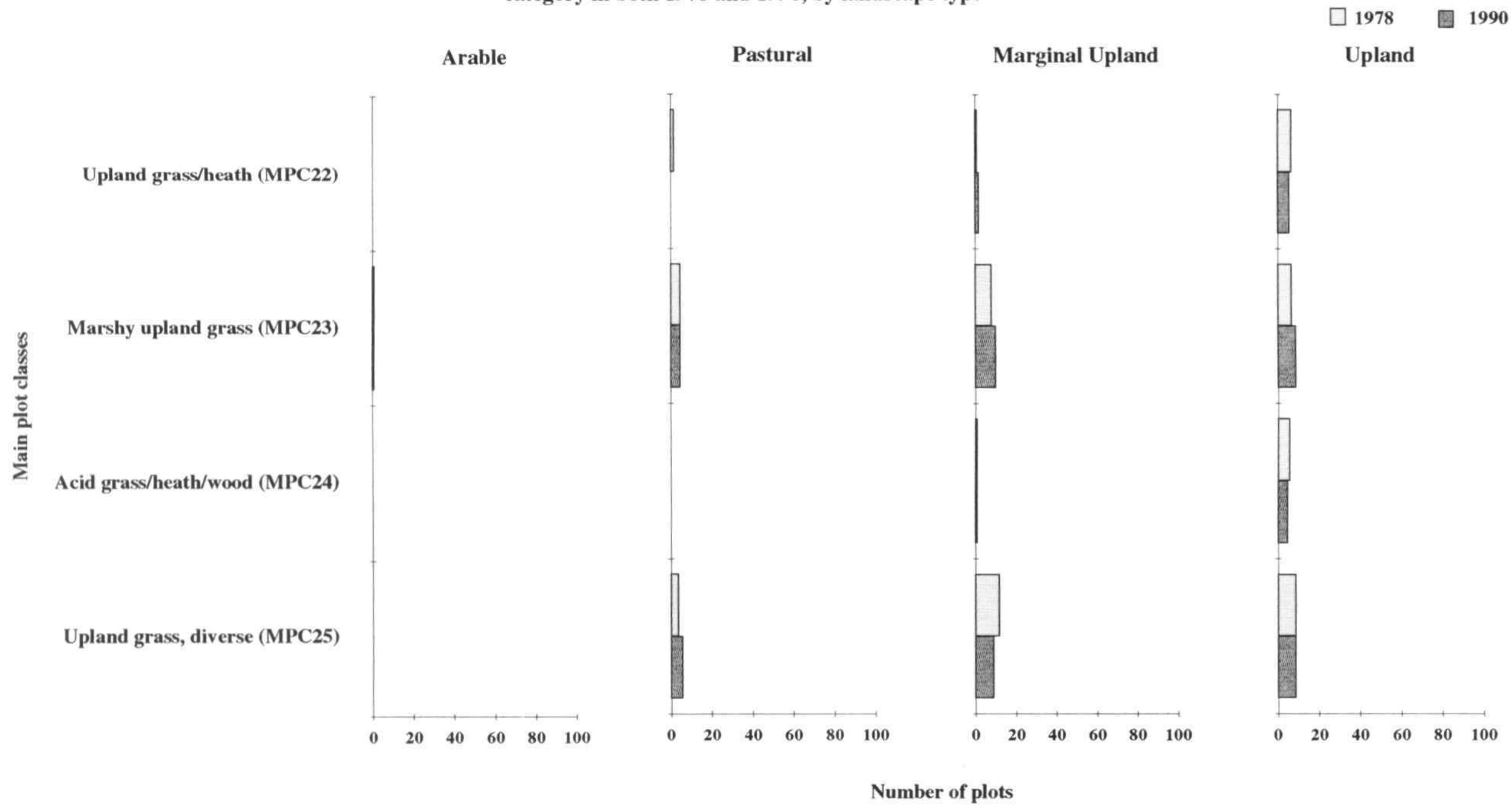


Table 5.12 Change (1978–90) in the species number recorded in paired plots that remained in the **'upland grass mosaics'** category of plot classes (MPC22–MPC25), derived by TWINSPAN analysis, by landscape type and GB

Plot class category	Landscape type	No of plots	% of plots in GB	Mean species no. 1978	Mean species no 1990	Change in mean species no	% change	SE of change	P
Upland grass mosaics (MPC22 -MPC25)	Pastural	11	1.0	25.9	22.1	-3.8	-14.7	2.1	
	Marginal upland	22	2.1	18.4	19.0	0.6	3.2	1.9	
	Upland	29	2.7	25.1	26.8	1.7	6.7	2.0	
	GB	63	5.9	23.2	23.4	0.2	1.0	1.2	

(Category I species only. Probability (P) is based on paired t-test: * <0.1, ** <0.01, *** <0.001)

category (MPC22–MPC25), by landscape type. In the pastural landscapes the plots were stable, whilst in the marginal upland landscapes there was a small decrease in the 'upland grass, diverse' class (MPC25) and small increases in the other three classes. In the upland landscapes there was little net change.

5.2.45 The difference in the direction of changes occurring in each landscape type can be simplified by considering the proportion of plots which have moved towards the intensive end of the principal gradient, as opposed to those which have moved to the extensive end; this is illustrated in Table 5.11. The majority of plots were stable, with pastural landscapes showing movement towards less intensively managed vegetation, and marginal upland landscapes moving in the opposite direction.

Change in species number

5.2.46 Table 5.12 shows the change in mean species number from plots which were in the 'upland grass mosaics' category (MPC22–MPC25) in both 1978 and 1990. None of the landscape types show a statistically significant change in species number, although the trend was for a decrease in the pastural landscapes and a slight increase in the marginal upland and upland landscapes.

Change in species groups

5.2.47 Figure 5.13 shows the change in the frequency of species in species groups in plots in the 'upland grass mosaics' category. In the pastural landscapes there has been some loss of 'old permanent pasture plants' (SG23) from the fields on neutral soils, as well as 'upland heath plants' (SG5) and 'dry heath plants' (SG6). In contrast, in the marginal upland landscapes there has been some increase in 'neutral/acid grassland plants' (SG12) and a loss of 'enriched flush plants' (SG11), 'acid flush plants' (SG4) and 'bog plants' (SG2). In the upland landscapes, there was an increase in 'acid flush plants' (SG4) and 'upland heath plants' (SG5).

Moorland (MPC26–MPC29)

Change between plot classes

5.2.48 Figure 5.14 shows the change in the proportion of plots in each of the four moorland plot classes (MPC26–MPC29). There were only a few examples of these types from the pastural landscapes, but these were relatively stable. However, in the marginal upland landscapes there has been a decline in the two most upland categories (MPC28 – 'dwarf shrub heath' and MPC29 – 'bog') and an increase in the least upland category (MPC26 – 'boggy moorland'), ie a shift down the principal gradient. In the upland landscapes there was also an increase in 'boggy moorland' (MPC26) and a decrease in 'bog' (MPC29). The majority of plots were stable, although more plots in the upland landscape type moved up the gradient than moved down, in contrast to plots in the pastural and marginal upland landscapes, where the reverse was true (Table 5.13).

Change in species number

5.2.49 Table 5.14 shows the change in species number for the plots which were in the

Table 5.13 Change (1978–90) in the relative positions of the paired Main plots on the principal vegetation gradient (derived by TWINSPAN analysis), using only those plots which remained in the **'moorland'** category (MPC26–MPC29), by landscape type

Direction of change in moorland	Landscape type: Arable	Pastural	Marginal upland	Upland
Up[1]	NA	7	18	21
Down[2]	NA	14	21	13
Same[3]	NA	79	61	66

[1]Percentage of plots that have moved up the principal gradient to more intensive plot classes
[2]Percentage of plots that have moved down the principal gradient to less intensive plot classes
[3]Percentage of plots that have remained in the same plot class
NA Not applicable

Figure 5.13 SPECIES GROUPS IN UPLAND GRASS MOSAICS

Change in the mean number of species for each of the 24 species groups (Table 5.3) characteristic of 'upland grass mosaics', (MPC22 - 25), by landscape type and using only those plots which were in the same category in both 1978 and 1990

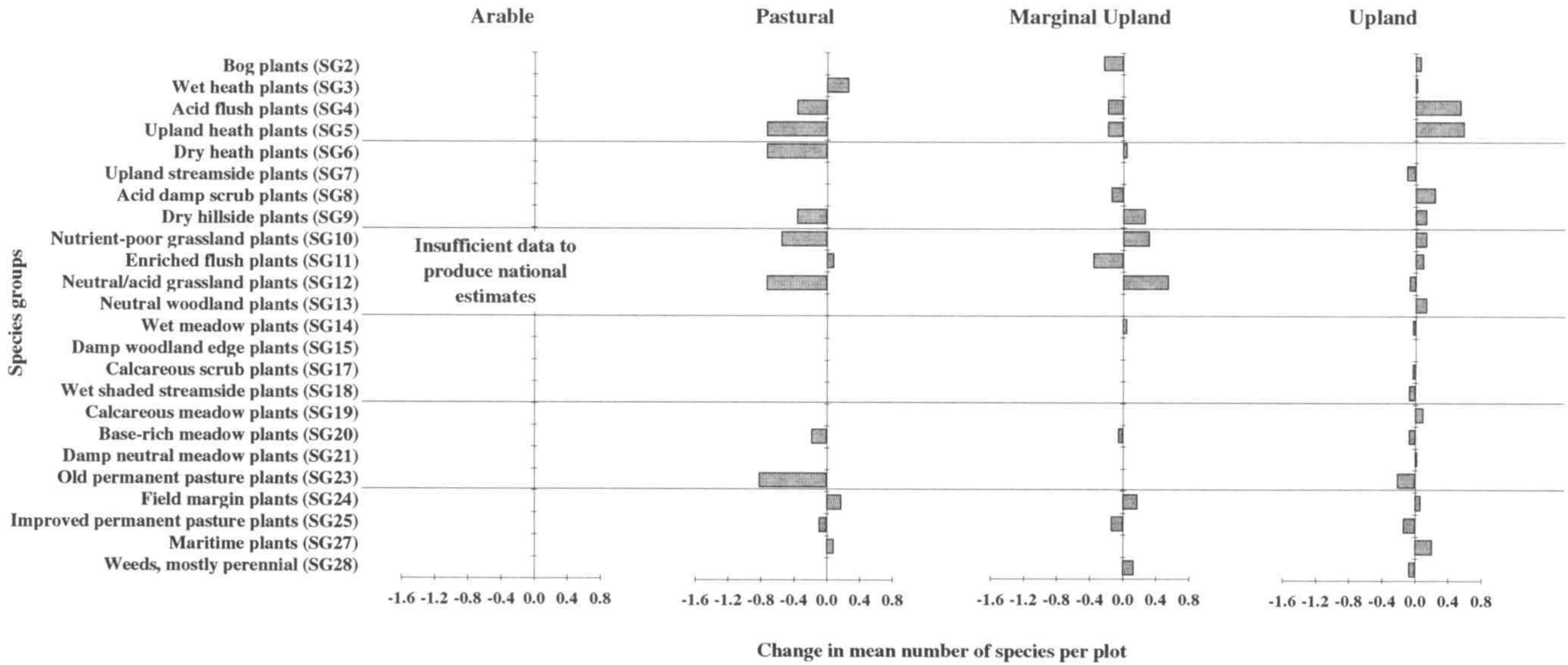


Figure 5.14 MAIN PLOT CLASSES IN MOORLAND Change in the frequency of the four Main plot classes (MPC26 - 29), (derived from TWINSPAN analysis of the Main plots), from the 'moorland' category, using only those plots which were in the same category in both 1978 and 1990, by landscape type

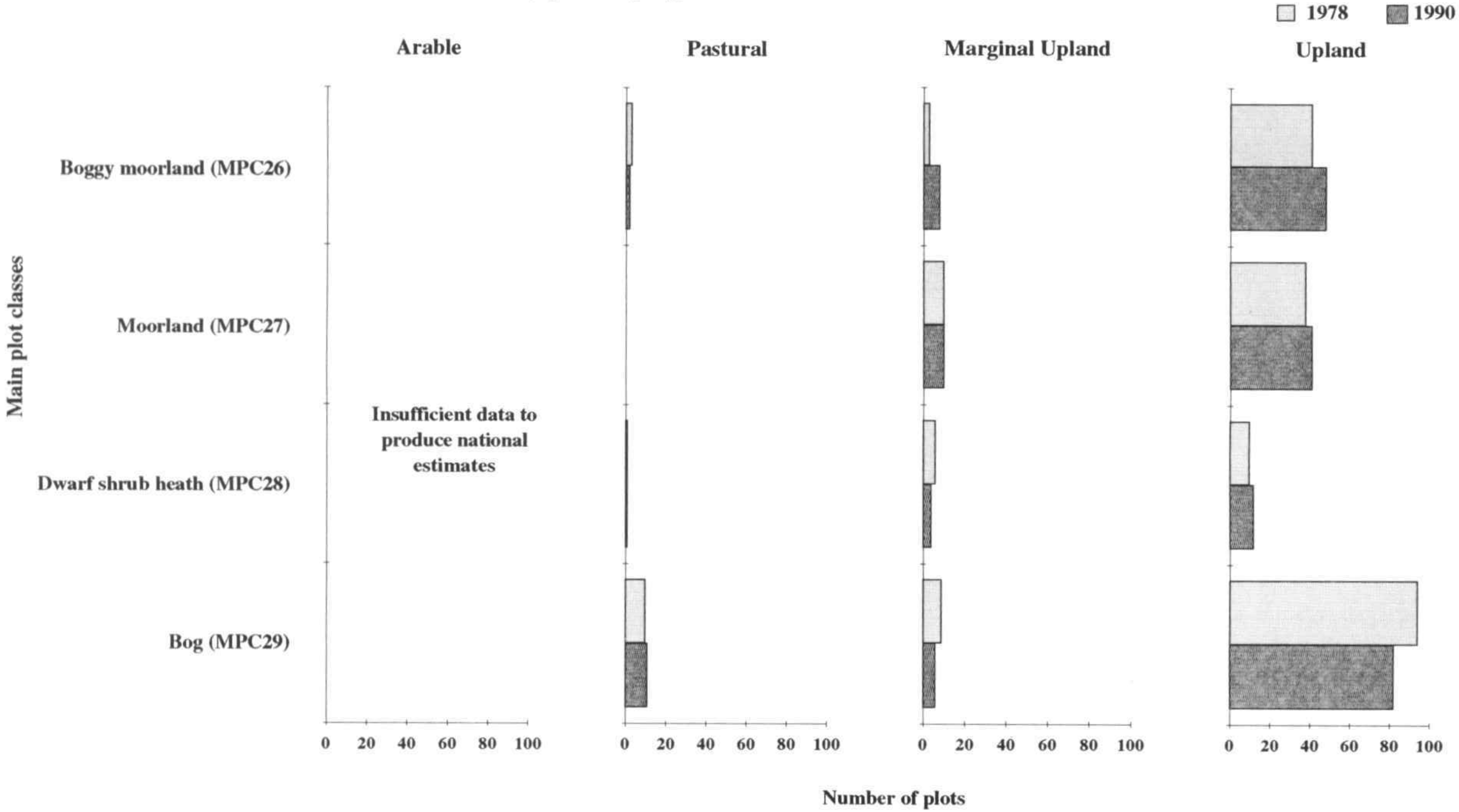


Table 5.14 Change (1978–90) in the species number recorded in paired plots that remained in the '**moorland**' category of plot classes (MPC26–MPC29), derived by TWINSPAN analysis, by landscape type and GB

Plot class category	Landscape type	No. of plots	% of plots in GB	Mean species no. 1978	Mean species no. 1990	Change in mean species no	% change	SE of change	P
Moorland	Pastural	14	1 3	15 6	12.1	-3.4	-22 0	1.1	**
(MPC26–	Marginal upland	28	2 6	12.4	16 3	3.9	31 7	1 3	**
MPC29)	Upland	183	17 1	18 9	20 2	1.3	6 6	0 6	*
	GB	230	21 5	17.7	19.0	1 4	7.8	0 5	**

(Category 1 species only. Probability (P) is based on paired t-test * <0.1, ** <0.01, *** <0.001)

'moorland' category in both 1978 and 1990. Both marginal upland and upland landscapes show a significant increase in species number, in contrast to the pastural landscapes where the species number has declined. Moorland habitats are inherently species-poor, so the increase in species number might indicate invasion by non-moorland species, implying a change in ecological character.

Change in species groups

5.2.50 Figure 5.15 shows the change in the frequency of species in species groups for these 'moorland' plots. In the pastural landscapes there was a loss of 'bog pool plants' (SG1) and 'bog plants' (SG2). In contrast, plots from the marginal upland and upland landscapes show increases in most groups; this suggests that whilst some of the increase in species number in these landscapes was of typical moorland species (SG1–SG3), in other cases it was due to invasion by species more typical of acid grassland (SG5–SG7). The largest increase in the upland landscapes was in species associated with acid flushes (SG4), which form an integral part of many moorlands.

Main plots: conclusions

5.2.51 Within the **arable landscapes** the overall trend has been one of reduction in diversity of vegetation, except in woodland. This loss in diversity was particularly marked in the arable fields, reflecting improved crop management and the use of herbicides and fertilizers. The loss in diversity reflects an overall decline in an already depleted resource; the species showing most decline were mainly widespread weeds in cultivated fields. The losses in semi-improved grassland are more significant in that they represent a reduction in the stock of an already restricted group of species. The loss of diversity in fields means that, in many areas, linear features provide the only remaining source of meadow species and, as such, provide an important but limited resource of plant diversity which could expand in response to suitable management practices.

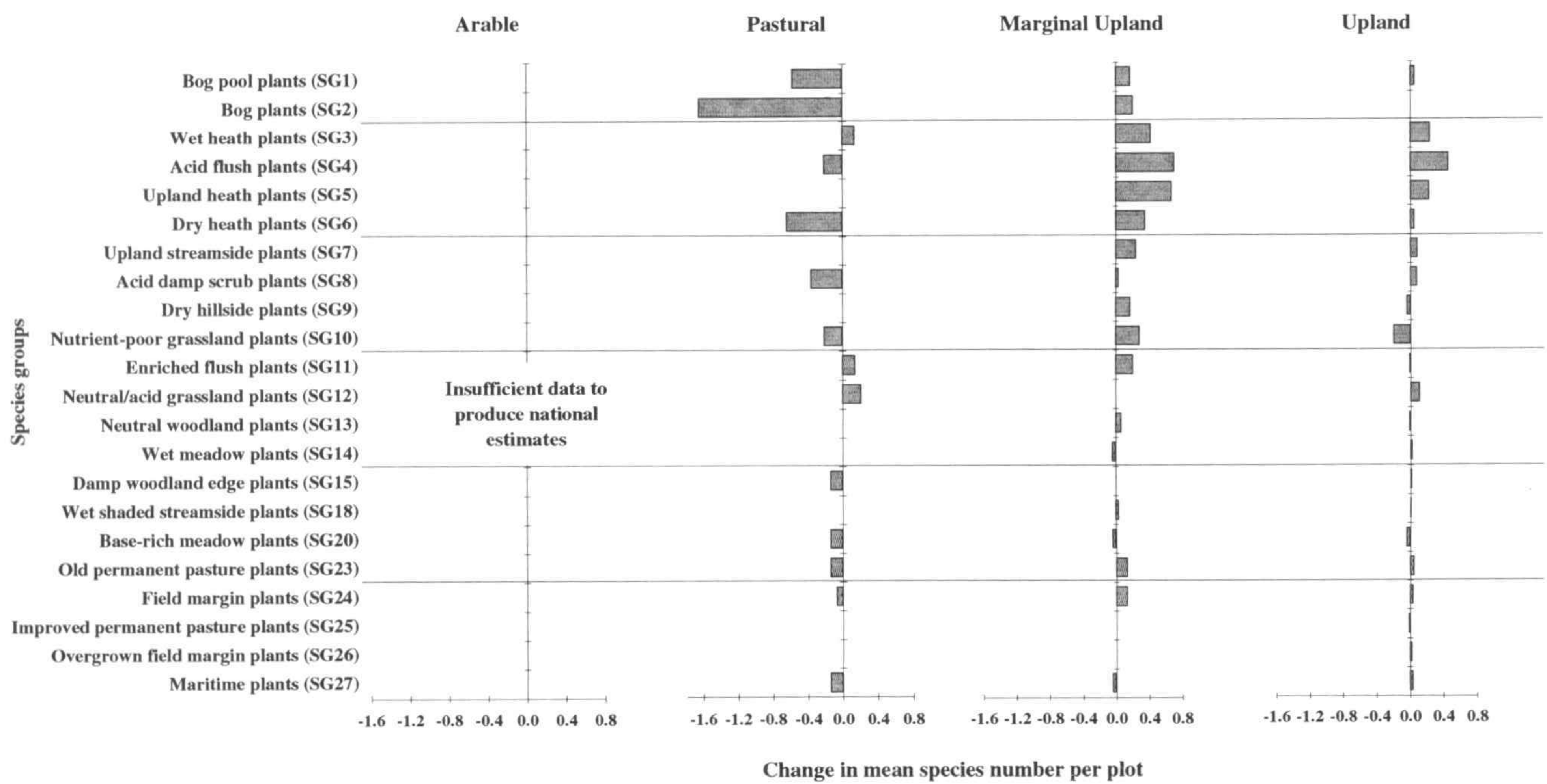
5.2.52 In the **pastural landscapes**, the loss of plant diversity has been greater in grassland than in arable fields. The loss of quality in grassland reported here supports the results of work by Hopkins and Wainwright (1989). Although the overall loss of species was higher in pastural landscapes than in arable landscapes, the proportional loss was lower because of the higher initial complement. However, the species declining include those which are already nationally scarce, ie those associated with unimproved meadows, which are intolerant of frequent disturbance and are unable to compete successfully against more vigorous species, except on infertile soils.

5.2.53 In the **marginal upland landscapes** there appears to be some polarisation between changes in the enclosed fields, and the unenclosed land. In the enclosed fields, losses and gains in diversity were taking place simultaneously. More detailed analysis of management on farms will be required to examine the cause of these changes. The unenclosed areas were more stable, although moorland shows a trend towards an increase in the number and range of species, indicating a negative effect on the integrity of the moorland habitat.

5.2.54 In comparison with the other landscape types, the **upland landscapes** appear stable, confirming the conclusions of the analysis of the land cover data (Chapter 3). The most obvious changes result from afforestation. There was some indication of a quality change in moorland with an increase in species number and a trend away from the most extreme types of upland vegetation.

Figure 5.15 SPECIES GROUPS IN MOORLAND

Change in the mean number of species for each of the 22 species groups (Table 5.3) characteristic of 'moorland' (MPC26 - 29), by landscape type and using only those plots which were in the same category in both 1978 and 1990



5.2.55 These changes in moorlands may be related to differences in grazing regimes. Grazing pressure has changed in different ways in different parts of the uplands over the 1978–90 period; for example, stocking levels for sheep have decreased in the Outer Isles (Watson 1988), but increased over much of the mainland, whilst deer grazing has increased considerably in most of Scotland (see Bunce *et al.* (1993) for further discussion). Change in moorland vegetation may also be an indirect result of afforestation through impact on catchment hydrology. The identification of the processes involved requires further survey and analysis.

5.2.56 It was expected that woodland would be relatively stable, since it is generally thought to be buffered against many of the changes affecting farmland and moorland. However, the results show that in the pastural, marginal upland and upland landscapes there has been an overall decline in species number within woodland but an increased proportion of species associated with disturbed grassland. Further study is required to determine the processes causing these changes (eg nitrogen loading, as described by Pitcairn *et al.* (1991)).

5.2.57 The upland grass mosaics were the most stable category of plot classes and the only significant change in land use in the uplands was afforestation. However, the increase in the number and type of species recorded in plots on moorland and bogs is noteworthy because, as Usher (1991) has emphasised, the diversification of inherently species-poor ecosystems represents ecological degradation.

5.2.58 The overall movement of plots in relation to the principal gradient is summarised in Table 5.15. This emphasises how much more stable the uplands were compared to the other landscape types, with over 50% of plots remaining in the same plot class. All four landscapes show a net change towards more intensively managed vegetation but this varies from 8% of plots in the uplands to 11% in the marginal upland landscapes, 27% in the pastural landscapes and 29% in the arable landscapes.

Table 5.15 Change in the relative positions of the 1978 and 1990 paired Main plots on the principal vegetation gradient (derived by TWINSPAN analysis) using plots from all categories (MPC1–MPC29), by landscape type

Direction of change	Landscape type Arable	Pastural	Marginal upland	Upland
Up[1]	48	49	36	27
Down[2]	19	22	25	18
Same[3]	34	29	36	55

[1]Percentage of plots that have moved up the principal gradient to more intensive plot classes
[2]Percentage of plots that have moved down the principal gradient to less intensive plot classes
[3]Percentage of plots that have remained in the same plot class

5.3 Habitat plots

5.3.1 In 1990, five 4 m^2 **Habitat plots** were recorded in each 1 km square, within semi-natural vegetation, in order to sample those scarce and fragmented habitats not covered by the randomly located Main plots. Because these plots were not recorded in 1978, no change data are available but the Habitat plots provide a baseline for monitoring future trends in such vegetation. Some habitats, eg lowland heath and saltmarsh, were so restricted that the sample was only slightly increased; in these cases, the only way to increase coverage would be to increase the sample size or specifically target these types of habitats (this is now being undertaken as part of the DOE 'Changes in Key Habitats' project). Whilst able to give a measure of the relative abundance of the habitats concerned, information from Habitat plots cannot be used in a statistical sense to estimate relative frequency of habitats.

5.3.2 Figure 5.16 shows the distribution of habitats sampled in this way, in each landscape type (these Habitat plots were grouped according to their dominant land cover code – as described in Chapter 3). There was a clear division between the lowland and upland landscapes. In the lowlands most of the plots were placed in fields of agricultural and unmanaged grassland, with quite a high proportion in woodland. In the uplands the emphasis was on unenclosed vegetation, especially diverse bogs and flushes, and upland grass. More information on the species present in the Habitat plots (as opposed to the randomly placed Main plots) will be available when these groups are analysed in more detail.

5.3.3 Comparisons of the relative occurrence of the five random (200 m^2) Main plots with the five (4 m^2) Habitat plots within the four landscape types are given in Figure 5.17.

5.3.4 In the arable landscapes the main coverage of the random Main plots was of crops and weed species in arable fields, whereas the

S

Figure 5.16 HABITAT PLOT CLASSES IN GB

Percentage frequency of Habitat plots in the twelve principal Habitat types in 1990, by landscape type

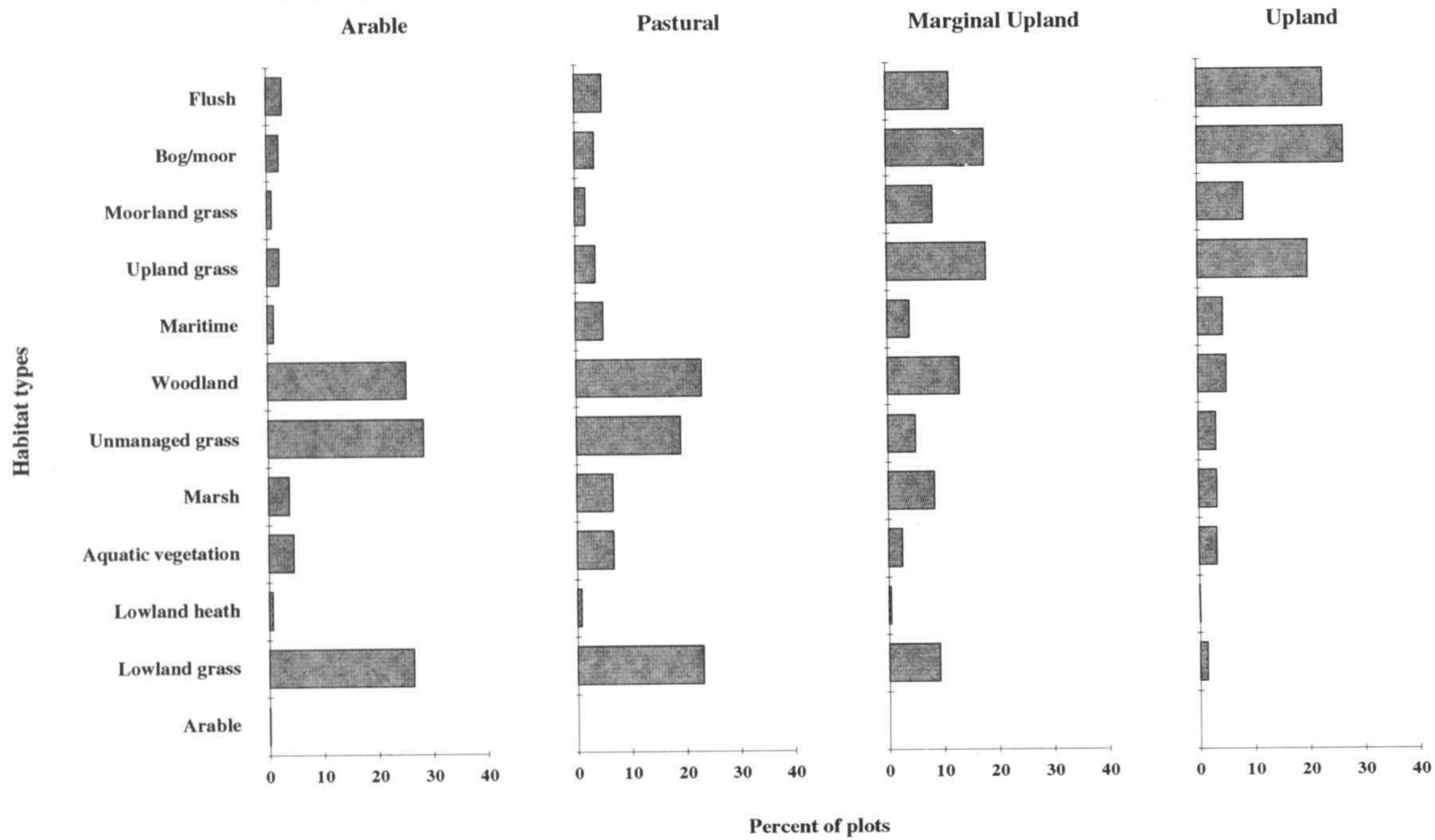
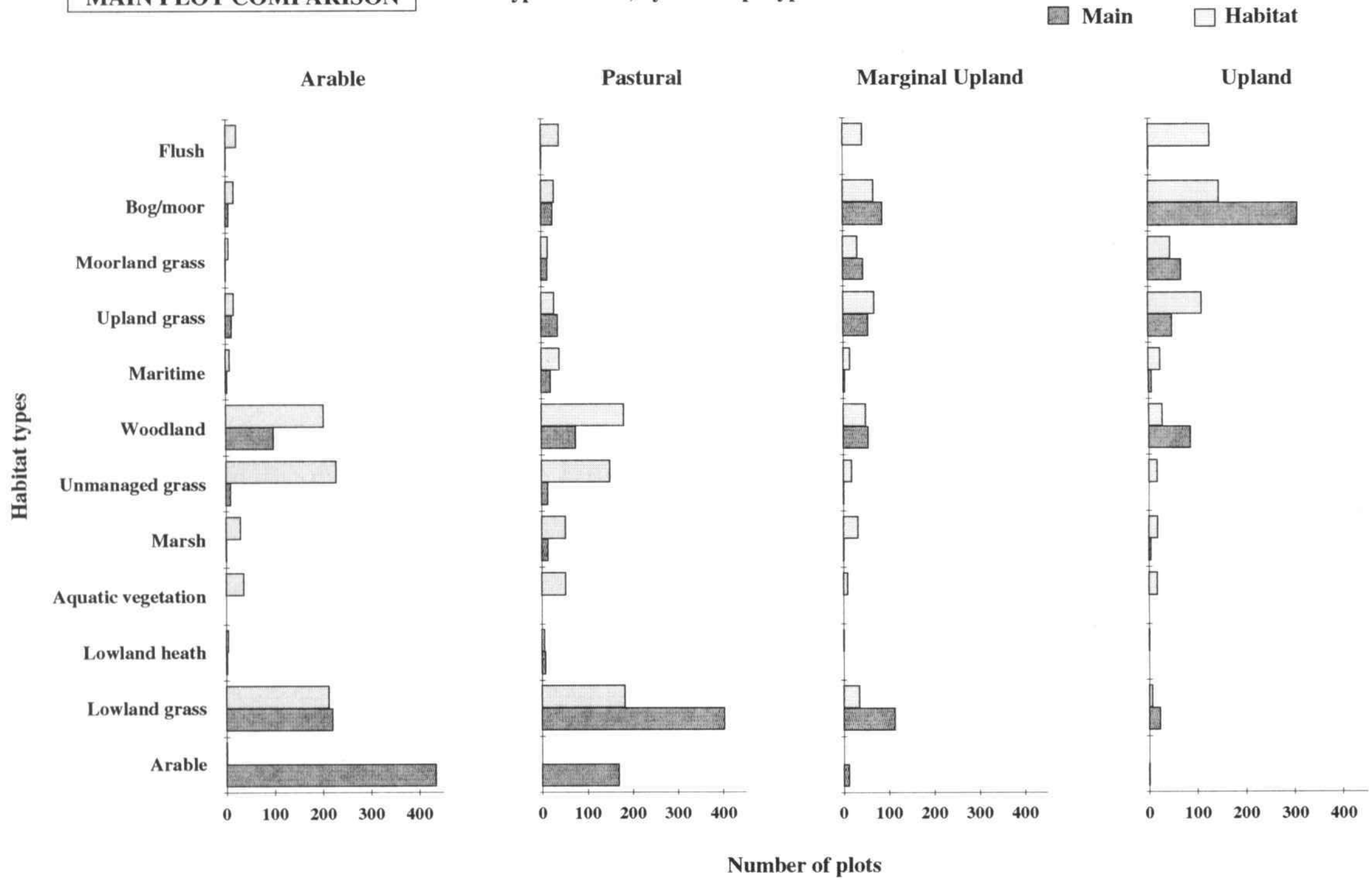


Figure 5.17 HABITAT AND MAIN PLOT COMPARISON Comparison of the relative frequency of Habitat plots and Main plots in the twelve principal Habitat types in 1990, by landscape type



Habitat plots are mainly in 'lowland grassland', 'unmanaged grassland' and 'woodland'.

5.3.5 In the pastural landscapes the random Main plots cover a greater range of vegetation than in the arable landscapes, but the Habitat plots extend the number of samples in woodland and unmanaged grass, together with less common habitats, such as marshes, flushes and aquatic margins.

5.3.6 In the marginal upland landscapes semi-natural vegetation was more widespread and was therefore well covered by the random Main plots. The Habitat plots extend the number of samples into some restricted habitats, such as marshes, unmanaged grassland and flushes.

5.3.7 In the upland landscapes, the random Main plots give good coverage of most of the moorland vegetation, but the Habitat plots add more samples of flushes and the more species-rich parts of the upland grassland. They also add to smaller and scarcer habitats such as marshes and maritime vegetation.

5.3.8 The Habitat plots double the coverage of woodland and greatly extend the number of plots placed in unmanaged grassland, as well as adding many more in lowland agricultural grassland. Further breakdown of these types may reveal that more diverse types, eg chalk grassland, were more frequently sampled by Habitat plots and that many more species were recorded, on average, in the Habitat plots, compared to Main plots. In addition, the Habitat plots have extended the coverage of other scarce habitats, such as marshes and heath.

Table 5.16 Frequency of total Hedge plots placed along hedgerows in 1990 from both targetted Hedge plots and those Boundary plots that were hedgerows, by landscape type

Landscape type	Hedge plots	Boundary (hedge) plots	Total hedge plots
Arable	268	200	468
Pastural	255	168	423
Marginal upland	410	18	59
Upland	0	0	0
Total GB	564	386	950

5.4 Linear features – Hedge plots

5.4.1 As outlined in Chapter 2, there were two types of plot which contributed data on hedgerows: the first of these were plots placed on boundaries adjacent to Main plots (Boundary plots – see section 2.3.11), some of which were adjacent to hedgerows; the second type were plots targeted specifically at hedgerows (Hedge plots – see 2.3.11).

5.4.2 Analysis of the numbers of different types of plots enables the landscape types to be compared. Table 5.16 presents the occurrence of Hedge plots in linear features and those Boundary plots which were adjacent to hedgerows, in each landscape and in Britain as a whole. The plots targetted on hedgerows over-sample hedges in 1 km squares where there is a limited hedgerow resource (because two Hedge plots were always placed, irrespective of the total length of hedgerow).

5.4.3 Considering boundaries other than hedgerows, Table 5.17 presents information on the types of boundary sampled by Boundary plots placed (being linked to the random 200 m^2 plots), and hence the frequency of different boundary types. The eight boundary types in Table 5.17 are based on the dominant boundary element. These data reproduce the results from the land cover mapping reported in Chapter 4.

5.4.4 A high proportion of field boundaries in the arable landscapes were fences, hedges and water edges. In a national context, the arable landscapes contained most instances where road verges and grass strips formed the field boundary.

5.4.5 Fences account for an even higher proportion of boundaries in pastural landscapes than in arable ones. Hedges and to a lesser extent walls were also common. Most of the banks occurring as boundaries were also in these areas.

5.4.6 In the marginal upland landscapes, fences were again the most common type of field

Table 5.17 Frequency of eight boundary types recorded in the Boundary plots placed adjacent to Main plots in 1990 by the four landscape types

Landscape type	Hedge	Fence	Wall	Water	Grass strip	Bank	Verge	Other	Total
Arable	199	268	39	130	24	15	79	8	762
Pastural	167	331	81	41	12	43	23	16	714
Marginal upland	18	126	51	8	0	2	5	1	211
Upland	0	84	28	6	0	0	2	0	120
Total GB	384	809	199	185	36	60	109	25	1807

Table 5.18 Classification of Hedge plots based on woody species present in hedgerows, after Cummins *et al* (1992)

Number	Name/Description	Short name
WSC1	Mostly planted non-native spp	Mostly non-native
WSC2	Wild privet present	Wild privet present
WSC3	Beech dominant	Beech
WSC4a	Hawthorn dominant	Hawthorn
WSC4b	Mixed hawthorn	Mixed hawthorn
WSC4c	Elder/Hawthorn	Elder/Hawthorn
WSC5a	Willow or rose dominant	Willow or rose
WSC5b	Mixed hazel predominant	Mixed hazel
WSC6	Blackthorn predominant	Blackthorn
WSC7	Elm predominant	Elm
WSC8	Gorse dominant	Gorse

Table 5.19 Classification of Hedge plots based on ground flora species, after Cummins *et al* (1992)

Number	Name/Description	Short name
HG1	Arable cropland	Arable
HG2	Other intensively managed ground (mainly lowland)	Intensive grass
HG3	Rough grazings and less intensively managed grasslands	Pasture
HG4	Woodland vegetation	Woodland

boundary, with a higher proportion of walls than in the lowlands. In the upland landscapes there were few boundaries of any type: 70% of Boundary plots recorded were alongside fences, with most of the rest being walls. No hedges were recorded in these upland landscapes.

5.4.7 Detailed analyses of the Hedge plots, including those Boundary plots that were adjacent to hedgerows, are given in 'Diversity in British Hedgerows' (Cummins *et al.* 1992) – which also contains more detail specific to hedgerows, eg individual species and cover information. Data used in that report are presented here in relation to the four landscape types.

Hedge plots: stock in 1990

5.4.8 The Hedge plots were classified in two ways, both using TWINSPAN, based on:

i woody species present in the hedge (WSC1–WSC11, as shown in Table 5.18); and

ii. the associated ground flora (HG1–HG4, as shown in Table 5.19).

5.4.9 Figure 5.18 shows the frequency of the 11 'woody species classes' (WSC) for three landscape types. This demonstrates the dominance of hawthorn hedgerows in each of the three landscapes where hedgerows occurred. Blackthorn was abundant in the lowland landscapes, but less so in the marginal upland landscapes. The proportion of mixed hazel hedges increased from arable, through pastural to marginal upland landscapes, whilst elm hedges were restricted to the lowlands, and gorse hedges to the pastural landscapes.

5.4.10 Figure 5.19 shows that in arable landscapes the 'arable' ground flora class (HG1) was most frequent. Also well represented was 'intensive grass' (HG2). In pastural landscapes most hedge ground floras belonged to the 'intensive grass' class (HG2), but 'arable' (HG1), 'woodland' (HG4) and 'pasture' (HG3) classes were also abundant. This shows that in the lowlands hedges represent an important reservoir of woodland and meadow species. Hedges were less common in the marginal upland landscapes; of those that do occur, 'woodland' (HG4) and 'pasture' (HG3) were the most frequent ground flora types, with a few examples of 'intensive grass' (HG2).

Hedge plots: change between 1978 and 1990

5.4.11 The analysis of change for hedges was based on the 251 Hedge plots sampled in 1978 and reliably relocated and recorded in 1990.

5.4.12 Of these paired Hedge plots, 63 (25%) no longer had a hedge present in 1990, in eight sites (3%) the last hedge in the whole 1 km square had been 'lost'. The overall loss due to total removal (as opposed to boundary replacement, or change) was 19%. The losses were approximately proportional to the abundance of the type in 1978, ie there was no indication that loss was related to hedge type, either in terms of woody species or ground flora (see Figures 5.18 & 5.19).

5.4.13 The changes in the proportion of plots in hedge ground flora classes (Figure 5.20) showed a distinct shift towards the 'arable' class (HG1), in both arable and pastural landscapes. In the marginal upland landscapes there was a minor trend away from the 'woodland' class (HG4) towards 'intensive grass' (HG2).

5.4.14 Table 5.20 shows that the only significant change in species number is a loss of species, in the pastural landscapes.

5.4.15 Figure 5.21 shows the changes in the frequency of species groups recorded in

Figure 5.18 HEDGE PLOT CLASSES : WOODY SPECIES OF LOST HEDGES Frequency and proportion of the Hedge plots in the eleven Hedge types (WSC1-8), (derived from TWINSPAN analysis of the woody species), lost between 1978 and 1990, by landscape type

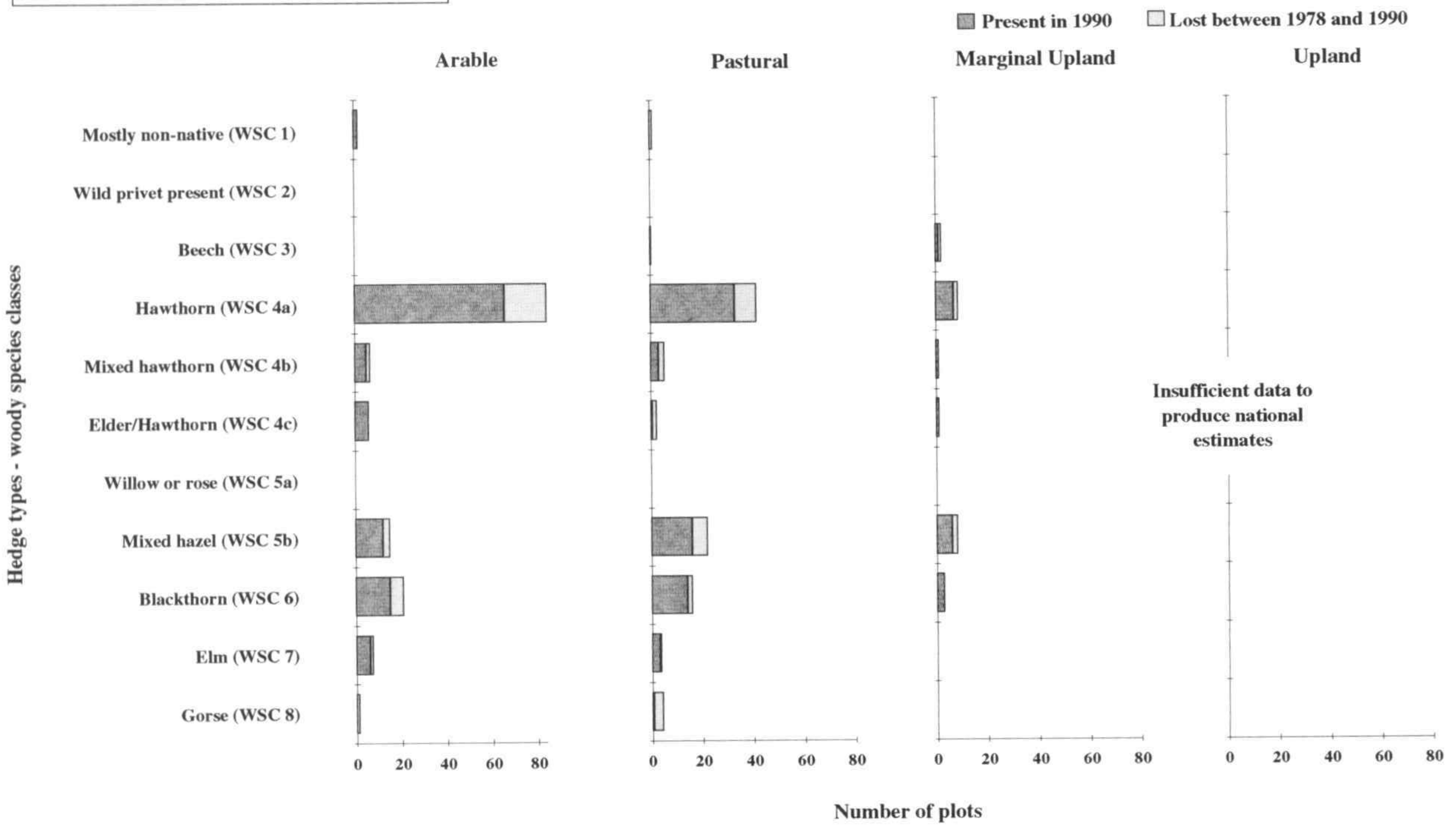


Figure 5.19 HEDGE PLOT CLASSES : GROUND FLORA OF LOST HEDGES

Frequency and proportion of Hedge plots in the four Hedge types (HG1-4), (derived from TWINSPAN analysis of the ground flora), lost between 1978 and 1990, by landscape type

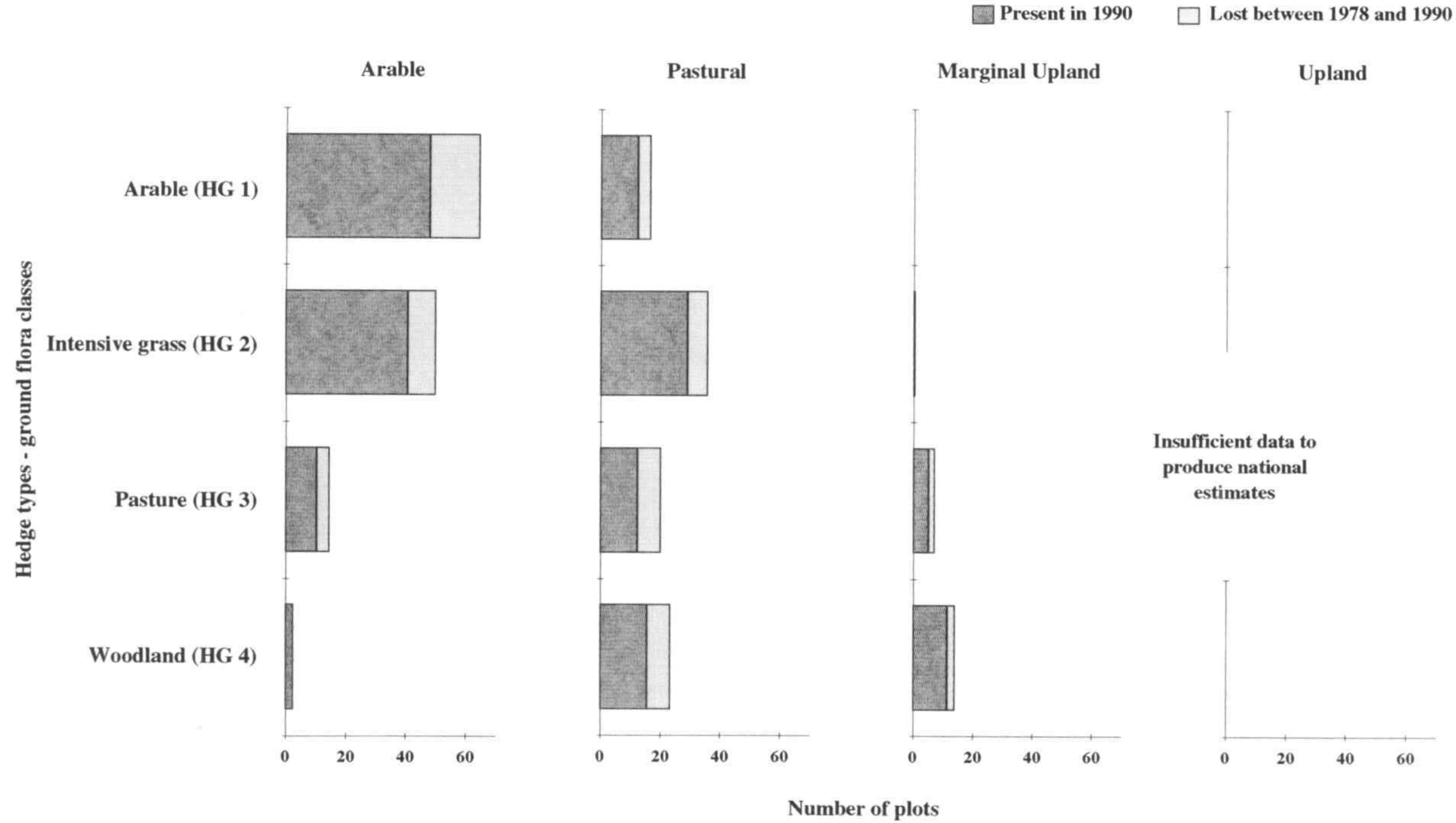


Figure 5.20 HEDGE PLOT CLASSES : CHANGE IN GROUND FLORA Change in the frequency of Hedge plots in the four Hedge types (HG1-4), (derived from TWINSPAN analysis of the Hedge plots recorded along hedgerows in both 1978 and 1990), by landscape type

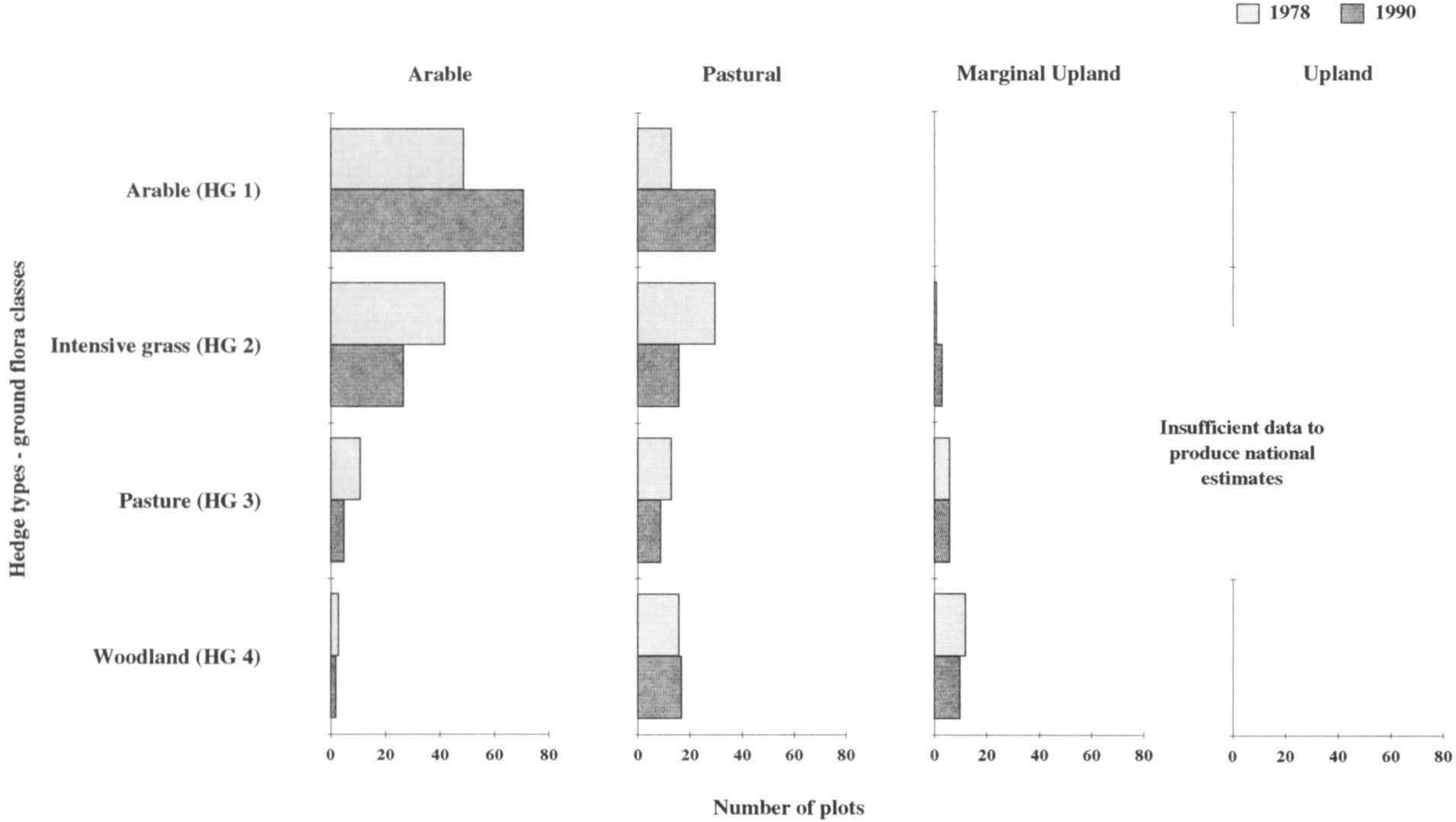


Figure 5.21 SPECIES GROUPS IN HEDGES

Change in the mean number of species by species group and by landscape type, using plots recorded along hedges, in both 1978 and 1990

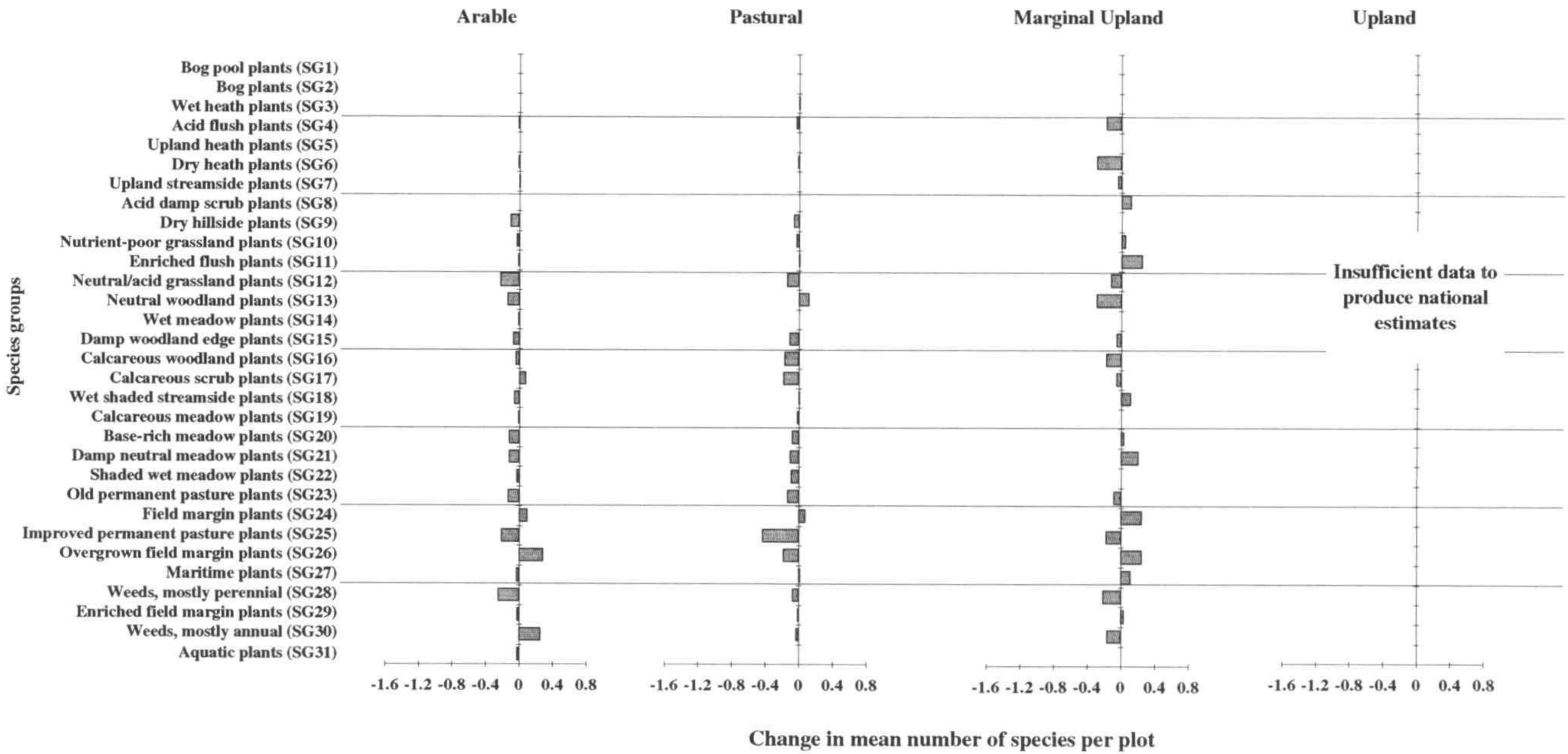


Table 5.20 Change (1978–90) in species numbers recorded in paired plots placed along hedgerows, by landscape type

Landscape type	No of plots	Mean species no 1978	Mean species no 1990	Change in mean species no	SE of change	P
Arable	116	11.0	10.2	-0.8	0.6	
Pastural	111	14.6	13.1	-1.5	0.6	*
Marginal upland	24	17.0	17.5	0.4	1.3	
GB	251	13.1	12.2	-1.0	0.4	*

(Significance is based on paired t-test. Probability (P) * <0.1, ** <0.01, *** <0.001)

Hedge plots (these are the same species groups used for the Main plots – see Section 5.1.4). In the arable landscapes the woodland species groups and some of the grassland groups have declined; the gains imply disturbance (SG30 – 'weeds mostly annual' and SG24 – 'field margin plants') and lack of management (SG26 – 'overgrown field margin plants' and SG17 – 'calcareous scrub plants').

5.4.16 In the pastural landscapes most of the species groups have declined, particularly the 'improved permanent pasture plants' (SG25), but also most of the meadow, calcareous, woodland and scrub groups. This indicates that the potential of hedges to provide a reservoir of species for future recolonisation has declined in these pastural landscapes. The marginal upland landscapes show more variability, with some indication of an increase in species which respond positively to higher nutrient levels (SG30, SG26, SG24).

Hedge plots: conclusions

5.4.17 Hawthorn hedges were the most frequent type found in all landscapes. Mixed hazel and blackthorn hedges were also common, especially in pastural landscapes.

5.4.18 The ground flora associated with hedges varied between landscapes. 'Arable' (HG1) and 'intensive grass' (HG2) ground flora classes were dominant in arable landscapes. 'Woodland' (HG4) and 'pasture' (HG3) ground flora classes were more important in pastural and marginal upland landscapes.

5.4.19 A quarter of the Hedge plots recorded in 1978 were no longer recorded as hedges in 1990. The loss of Hedge plots affected all classes of hedge equally. The remaining hedges continued to hold a high species diversity (10–17 species per plot), though there was a trend towards ground floras associated with more intensive land management.

5.4.20 A significant loss of species was recorded for Hedge plots in pastural landscapes (from 15 to 13 species per plot).

5.4.21 In arable and pastural landscapes there were increases in the numbers of Hedge plots in the 'arable' (HG1) ground flora class and decreases in 'intensive grass' (HG2) and 'pasture' (HG3) classes. In marginal upland landscapes there were slight increases in 'intensive grass' (HG2) and decreases in 'woodland' (HG4) classes. These changes represent an overall shift to more intensively managed vegetation.

5.5 Linear features – Verge plots

5.5.1 Verge plots were recorded as 10 m x 1 m plots adjacent to the edge of roads or tracks, starting at the interface between soil and tarmac. Where the verge was more than 2 m wide (from the edge of the road to 1 m from the centre of the next feature), additional species were recorded in a second 10 m x 1 m plot, parallel to the first (these data were not included in the TWINSPAN analysis from which the verge classes were derived).

5.5.2 In each 1 km square, two plots (which had previously been recorded in 1978) were randomly located and three further plots (new in 1990) were targetted to ensure coverage of the different categories of roads and tracks present. These categories were:

- 'A' and 'B' class roads, including dual carriageways – these were referred to as **main** roads in this report (motorway verges were not recorded);
- other tarmac roads – referred to as **minor** roads;
- constructed tracks and non-tarmac roads – referred to as **tracks**.

5.5.3 Table 5.21 shows the distribution of Verge plots by landscape type and road category. The arable landscapes had more main roads than any other type, whereas the pastural landscapes were dominated by minor roads. Marginal uplands had similar numbers of plots along both minor roads

Table 5.21 Verge plots recorded in 1990 in each road category, in each landscape type

Landscape type	Main roads	Minor roads	Tracks	Total
Arable	276	251	250	777
Pastural	192	353	184	729
Marginal upland	67	92	94	253
Upland	52	30	107	189
GB	587	726	635	1948

and tracks, and the uplands were dominated by the latter category.

5.5.4 A total of 1948 Verge plots were recorded from 394 1 km squares throughout GB in 1990. In order to describe this vegetation, the species data from all these plots (plus data from 359 plots previously recorded in 1978) have been classified using the multivariate statistical technique, TWINSPAN, to create eight 'Verge plot classes' (VPCs). These have been given short descriptive names to aid presentation of the results, as shown in Table 5.22.

Verge plots: stock in 1990

5.5.5 Figure 5.22 shows the distribution of plots between Verge plot classes, for those plots recorded in the same location in both 1978 and 1990 only (paired plots), in each landscape type. There was a clear difference between the types of verge vegetation recorded in the lowlands (arable and pastural landscapes) compared with the marginal upland and upland landscapes.

5.5.6 Arable landscapes have relatively few shady verges adjacent to hedges or woods (VPC1), and no verges in the 'upland' class (VPC8). They have a high proportion of Verge plots in the 'overgrown grassy' (VPC2) and 'overgrown eutrophic' (VPC3) classes, which were dominated by rank tussocky grasses like *Arrhenatherum elatius* (false oat grass). 'Overgrown eutrophic' verges (VPC3) were the most common type overall; this class included competitive tall herbs, like *Urtica dioica* (stinging nettle) and *Anthriscus sylvestris* (cow parsley).

Table 5.22 Classification of Verge plots into Verge plot classes

Verge plot class	Name/Description	Short name
VPC1	Shaded verges, next to hedges or woods	Shaded
VPC2	Overgrown grassy verges, with tall mesotrophic herbs and tussocky grasses, locally disturbed	Overgrown grassy
VPC3	Overgrown eutrophic verges, with vigorous grasses and tall herbs, especially *Urtica dioica* (stinging nettles), often next to hedges	Overgrown eutrophic
VPC4	Mown grassy verges with some meadow species, lacking diversity	Mown grassy
VPC5	Mown weedy disturbed verges, lacking diversity	Mown weedy disturbed
VPC6	Diverse mesotrophic verges, often mown and disturbed, species-rich	Diverse mesotrophic
VPC7	Northern mown grassy verges, often on less fertile soils, species rich	Mown infertile
VPC8	Upland verges associated with acid grassland or moorland	Upland

5.5.7 The 'mown grassy' verges (VPC4) and 'mown weedy disturbed' verges (VPC5) both comprised short grassy swards dominated by species like *Lolium perenne* (rye grass) and *Dactylis glomerata* (cocks foot). The 'mown grassy' verges (VPC4) had some small herb species, eg *Plantago lanceolata* (ribwort plantain) and *Achillea millefolium* (yarrow), whilst the 'mown weedy disturbed' verges (VPC5) were characteristic of disturbed ground, and typically had ruderals colonising the bare patches, eg *Polygonum aviculare* (knotgrass), and *Matricaria matricarioides* (pineapple weed).

5.5.8 The 'diverse mesotrophic' class (VPC6) included some of the more species-rich verges, including herbs like *Centaurea nigra* (knapweed) and *Lathyrus pratensis* (meadow vetch). About 20% of plots in arable landscapes occurred in this category.

5.5.9 In the pastural landscapes there was a similar pattern, with more 'shaded' verges (VPC1) but fewer 'overgrown eutrophic' examples (VPC3).

5.5.10 In the marginal upland landscapes there was a higher proportion of 'mown fertile' verges (VPC7) and 'upland' verges (VPC8) which contained species associated with acid grassland and moorland. These areas also had the highest proportion of the 'diverse mesotrophic' verges (VPC6). The upland landscapes had a restricted range of Verge plot classes, as well as fewer verges overall. Many of them occurred where roads or tracks ran though unenclosed land and therefore were similar to the surrounding vegetation.

Road category

5.5.11 Figure 5.23 shows the relationship between road category and Verge plot class. In arable landscapes there was an even

Figure 5.22 VERGE PLOT CLASSES

Frequency of plots in 1978 and 1990 in the eight Verge plot classes (VPC1-8), (derived from TWINSPAN analysis of the plots recorded along verges in both 1978 and 1990), by landscape type

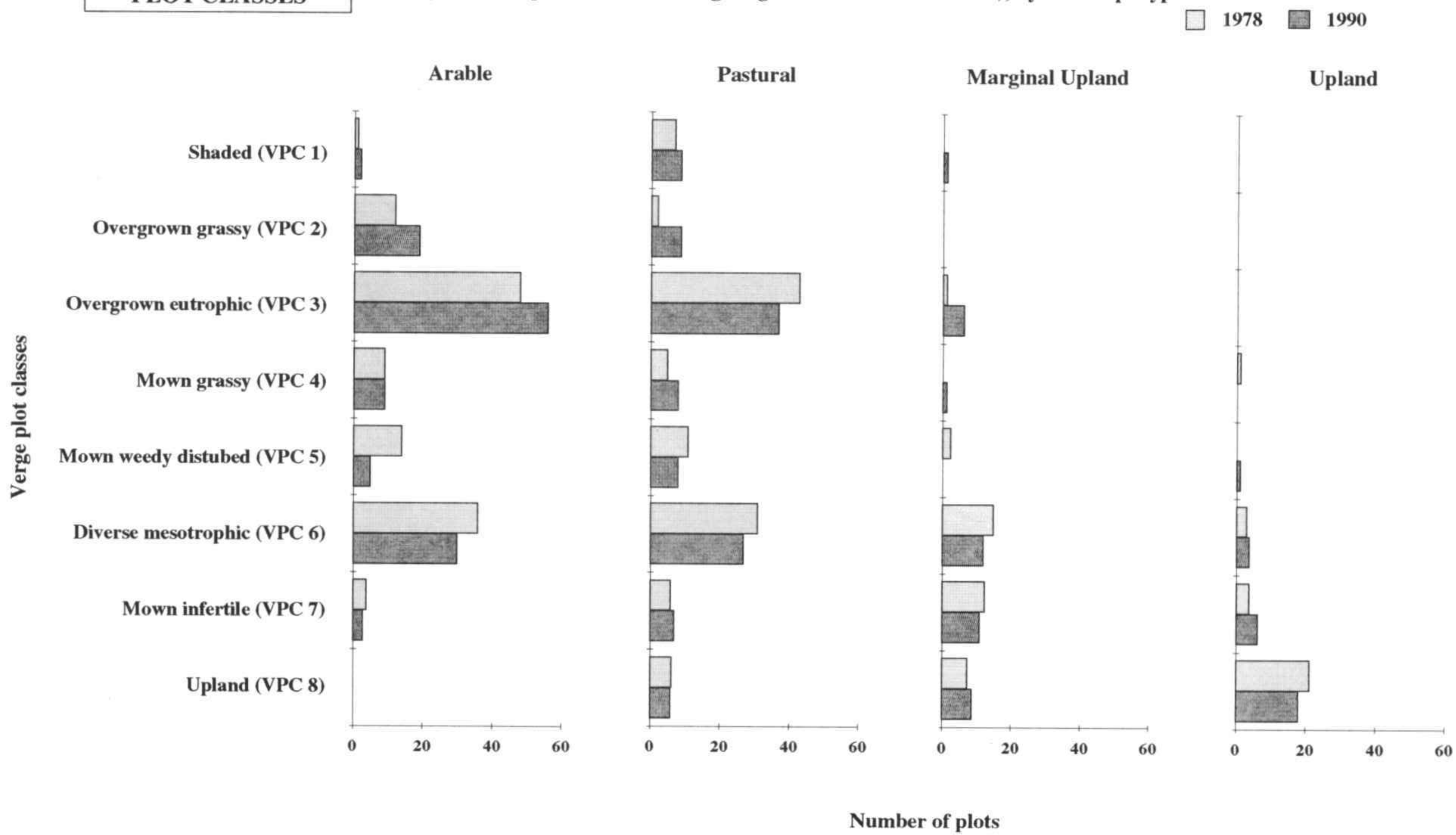
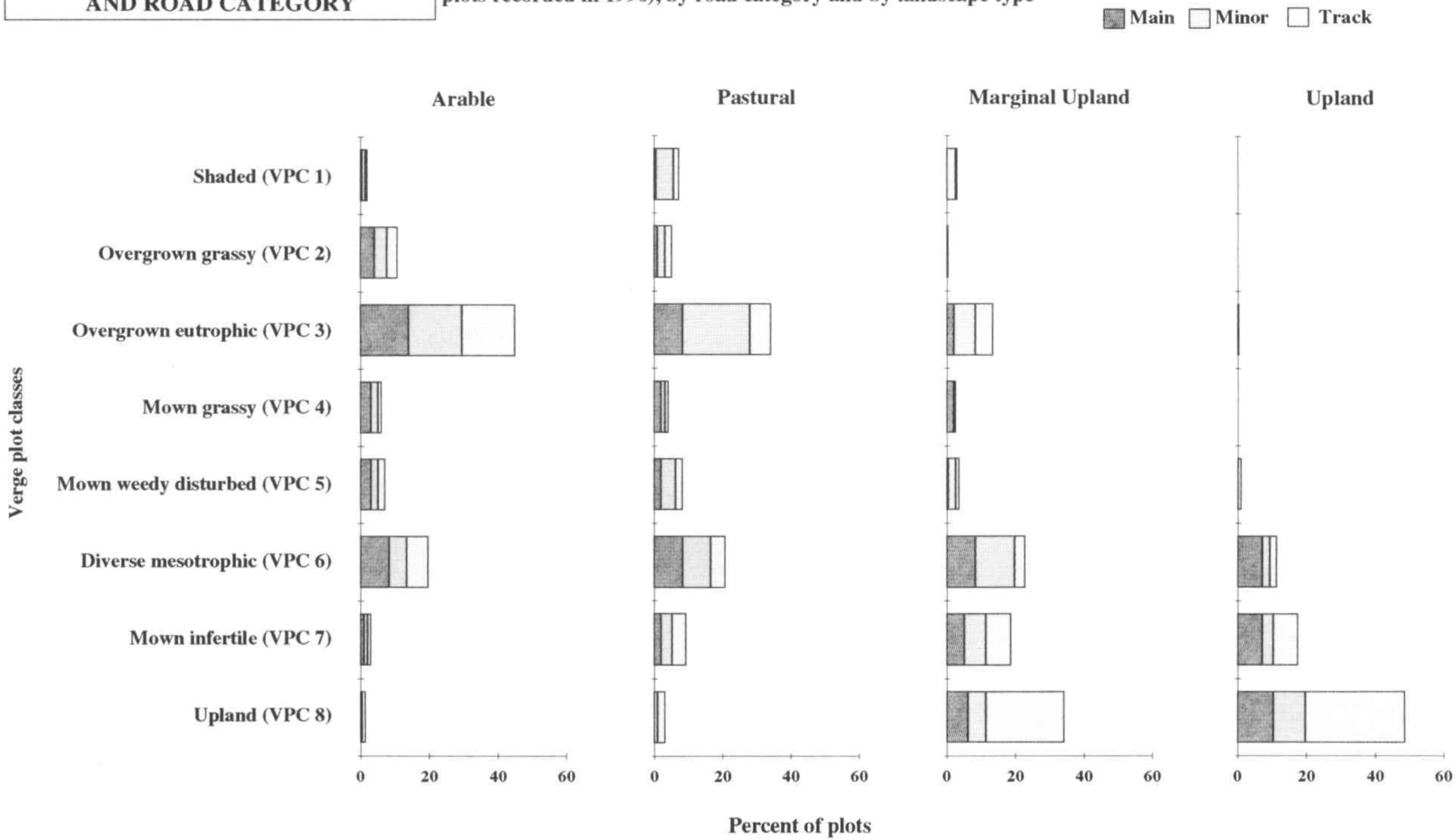


Figure 5.23 VERGE PLOT CLASSES AND ROAD CATEGORY

Percentage frequency of the eight Verge plot classes (VPC1 - 8), (derived from TWINSPAN analysis of the Verge plots recorded in 1990), by road category and by landscape type



distribution between road categories. 'Mown grassy' verges (VPC4), 'mown weedy disturbed' verges (VPC5) and 'diverse mesotrophic' verges (VPC6) were found more often on main roads, which may reflect more regular management regimes. 'Mown infertile' verges (VPC7) and 'upland' verges (VPC8) were more often found on minor roads and tracks.

5.5.12 In pastural landscapes the 'overgrown eutrophic' verges (VPC3) and 'shaded' verges (VPC1) were more frequent on minor roads. The 'diverse mesotrophic' verges (VPC6) were less common beside tracks.

5.5.13 In marginal upland landscapes also, the 'diverse mesotrophic' verges (VPC6) were less common beside tracks. Upland landscapes were dominated by 'mown infertile' verges (VPC7) and 'upland' verges (VPC8) which are characteristic of less fertile soils; they also had a limited representation of the more diverse types.

Wide verges

5.5.14 The species most often recorded as additional in the second 1 m plot are shown in Table 5.23. In the lowland and marginal upland landscapes these were largely tall competitive herbs, like *Urtica dioica* (stinging nettle), *Heracleum sphondylium* (hogweed) and *Anthriscus sylvestris* (cow parsley), but they also include tall meadow species, for example *Centaurea nigra* (knapweed). The varied structure of the wider verges is important in allowing the persistence of species unable to tolerate regular cutting, and in allowing meadow species to flower. These verges provide an important seed source for colonisation, as well as food sources and habitat for invertebrates, birds and small mammals.

Table 5.23 Frequency of the species most often found only in the second 1 m of Verge plots

Arable landscapes	% of plots	Pastural landscapes	% of plots
Urtica dioica	19	*Rubus fruticosus*	19
Galium aparine	18	*Urtica dioica*	19
Arrhenatherum elatius	15	*Galium aparine*	14
Rubus fruticosus	12	*Arrhenatherum elatius*	13
Heracleum sphondylium	10	*Heracleum sphondylium*	11
Anthriscus sylvestris	9	*Anthriscus sylvestris*	9
Rumex obtusifolius	9	*Cirsium arvense*	7
Holcus lanatus	8	*Holcus lanatus*	6
Lamium album	7	*Rumex obtusifolius*	6
Cirsium arvense	6		
Bromus sterilis	6		
Centaurea nigra	5		
Festuca rubra	5		
Marginal landscapes	**% of plots**	**Upland landscapes**	**% of plots**
Urtica dioica	14	*Juncus effusus*	10
Heracleum sphondylium	13	*Rumex acetosa*	10
Galium aparine	11	*Blechnum spicant*	7
Anthriscus sylvestris	9	*Urtica dioica*	7
Arrhenatherum elatius	9	*Galium saxatile*	7
Rubus fruticosus	9	*Calluna vulgaris*	6
Lathyrus pratensis	9	*Cerastium fontanum*	6
Cerastium fontanum	8	*Cirsium vulgare*	6
Cruciata laevipes	8	*Rubus fruticosus*	6
Veronica chamaedrys	8	*Rumex obtusifolius*	6
Rumex obtusifolius	8		

5.5.15 In the upland landscapes the vegetation in these plots differs in that many of them were alongside unenclosed roads and therefore have similar species to the surrounding upland vegetation.

Verge plots: change between 1978 and 1990

5.5.16 Analysis of change for the verge data was based on 304 paired plots from 167 squares throughout GB which were recorded in both 1978 and 1990. Data from these pairs of plots are used here to consider how verge vegetation has changed over this period.

5.5.17 Figure 5.22 shows the changes in the proportion of plots in the Verge plot classes. In the arable landscapes, there was an increase in the 'overgrown grassy' verges (VPC2) and the 'overgrown eutrophic' verges (VPC3), and a decrease in the 'mown weedy disturbed' verges (VPC5) and 'diverse mesotrophic' (VPC6) verges; the latter declined by 5%. In the pastural landscapes the changes were small, including an increase in the 'overgrown grassy' class (VPC2). Verges in the marginal upland landscapes showed a decline in the 'mown infertile' class (VPC7) and 'diverse mesotrophic' class (VPC6), and an increase in 'shaded' verges (VPC1) and 'overgrown eutrophic' verges (VPC3). Verges in the uplands were more stable.

5.5.18 Table 5.24 shows the change in species number for Verge plots in each landscape type. The only statistically significant change occurred in plots in the arable landscape where the mean species number has declined from 14.5 to 13.2.

5.5.19 Figure 5.24 shows the changes in species groups between 1978 and 1990. In the arable landscapes the largest changes were a loss of 'base-rich meadow plants' (SG20),

Figure 5.24 SPECIES GROUPS IN VERGES

Change in the mean number of species, by species groups and by the four landscape types, using plots recorded along verges in both 1978 and 1990

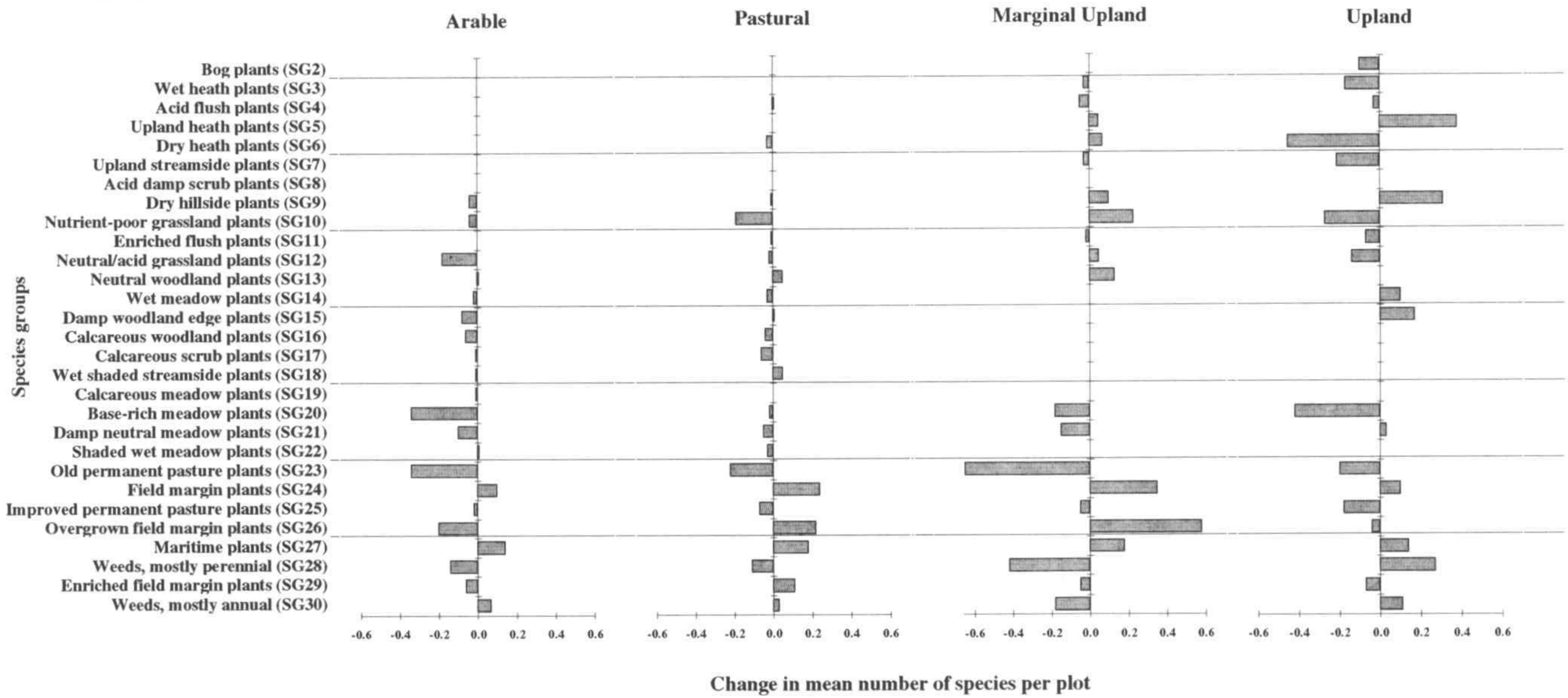


Table 5.24 Change in species numbers recorded in paired plots placed along verges in 1978 and 1990, by landscape type and GB

Landscape type	No of plots	Mean species no 1978	Mean species no 1990	Change in mean species no	SE of change	P
Arable	124	14 5	13 2	-1 3	0 7	*
Pastural	111	15 8	15 9	0 0	0 7	
Marginal upland	40	17 0	17 2	0 2	0 9	
Upland	29	19 5	18 8	-0 7	1 4	
GB	304	15 8	15 2	-0 6	0 4	

(Significance is based on paired t-test . Probability (P) * <0 1 ** <0.01, *** <0 001)

and 'old permanent pasture plants' (SG23) – similar to the groups which have declined in the Main plots (see 5.2.34–5.2.38).

5.5 20 Verges in the pastural and marginal upland landscapes also showed a decline in 'old permanent pasture plants' (SG23), and an increase in 'overgrown field margin plants' (SG26) and 'field margin plants' (SG24). In the uplands, the 'old permanent pasture plants' (SG23) and the 'base-rich meadow plants' (SG20) have declined, along with some of the upland grass classes (SG6, SG7 and SG10). In some plots, characteristic of more fertile soils, there has been an increase in perennial weeds (SG28), while on the unenclosed land there has been an increase of 'dry hillside plants' (SG9) and 'upland heath plants' (SG5).

Verge plots: conclusions

5.5.21 Verges in the lowlands (arable and pastural landscapes) were mainly in the 'overgrown eutrophic' (VCP3) and 'diverse mesotrophic' (VCP6) classes. These include many species groups which are less well represented in the surrounding agricultural fields. The 'diverse mesotrophic' class (VPC6) is an important source of plant diversity.

5.5.22 Verges in the marginal upland and upland landscapes are characterised by more species-rich upland, mown infertile and diverse mesotrophic types, which often have a similar species composition to the adjacent land.

5.5.23 Wider verges contain more meadow species and more tall competitive herbs, which play an important role in providing habitats and a food source for a wide variety of invertebrate and bird species.

5.5.24 In the lowlands there has been an increase in plots from 'overgrown grassy' verges (VPC2) and 'overgrown eutrophic' verges (VPC3), and a decrease in plots in the 'diverse mesotrophic' class (VPC6). There has been a small but significant loss of species numbers in Verge plots in arable landscapes (from 14.5 to 13 2 species per plot).

5.5.25 Verges are susceptible to a number of factors which influence their species composition. The management of verges tends to be different from that in the surrounding countryside. Verges are also vulnerable to disturbance, eg from road works and car parking. It was noticeable in 1990 (being a year of drought in the south and east) that some verges dried out However, the Quality Assurance Exercise (see Appendix 4), using comparable data from 1990 and 1991, showed that there were only small differences due to annual variation.

5.6 Linear features – Streamside plots

5.6.1 Vegetation plots were recorded adjacent to ditches, streams, rivers, and canals (for convenience referred to here as streamsides). They were recorded as 10 m x 1 m plots adjacent to the waterside edge (as defined in the Field Handbook (Barr 1990)). In addition, a further linear plot of the same size was recorded in the aquatic margin, to pick up species which were rooted or floating in the water.

5.6.2 In each 1 km square, two plots (which had previously been recorded in 1978) were randomly located and three further plots (new in 1990) were recorded to ensure different categories of watercourse were sampled. These categories were river or canalised river; stream; canal; non-roadside ditch; and roadside ditch.

Table 5.25 Frequency of Streamside plots recorded along six watercourse categories in 1990 in the four landscape types

Landscape type	River	Stream	Canal	Ditch	Road ditch	Other	Total
Arable	78	197	10	298	41	6	630
Pastural	98	376	4	156	19	8	661
Marginal upland	337	250	0	49	6	2	344
Upland	47	438	1	42	8	1	537
GB	260	1261	15	545	74	17	2172

Table 5.26 Classification of Streamside plots into Streamside plot classes

Streamside plot class	Name/Description	Short name
SPC1	Overgrown eutrophic grassland with tall herbs and brambles, mainly by lowland ditches	Overgrown eutrophic grassland
SPC2	Scrub and shade tolerant herbs, species-poor, mainly by lowland streams	Woodland margin
SPC3	Woodland on mineral soils, by streams or rivers, lowland	Woodland
SPC4	Woodland with heavy shade, on mildly acid soils, by streams, lowland/marginal	Shaded woodland
SPC5	Reed beds, species-poor mainly by rivers, lowland	Reed beds
SPC6	Overgrown grassland with perennial weeds, mainly by ditches, in lowland and marginal landscapes	Overgrown grassland
SPC7	Lightly grazed grassland with impeded drainage, by streams and ditches, in lowland and marginal landscapes	Rushy grassland
SPC8	Grazed improved pasture, mainly by streams, mainly lowland landscapes	Improved pasture
SPC9	Grazed neutral/acid pastures, mainly by streams, species-rich, mainly lowland landscapes	Neutral/acid pasture
SPC10	Acid marshy pasture, mainly by streams some lowland, mainly marginal and upland landscapes	Acid marshy pasture
SPC11	Moorland grass, mainly by streams, species-rich, mainly in upland landscapes	Moorland grass
SPC12	Moorland shrub heath, by streams, species-rich, mainly in upland landscapes	Dwarf shrub heath
SPC13	Valley bog, by streams, some lowland and marginal mainly in upland landscapes	Valley bog
SPC14	Peat bog by streams, mainly in upland landscapes	Peat bog
SPC15	Saltmarsh, species-poor, in lowland landscapes	Saltmarsh

5.6.3 Table 5.25 shows Streamside plots recorded in 1990 in terms of landscape type and watercourse category.

5.6.4 A total of 2172 Streamside plots were recorded from 446 squares throughout GB in 1990. In order to describe this vegetation, the species data from all these plots (plus data from 374 plots previously recorded in 1978) have been classified using the multivariate statistical technique, TWINSPAN, to create 15 'Streamside plot classes' (SPCs). These are shown in Table 5.26, ordered on the principal gradient, with short descriptive names which have been given to aid presentation of the results.

Streamside plots: stock in 1990

5.6.5 Figure 5.25 shows the distribution of the different Streamside plot classes recorded in 1990, in each landscape type. Unlike the verges, there was no pronounced separation between the lowlands and uplands, rather a continuous distribution of plot classes across all four landscapes, although they show different patterns.

5.6.6 In arable landscapes, most of the plots were in grassy vegetation (SPC6–SPC8), many of them overgrown (SPC6); these include ditches running through arable fields, and unmanaged vegetation beside rivers. Most of the 'reed beds' (SPC5) occur in this landscape type. Compared to other landscape types, only a small proportion of plots were in grazed pastures. There were also a small number occurring within woodlands (SPC3, SPC4) or on 'woodland margins' (SPC2). In the pastural landscapes most of the plots were beside streams or ditches running through 'rushy grassland' (SPC7); others were in woodland (SPC3, SPC4) or on moorland (SPC11, SPC13). In the marginal upland landscapes more of the plots were in neutral/acid (SPC9) and marshy (SPC7) pasture, whereas in the uplands most of the plots were on streams draining bogs (SPC13, SPC14) or running through moorland (SPC11, SPC12).

Watercourse category

5.6.7 Figure 5.25 also shows the relationship between watercourse category and Streamside plot class. In the arable landscapes, the 'reed beds' plot class (SPC5) occurs mainly on rivers, whereas ditches often have the overgrown plot classes (SPC1, SPC6). In the pastural landscape, streamsides contained all of the plot classes, whilst ditches had more restricted vegetation confined largely to grassland types (SPC6, SPC7, SPC8). In the marginal upland landscapes the same pattern holds, but a higher proportion of plots were beside streams. In the upland landscapes fewer plot classes were recorded, with the majority of plots beside streams.

Water plots (second 1 m)

5.6.8 Table 5.27 shows the species recorded most often in the second 10 m x 1 m plot, adjacent to the Streamside plot (see

Figure 5.25 STREAMSIDE PLOT CLASSES AND WATERCOURSE CATEGORY

Percentage frequency of the 15 Streamside plot classes (SPC1 - 15), (derived from TWINSPAN analysis of the Streamside plots recorded in 1990), by watercourse category and by landscape type

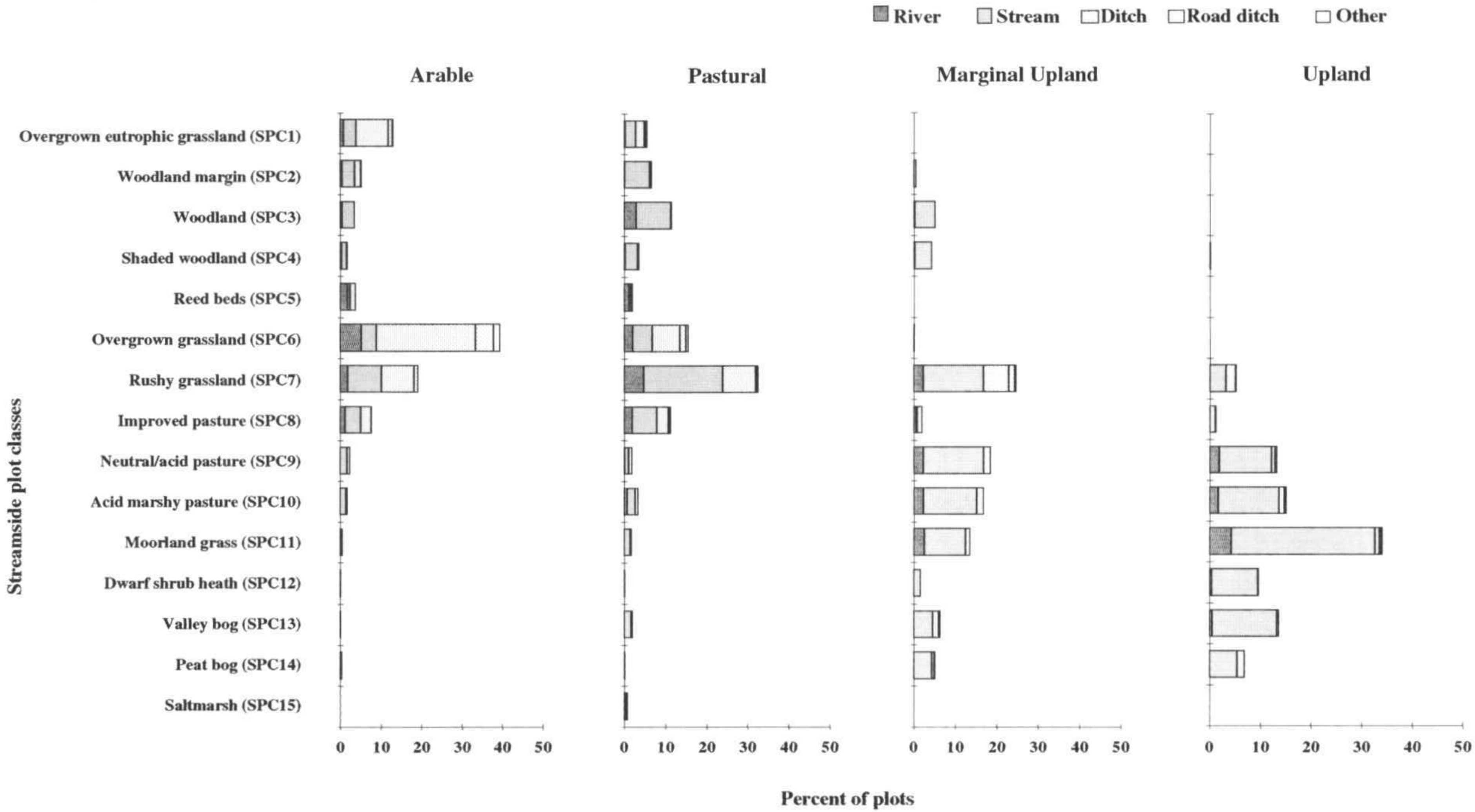


Table 5.27 Frequency of the species most often found only in the second 1 m of Streamside plots

Arable landscapes	% of plots	Pastural landscapes	% of plots
Callitriche spp	15	*Apium nodiflorum*	15
Lemna spp	14	*Callitriche* spp	15
Nasturtium officinale	12	*Glyceria fluitans*	14
Veronica beccabunga	11	*Lemna minor*	13
Apium nodiflorum	10	*Veronica beccabunga*	13
Sparganium erectum	10	*Nasturtium officinale*	13
Glyceria fluitans	9	*Lemna* spp	8
Myosotis scorpiodes	6	*Mentha aquatica*	7
		Phalaris arundinacea	6
		Sparganium erectum	6

Marginal upland landscapes	% of plots	Upland landscapes	% of plots
Callitriche spp	15	*Ranunculus flammula*	17
Glyceria fluitans	15	*Potamogeton* sp	10
Potamogeton spp	10	*Montia fontana*	9
Fontinalis antipyretica	8	*Equisetum fluviatile*	8
Juncus bulbosus	7	*Callitriche* spp	7
Myosotis scorpiodes	7	*Juncus articulatus/acutiflorus*	7
Potamogeton polygonifolius	7	*Potamogeton polygonifolius*	6
Juncus effusus	7	*Caltha palustris*	5
Epilobium palustre	5	*Veronica beccabunga*	5
Myosotis laxa	5	*Nasturtium officinale*	5
Mimulus guttatus	5	*Myosotis scorpioides*	5
Apium nodiflorum	5	*Juncus bulbosus*	5
Polygonum hydropiper	5	*Rhynchostegium riparioides*	5
		Glyceria fluitans	5

2.3.11), usually wholly within running water. In the lowland landscapes they contain mainly species associated with slow-flowing water on eutrophic, silted substrata, eg *Lemna* spp. (duckweeds) and *Sparganium erectum* (branched burweed). The marginal upland landscapes have a greater number and range of species, including those associated with acidic situations, eg *Juncus bulbosus* (bulbous rush). In the upland streams there were more species associated with stony stream beds, eg *Ranunculus flammula* (lesser spearwort).

Streamside plots: change between 1978 and 1990

5.6.9 Analysis of change for the streamside data was based on 322 plots from 179 squares throughout GB, which were recorded in both 1978 and 1990. Data from these pairs of plots are summarised in Figure 5.26.

5.6.10 In the arable landscapes there has been an increase in the 'overgrown grassland' (SPC6), and a decrease in the 'rushy grassland' (SPC7) plot classes. In pastural landscapes the changes were small, but showed a trend towards the eutrophic plot classes. In marginal upland landscapes the small changes involve a loss from the 'moorland grass' (SPC11) class, with an

Table 5.28 Change in species numbers recorded in paired plots placed along streamsides in 1978 and 1990 in the four landscape types

Landscape type	No of plots	Mean species no 1978	Mean species no 1990	Change in species	SE of Change	P
Arable	84	16.1	14.6	-1.5	0.9	
Pastural	103	18.1	15.0	-3.2	0.9	***
Marginal upland	50	20.7	19.5	-1.2	1.4	
Upland	85	23.9	20.7	-3.2	1.4	**
GB	322	19.5	17.09	-2.4	0.5	***

(Significance is based on paired t-test. Probability (P) * < 0.1, ** <0.01, *** <0.001)

increase in plots in the 'neutral/acid pasture' (SPC9) and shaded woodland classes (SPC3, SPC4). In the upland landscapes, the main change was a decline in 'dwarf shrub heath' (SPC12), with a corresponding increase in the 'moorland grass' class (SPC11). The 'rushy grassland' (SPC7) category has decreased in all landscape types, whereas 'overgrown grass' (SPC6) has increased, notably in the arable and pastural landscapes.

5.6.11 Table 5.28 shows the average change in the species number for each landscape type, from plots recorded in 1978 and 1990. Species number has not changed significantly in the arable and marginal upland landscapes, although losses were recorded. However, streamsides in the pastural and upland landscapes have lost an average of three species per plot.

5.6.12 Figure 5.27 shows changes in species groups between 1978 and 1990. The pastural and upland landscapes show a decline in almost all groups, the loss in species number occurring across the spectrum.

5.6.13 Drying out was implied by the loss of some species, eg 'wet meadow plants' (SG14) such as *Veronica beccabunga* (brook weed) and *Nasturtium officinale* (water cress), and 'aquatic plants' (SG31) such as *Rumex hydrolapathum* (water dock); species from these two groups have declined in all four landscapes, though more so in the lowlands. However, the Quality Assurance Exercise (see Appendix 4), using comparable data from 1990 and 1991, showed that there were only small differences due to annual variation.

5.6.14 'Wet shaded streamside plants' (SG18), eg *Veronica montana* (wood speedwell) and *Ajuga reptans* (bugle), have declined in the lowlands, as well as 'damp woodland edge

Figure 5.26 STREAMSIDE PLOT CLASSES

Change in the frequency of the 14 Streamside plot classes (SPC1 - 14), (derived from TWINSPAN analysis of the Streamside plots recorded in both 1978 and 1990), by landscape type

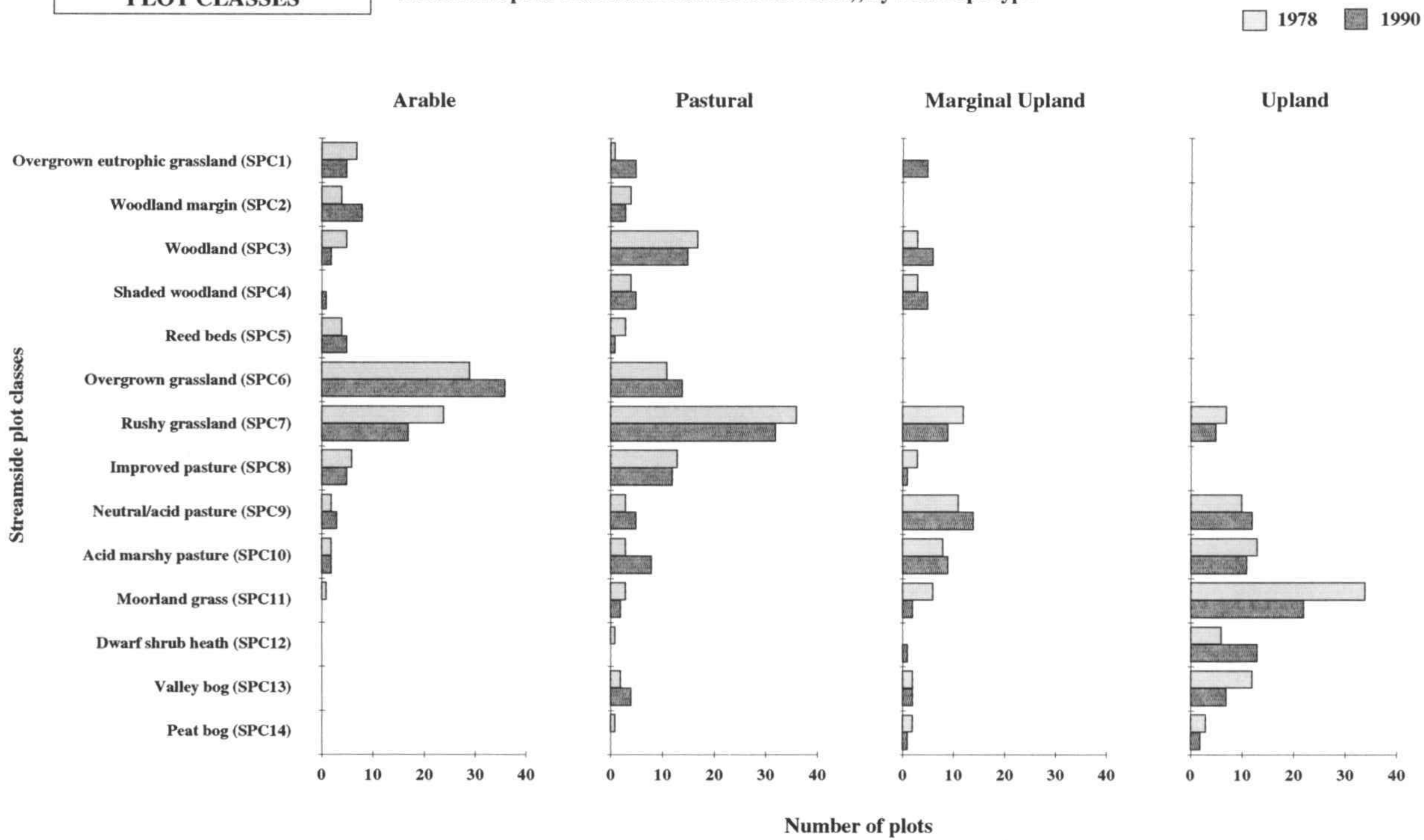
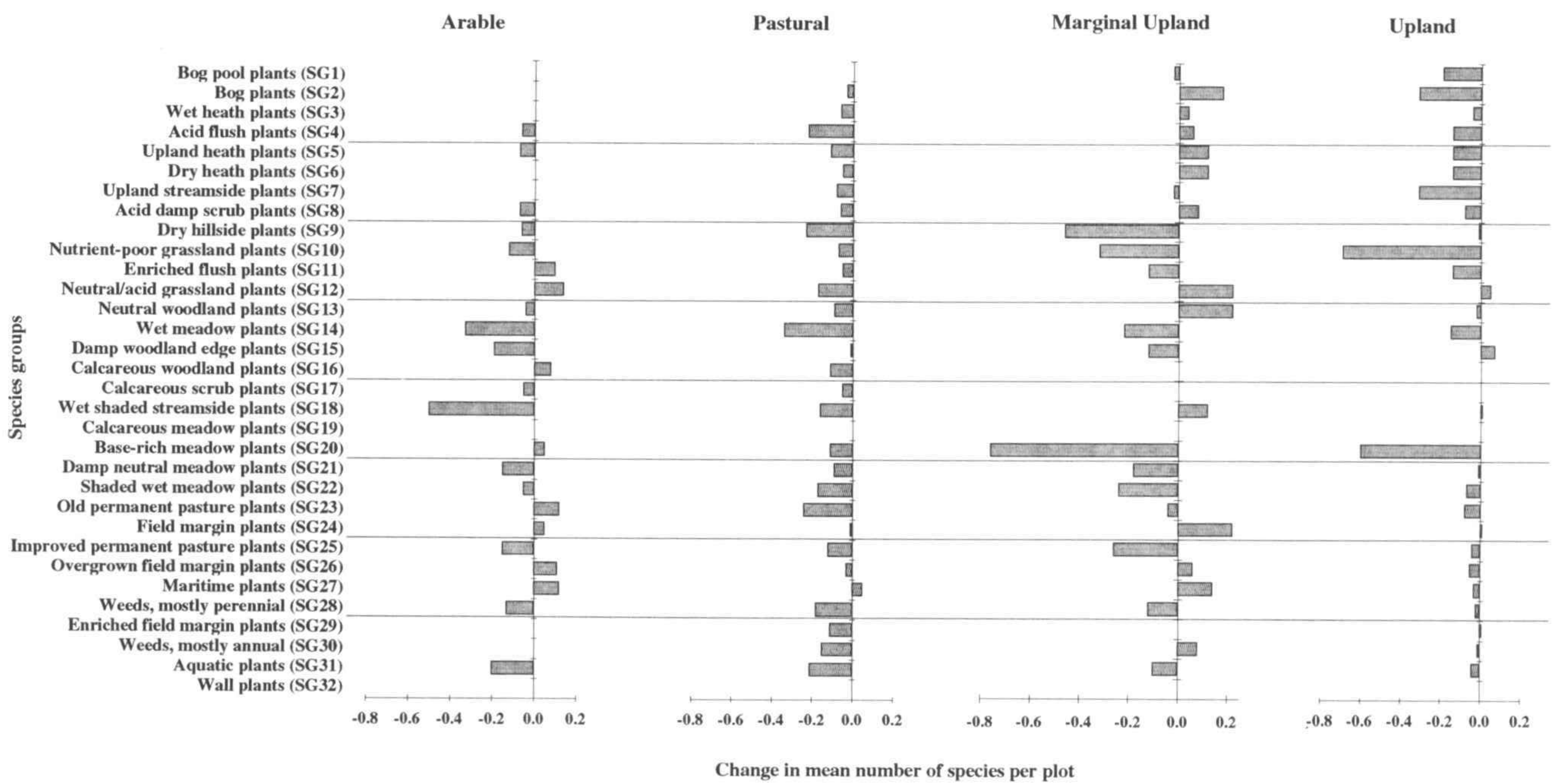


Figure 5.27 SPECIES GROUPS IN STREAMSIDES

Change in the mean number of species, by species group and by landscape type, using plots recorded along Streamsides in both 1978 and 1990



plants' (SG15), eg *Valeriana officinalis* (valerian) and *Angelica sylvestris* (angelica) in the arable and marginal upland landscapes. The largest losses of any species group, in any landscape type, were of the 'base-rich meadow plants' (SG20) in the marginal upland and upland landscapes and the 'infertile grassland plants' (SG10) which have declined in the uplands.

Streamside plots: conclusions

5.6.15 Streamside vegetation plots in the lowlands were dominated by overgrown grassland and rushy pastures. In the marginal uplands they were characterised by a variety of wet pasture types, whilst in the uplands moorland types were present.

5.6.16 The extent of grassland with impeded drainage decreased in all landscape types, whilst overgrown grassland increased in the lowlands.

5.6.17 There was an overall loss in species numbers in all Streamside plots, especially in the pastural and upland landscapes.

5.6.18 Streamsides contain a range of species infrequent in other parts of lowland landscapes and so hold a substantial proportion of lowland plant diversity. The loss of diversity and the contributory factors will require further study.

5.7 Conclusions and summary of Chapter 5

5.7.1 In the above discussion, the results have been analysed for each component of the landscape in turn. In concluding, it is important to consider the British countryside as a whole.

5.7.2 Figures 5.28, 5.29, 5.30 and 5.31 compare, for each landscape type, in 1990, the relative abundance of species groups in the three linear features (ie verges, streams and hedges) with that in the Main plots. In interpreting these diagrams, it should be remembered that plots in the linear features were 10 m^2 whilst the Main plots were 200 m^2.

5.7.3 In the two lowland landscape types, there were more species in the 10 m^2 linear plots than in the 200 m^2 Main plots, for most species groups. 'Field margin plants' (SG24), 'improved permanent pasture plants' (SG25) and 'weeds, mostly perennial' (SG28) were most frequent in the verges. 'Wet meadow plants' (SG14), 'damp neutral meadow plants' (SG21) and 'aquatic plants' (SG31) were most abundant in Streamside plots, whilst the hedges had more woodland species (SG13, SG16 and SG26). The 'base-rich meadow plants' (SG20), described (above) as being widely in decline, were most abundant on streamsides and verges in the arable landscapes, and in verges and fields (ie Main plots) in the pastural landscapes.

5.7.4 In marginal upland landscapes, 'infesrtile grassland plants' (SG10), 'neutral/acid grassland plants (SG12), and moorland plants (SG1 -SG5) were most frequently represented in the Main plots and streamsides. The 'old permanent pasture plants' (SG23) and 'base-rich meadow plants' (SG20), along with most of the grassland groups, were most abundant on verges, though also widespread elsewhere. 'Wet meadow plants' (SG14) and 'enriched flush plants' (SG11) were most common beside streams, whilst 'neutral woodland plants' (SG13) and 'dry hillside plants' (SG9) were most frequently recorded in Hedge plots. Groups associated with upland habitats, ie 'upland streamside plants' (SG7), 'wet heath plants' (SG3) and 'bog plants' (SG2) were best represented in the Main plots and Streamside plots.

5.7.5 In the upland landscapes, vegetation recorded in the Main plots was more uniform than in the other landscape types, in that there were more species in fewer plot classes. Verges contained the highest proportion of 'old permanent pasture plants' (SG23) and 'base-rich meadow plants' (SG20), and therefore represent a major resource of this type. Upland vegetation in the unenclosed land was well represented by the Main plots. Verges are important for their variety of 'infertile grassland plants' (SG10), and the streamside vegetation also contains a high proportion of species in these categories. Overall, the linear features were shown to be important in all four landscapes, in terms of their contribution to the diversity of plant species. This was least obvious in upland landscapes, where hedges were absent and there were fewer verges than elsewhere in the country. Verges, and especially streamsides, were less distinctive in their species composition in the uplands than in other landscapes, since they are mainly contiguous with the

Figure 5.28 SPECIES GROUPS IN ARABLE LANDSCAPES

Comparison between the mean number of species in the species groups, recorded in the Main plots and linear plots in 1990, in arable landscapes

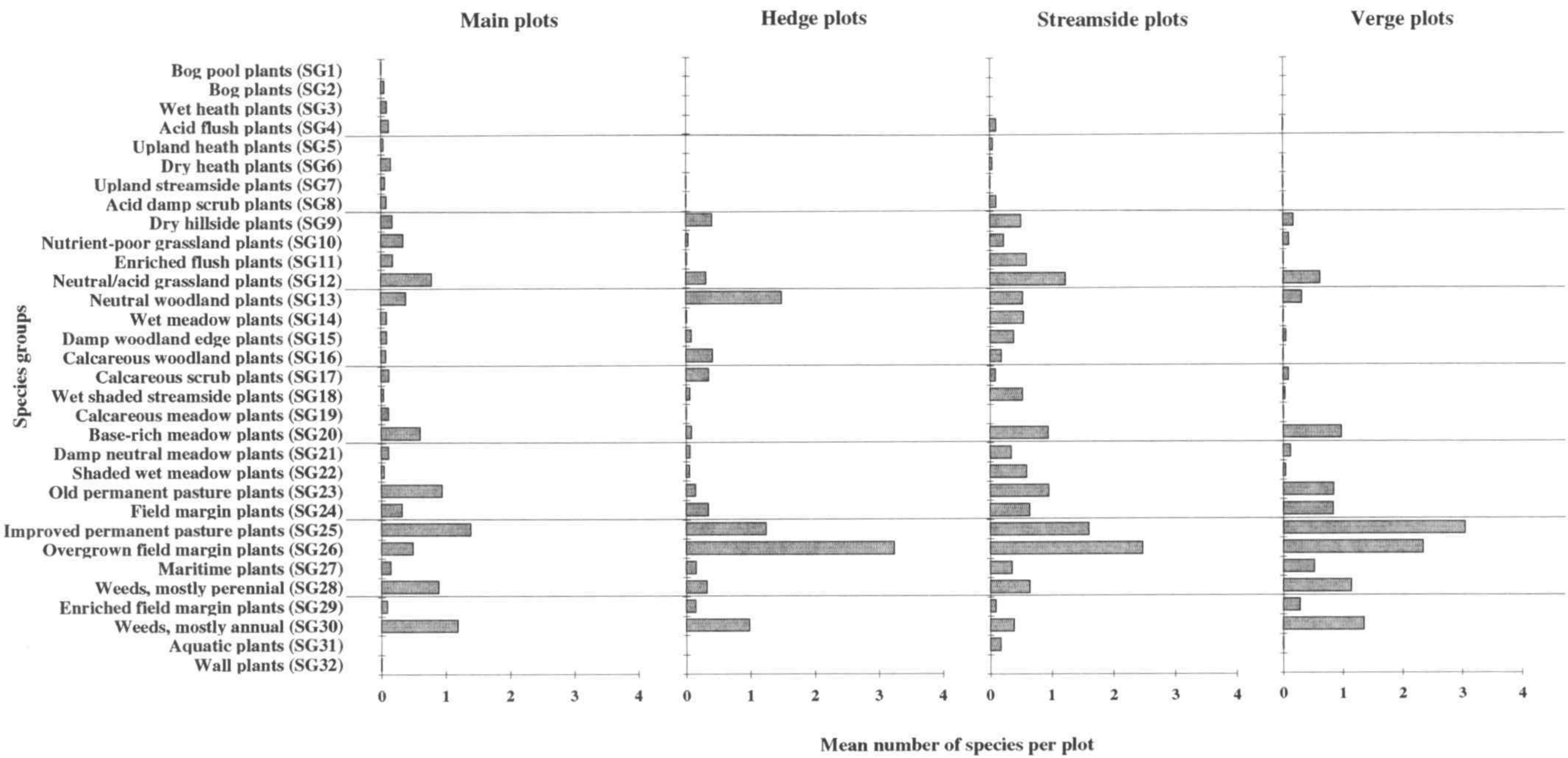


Figure 5.29 SPECIES GROUPS IN PASTURAL LANDSCAPES

Comparison between the mean number of species in the species groups, recorded in the Main plots and linear plots in 1990, in pastural landscapes

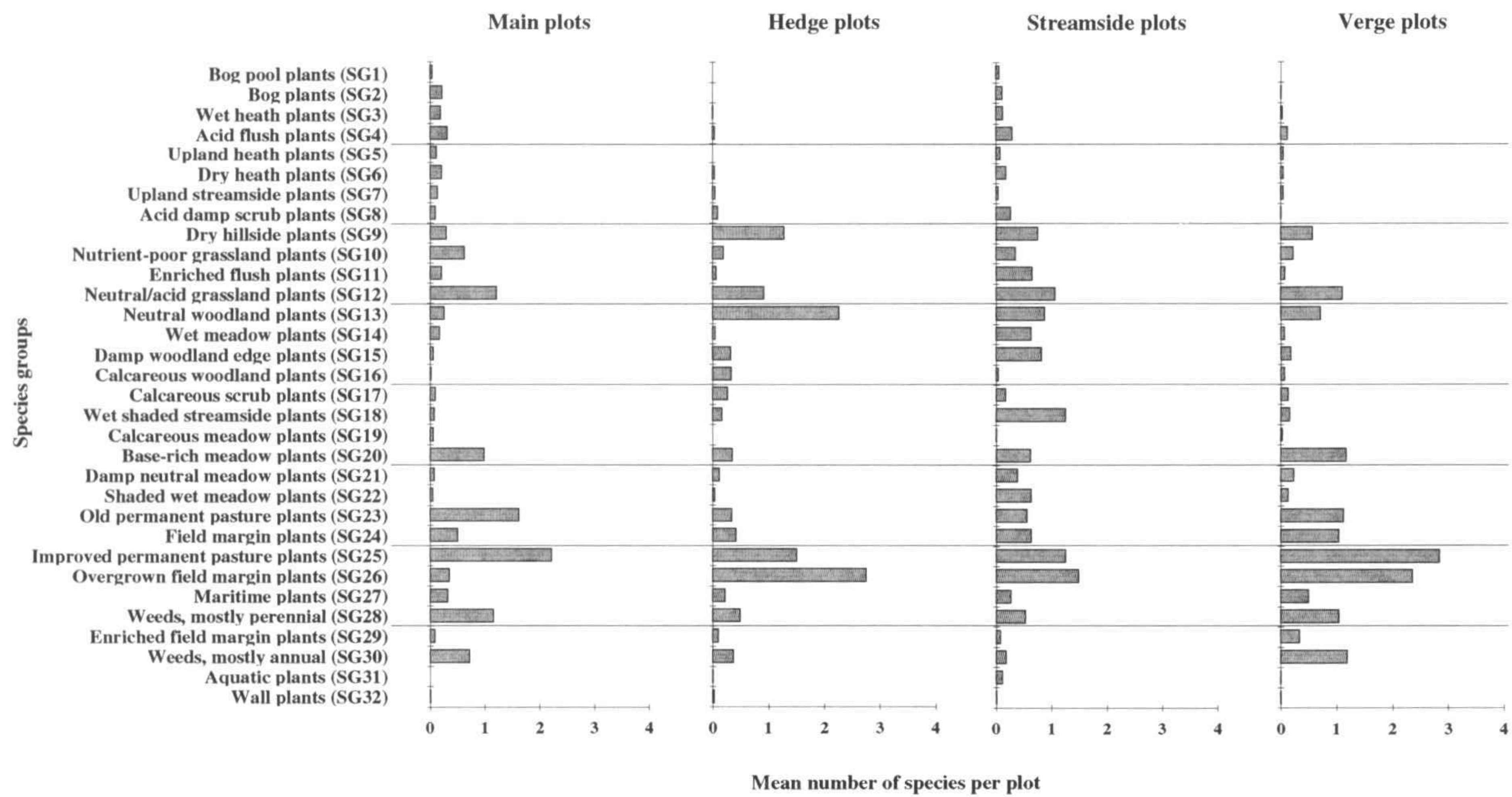


Figure 5.30 SPECIES GROUPS IN MARGINAL UPLAND LANDSCAPES

Comparison between the mean number of species in the species groups, recorded in the Main plots and linear plots in 1990, in marginal upland landscapes

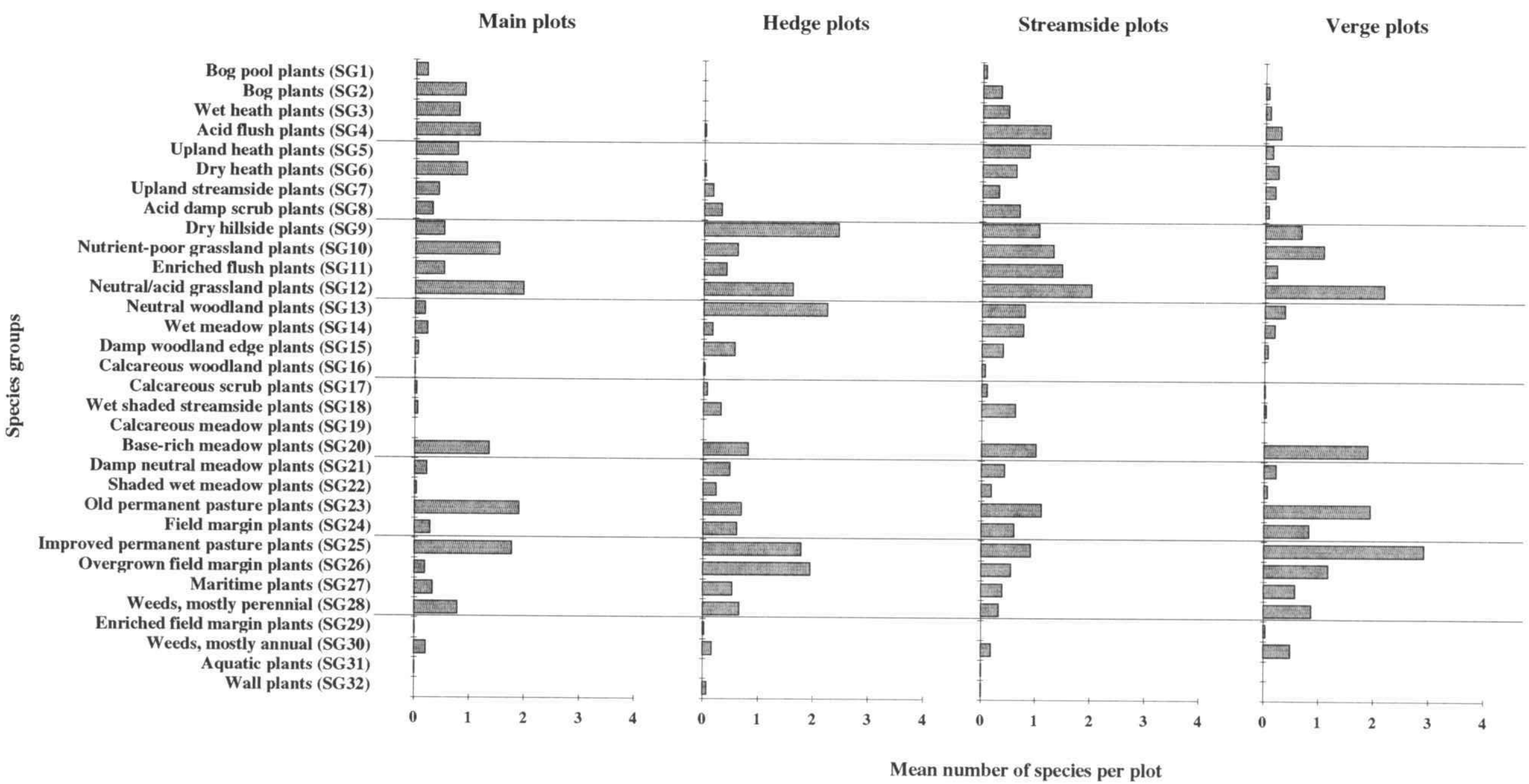
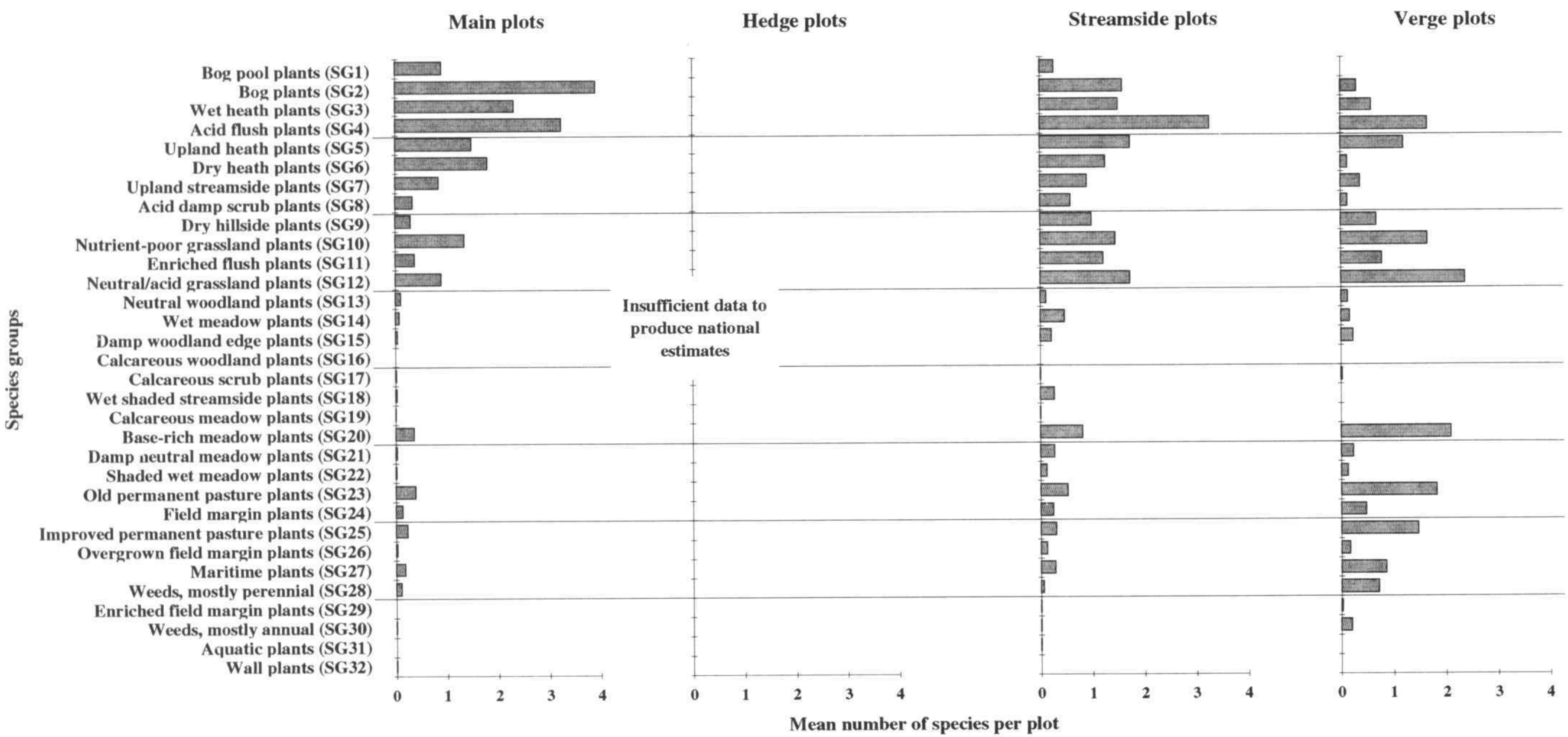


Figure 5.31 SPECIES GROUPS IN UPLAND LANDSCAPES

Comparison between the mean number of species in the species groups, recorded in Main plots and linear plots in 1990, in upland landscapes



surrounding open moorland and grassland; however, they still make a major contribution to the overall diversity.

5.7.6 In the marginal upland and lowland landscapes the contribution of hedges, verges and streams to botanical diversity was more apparent. The hedges contain many woodland and shrub species, and, together with the verges, provide a refuge for many meadow and pasture species. The streamsides also contain grassland species which require damp conditions and that are absent elsewhere in the countryside. The significance of linear features was most obvious in the arable landscapes where the fields were generally species-poor, and most of the remaining diversity of native plant species occurs in the restricted areas which were covered by the Habitat plots.

5.7.7 The extent and types of change affecting the areal habitats and linear features have been discussed earlier, and it is useful at this point to draw these together to provide a summary of the overall impact on the wider countryside.

5.7.8 In the **arable landscapes**, the arable fields have lost diversity from an already low base. The hedge-bottom flora was increasingly becoming dominated by species associated with cultivated land. Both verges and streamsides show increases in vigorous species as opposed to a decline in more sensitive meadow species. Streamsides have lost species overall, especially those associated with aquatic margins, wet meadows and moist woodland. The woodland and semi-improved grassland plot classes show little change.

5.7.9 In the **pastural landscapes**. the semi-improved grassland shows a significant decline in species. especially those typical of unimproved mesotrophic meadows. The latter have also declined in the hedge bottoms, verges and streamsides. The verges have become more overgrown and show an increase in coarse grasses as well as species associated with disturbance. The streamsides also have fewer species indicative of aquatic margins and wet meadows. Woodland shows a decline in species number and evidence of disturbance, with a trend towards a more grassy ground flora. The loss of meadow species, which were once an important component of the pastural landscapes, has further reduced an already depleted resource. This landscape type has the highest degree of change, in part because of the extent of the changes themselves, and in part because of the range of types present.

5.7.10 In the **marginal upland landscapes**, the results show an interchange between the grassland types. The hedge bottoms have more species associated with improved grassland, and fewer woodland species. The woods themselves show a loss in species number which has affected most species groups. Some semi-improved fields show a small increase in species number and a trend towards increasing abundance of species associated with unimproved and infertile soils. These species have also increased in the upland grass mosaics, which otherwise were relatively stable. There was a decline in wet meadow species from the streamsides, which have also lost some species associated with unimproved and infertile soils. The verges include more plot classes characteristic of overgrown and shaded conditions, as was the case in the lowland landscapes, with fewer meadow species and more coarse grasses. Moorland shows an increase in species, particularly those from grassland species groups, at the expense of heathland groups. This agrees with the widely held view that these marginal upland areas are particularly sensitive to change and may be associated with the mixture of upland and lowland types of vegetation in close proximity.

5.7.11 In the **upland landscapes**, woodland has lost species from most groups. The upland grass mosaics have also lost diversity overall, whereas moorland shows a small increase in diversity, especially in species associated with flushes. Overall, there was a limited range of plot classes in the uplands, but these contain a large number of individual species. The changes, therefore, were relatively small in comparison with this total resource.

Chapter 6 THE RESULTS (IV): FRESHWATER STUDIES

6.1 Introduction

6.1.1 The 1990 survey was the first of the three countryside surveys (1978, 1984 and 1990) to incorporate the study of running-water macro-invertebrate assemblages. Change statistics of the type given elsewhere in this report are therefore not yet available for freshwater assemblages. The data presented here provide a baseline against which future change can be assessed.

6.1.2 Sites sampled in Countryside Survey 1990 (CS1990) sites were mainly on small streams, as described in Chapter 2. In order to make between-landscape comparisons of macro-invertebrate assemblages in larger watercourses, analyses of other appropriate Institute of Freshwater Ecology (IFE) and water industry data sets need to be undertaken. This is to be the subject of a separate thematic report (Furse *et al.* in prep.).

6.2 CS1990 field survey

Sampling sites

6.2.1 Each of the 508 1 km squares were surveyed for possible freshwater sampling sites. Of these, only 361 squares had a suitable running watercourse which was sampled for aquatic macro-invertebrates. Of the remaining squares, 64 had no watercourses marked on OS 1:10 000 maps or any apparent in the square during survey. A further 66 sites had marked channels which were found to be dry when surveyed. In 15 squares the only rivers or canals present were not eligible for sampling (see 2.5.3) and no samples were available for the two remaining squares.

6.2.2 The greatest number and proportion of dry squares were in the arable landscapes (Table 6.1), whereas there were very few such squares in either the marginal upland or upland landscapes. In a high proportion of squares in the arable landscapes, all watercourses present were dry at the time of survey; these were predominantly lowland squares in south-east England, the east Midlands and East Anglia, and often associated with chalk soils. In the pastural landscapes the highest proportion of dry squares of this kind were in the south, the Midlands, and coastal areas.

Table 6.1 The number (and proportion) of 1 km squares surveyed, sampled, dry or unsuitable in each of the four landscape types

Landscape type	Surveyed	Sampled	Dry: No streams	Dry: Dry streams	Unsuitable or unavailable
Arable	162	81 (50%)	37 (23%)	37 (23%)	7 (4%)
Pastural	158	110 (70%)	18 (11%)	23 (15%)	7 (4%)
Marginal upland	77	66 (86%)	7 (9%)	3 (4%)	1 (1%)
Upland	111	104 (94%)	2 (2%)	3 (3%)	2 (2%)
GB	508	361 (71%)	64 (13%)	66 (13%)	17 (3%)

6.2.3 A comparison between squares sampled in the 1988 pilot study, and those surveyed for sampling in 1990 provides further information on intermittently dry squares (Table 6.2). Overall, 9% of the 156 squares sampled in 1988 were dry in 1990. A large majority of these dried squares were in the east Midlands and East Anglia.

Environmental characteristics

6.2.4 The environmental characteristics of streams in the four landscapes, and their dominant riparian vegetation and adjacent land use are compared in Tables 6.3 and 6.4. Channel

Table 6.2 The numbers of squares in each landscape type which were sampled in 1988 and surveyed in 1990, together with the number (and proportion) which had flowing watercourses in 1988 (wet) but none in 1990 (dry)

Landscape type	Squares visited in 1988 and 1990	Squares wet in 1988 but dry in 1990
Arable	42	8(19%)
Pastural	53	4(8%)
Marginal upland	25	2(8%)
Upland	36	0(0%)
GB	156	14(9%)

Table 6.3 A comparison of the means and standard errors (SE) of environmental characteristics of watercourses in each landscape type

Variable	Arable		Pastural		Marginal upland		Upland	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Stream width (m)	2.0	0.2	1.8	0.2	1.6	0.2	1.5	0.1
Stream depth (cm)	24.8	2.7	21.6	2.3	15.6	1.4	18.6	1.3
Current velocity (m/s)	1.5	0.1	1.7	0.1	2.2	0.1	2.3	0.1
Rock pavement (%)	0.5	0.5	1.1	0.5	6.7	2.3	4.8	1.5
Boulders and cobbles(%)	9.8	2.2	21.0	2.7	39.8	4.0	39.7	3.2
Pebbles and gravel (%)	21.7	3.1	25.9	2.8	33.9	3.4	32.4	2.5
Sand (%)	11.5	2.0	9.9	1.6	7.1	1.3	10.0	1.7
Silt and clay (%)	57.1	4.5	42.2	3.8	19.3	3.9	17.9	3.0
Aquatic vegetation cover (%)	28.9	4.2	16.3	2.7	18.4	3.4	12.6	2.4
Altitude (m)	59.2	6.3	78.6	5.6	212.3	13.8	252.6	18.5
Discharge category	1.1	0.1	1.2	0.1	1.1	0.1	1.2	0.1
Distance from source (km)	3.4	0.5	3.5	0.6	2.1	0.3	1.5	0.2
Slope (m/km)	17.4	4.4	26.9	3.2	87.5	10.7	98.6	10.1

management practices, visible pollution and the presence of bridges, weirs and other influences are also compared (Table 6.5).

6.2.5 Although watercourses in the study sites were generally small, there was a high level of variability in the in-stream and riparian characteristics, within each landscape type. This is partially because all forms of running watercourses were considered together, including streams, canals and drains, partially because of the inherent variability of these characters along a watercourse channel, and partially because of the intrinsic differences between the component Land Classes of each of the four major landscape types. As a consequence, standard errors of the mean value of each variable in each landscape are high in relation to the means.

6.2.6 The watercourses sampled in each landscape type had similar mean discharges (Table 6.3), reflecting the generally small size of each of them.

6.2.7 The apparent tendency for arable and pastural sites to be deeper, wider and further from the source than the other two landscapes is because second- and third-order streams are generally larger in the stream systems of the more lowland landscapes. Higher-order streams were preferentially selected in each square (see section 2.5.5)

6.2.8 A distinct altitudinal gradient of the sampling sites existed from the upland landscape (253 m) down through marginal upland (212) and pastural (79) to arable (59). There were concomitant decreases in slope,

Table 6.4 A comparison of the means and standard errors (SE) of dominant bankside characteristics of watercourses in landscape types

Variable	Arable		Pastural		Marginal upland		Upland	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Riparian vegetation								
Bank stability[1]	0.28	0.07	0.51	0.08	0.50	0.09	0.23	0.06
Trees[2]	0.51	0.08	0.87	0.08	0.56	0.11	0.24	0.06
Bushes[2]	0.41	0.08	0.34	0.06	0.14	0.05	0.13	0.05
Reeds and rushes[2]	0.33	0.08	0.47	0.07	0.38	0.09	0.43	0.08
Low plants[2]	1.49	0.09	1.19	0.08	1.56	0.09	1.48	0.08
Other vegetation[2]	0.03	0.02	0.02	0.02	0.03	0.02	0.03	0.02
Shading[3]	1.57	0.17	1.76	0.15	1.30	0.20	0.80	0.13
Adjacent land cover								
Urban land[4,5]	0.10	0.04	0.10	0.04	0.00	-	0.01	0.01
Arable[4]	0.53	0.09	0.53	0.06	0.28	0.06	0.12	0.02
Pastural[4]	0.94	0.10	1.09	0.09	0.91	0.12	0.52	0.09
Moorland[4]	0.17	0.06	0.17	0.05	0.62	0.11	1.24	0.09
Broadleaf woodland[4]	0.42	0.08	0.44	0.07	0.29	0.08	0.11	0.04
Coniferous woodland[4]	0.06	0.04	0.06	0.03	0.18	0.07	0.27	0.06

NB For bankside variables, figures are the mean number of banks per site at which a vegetation type or land cover predominates

[1]Bank stability is expressed as the mean number of banks per site which are considered to be eroding

[2]Bankside vegetation (eg trees, bushes, etc) refers to the dominant one or two vegetation types in a 10 m corridor landward from the water's edge

[3]Shading values vary from 0, no shading, to 4, heavy shading from both banks

[4]Adjacent land cover (eg urban, arable, etc) refers to the dominant one or two uses in a zone between 10 and 30 m to the landward of the water's edge. Each bank of the watercourse was recorded separately

[5]Urban land includes land which is not covered by agriculture or natural and semi-natural vegetation. It includes domestic, industrial and agricultural housing and associated curtilages, roads and vehicular tracks and recreational areas

velocity and substratum cover of rock pavement and boulders and cobbles. These were accompanied by parallel increases in cover of silt and clay and aquatic vegetation moving from upland to arable landscapes.

6.2.9 Sampling sites in arable and pastural landscapes were differentiated from those in marginal upland and upland landscapes by their higher degree of shading; this was due to the comparatively high frequency of bankside trees, in pastural landscapes, and bushes (large shrubs, eg hazel) in arable landscapes (Table 6.4).

6.2.10 Where trees were the cover category recorded in land adjacent to arable and pastural sites, approximately 90% were broadleaf rather than coniferous. In marginal upland landscapes this figure fell to just over 60% and in upland sites the dominance was reversed, with about 60% of all records being coniferous (Table 6.4).

6.2.11 Upland landscape sites have the most open bankside vegetation on average. In proportional terms, 64% of all upland bankside vegetation records are relatively low-growing plants (grasses and dwarf shrubs, eg heather), compared with 58% marginal upland, 54% arable and just 41% in the pastural landscape. Conversely, pastural sites are the most likely to have tall, closed bankside vegetation.

6.2.12 Sites in arable and pastural landscapes are equally likely to be bordered by urban land (including gardens) but in absolute terms only 5% of site banks in each landscape had dominant urban land in their corridor. Urban land was almost totally absent adjacent to marginal upland and upland sites.

6.2.13 In terms of adjacent land cover, both arable and pastural landscape sites were very similar in the frequencies of occurrence of arable and pastural land and of moorland. This demonstrates the inherent variation in the four landscape types (see 1.3.7).

6.2.14 The frequency of arable land alongside marginal upland sites was half that of sites in arable and pastural landscapes but adjacent pasture was only slightly less common. However, the character of pasture in marginal upland landscapes is likely to be very different to that bordering lowland sites. The frequencies of adjacent arable and pastural land in the upland landscapes were each approximately half those of marginal upland sites but moorland was twice as frequent.

6.2.15 Arable stream sites were far more prone to channel management than any of the other landscape types (Table 6.5). This applied to bank maintenance, weed-cutting, channel straightening and dredging. The incidence of bridges and weirs within 25 m of the sampling site was also highest in arable landscapes.

6.2.16 Although standard error terms are high, records of visible evidence of weed cuts were almost exclusively confined to arable sites, whilst the percentage frequencies of dredging ($P<0.01$), bankside maintenance ($P<0.05$) and channel straightening ($P<0.01$) were all significantly greater at arable than non-arable sites. (The statistical test applied was Student's t-test with unequal variance.) Indications of chemical pollution, however, were most commonly noted at pastural sites.

6.2.17 Marginal upland and upland sites were both less prone to the human influences under consideration than either of the other two

Table 6.5 A comparison of the means and standard errors (SE) of the percentage frequencies of occurrence of stream maintenance, perceived pollution and human artefacts at watercourses in each landscape type

Percentage of sites with:	Arable Mean	Arable SE	Pastural Mean	Pastural SE	Marginal upland Mean	Marginal upland SE	Upland Mean	Upland SE
Weed cutting	4.9	2.4	0.0	-	1.5	1.5	0.0	-
Dredging	12.3	3.7	8.2	2.6	4.6	2.6	0.0	-
Bankside maintenance	9.9	3.3	0.9	0.9	4.6	2.6	1.0	1.0
Channel straightening	17.3	4.2	7.3	2.5	4.6	2.6	3.9	1.9
Chemical pollution[1]	8.6	3.1	13.6	3.3	6.1	3.0	1.0	1.0
Physical pollution[1]	2.5	1.7	4.6	2.0	0.0	-	0.0	-
Bridge within 25 m	17.3	4.2	12.7	3.2	9.1	3.6	4.8	2.1
Weir within 25 m	6.2	2.7	2.7	1.6	1.5	1.5	0.0	-
Other influences	17.3	4.2	15.5	3.5	16.7	4.6	7.7	2.6

NB For binary, presence/absence variables such as the presence of bridges or visible organic signs of pollution the proportions of sites with positive observations have been used

[1]Pollution refers to in-stream conditions and includes visible or olfactory evidence of degradation of water or environmental quality

landscape types, with upland sites especially free of maintenance activities, bridges and weirs.

Freshwater environmental quality

6.2.18 The RIVPACS methodology (see Chapter 2) was used to assess the environmental quality of sites, as indicated by their macro-invertebrate assemblages.

6.2.19 In general terms, the higher the total or average score attained by a site the greater its environmental quality is assessed to be (but see 6.2.23). RIVPACS uses a system of prediction by analogy to forecast target Biological Monitoring Working Party (BMWP) scores and Average Score Per Taxon (ASPT) of sites, based on their measured environmental characteristics.

6.2.20 The means of the observed and RIVPACS-predicted BMWP scores, number of scoring taxa and ASPT for sites in each landscape type are shown in Table 6.6 and in Figure 6.1.

6.2.21 Mean predicted BMWP index values are consistently higher than those observed in the samples collected. This is simply because mean predictions are based upon the idealised fauna in the absence of pollution, whereas the mean observed values are derived from both clean and polluted sites. Mean observed scores are a reflection of the average degree to which the component sites are polluted, or otherwise stressed.

6.2.22 The most marked difference between landscape types was in ASPT, which tended to increase from sites in arable landscapes, through pastural and marginal upland to upland. This shift was more marked in observed than predicted values and indicated a possible environmental quality gradient, increasing in the direction of the upland landscapes.

6.2.23 The values given in Table 6.6 can be used as a basis for monitoring future change. However, because of their underlying environmental characteristics, sites differ in the actual score they can attain, even when unpolluted. This is shown by the between-landscape predicted values in the Table. This critical factor needs to be taken into account when making spatial comparisons between sites in different landscapes.

6.2.24 Comparisons were also made between the Environmental Quality Index (EQI) values for sites in each landscape type (Table 6.6). There is little difference between landscapes in their EQI values for BMWP score and number of scoring taxa. However, the biological quality of the watercourses is best indicated by their EQIs for the ASPT (Wright *et al.* 1988). Here the gradient of improved quality from arable to upland, suggested in section 6.2.22, is confirmed by a pattern of increasing EQI values for each landscape type.

6.2.25 All 339 sites in CS1990, for which RIVPACS is operative (see 2.5.20), were assigned to an ASPT quality band using the methodology described in Chapter 2. The distribution of sites in four quality bands is shown in Table 6.7.

6.2.26 Overall, 71% of the sites were assigned to the highest quality band, band A, which comprises sites sufficiently close to their

Table 6.6 A comparison of the means and standard errors (SE) of river quality characteristics of watercourses in each landscape type

	Arable		Pastural		Marginal upland		Upland	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Observed BMWP score	60.5	3.6	71.9	4.1	68.3	5.1	61.3	3.1
Observed number of taxa l	3.3	0.6	14.0	0.6	11.8	0.7	10.4	0.4
Observed ASPT	4.2	0.1	4.8	0.1	5.5	0.2	5.7	0.1
Predicted BMWP score	94.4	1.0	104.0	1.8	110.2	2.6	96.7	0.9
Predicted number of taxa	18.5	0.3	19.1	0.2	18.2	0.4	16.2	0.1
Predicted ASPT	5.1	0.1	5.4	0.1	6.0	+	6.0	+
EQI BMWP score	0.64	0.04	0.68	0.04	0.62	0.05	0.63	0.03
EQI number of taxa	0.72	0.03	0.73	0.03	0.65	0.04	0.64	0.03
EQI ASPT	0.84	0.02	0.88	0.02	0.91	0.03	0.96	0.02

NB The ratio of the observed score or ASPT of a sample collected from a site and that predicted for it by RIVPACS is termed the Environmental Quality Index (EQI) and is an expression of the extent to which the fauna of a site matches that to be expected in the absence of environmental stress. (Wright *et al.* 1988). A perfect match provides an EQI of 1, whilst a site without taxa will have an EQI of zero. Using this procedure sites of entirely different environmental character, in different parts of the country, may be compared on a common basis (NB + = <0.05)

Figure 6.1 The proportion of sites in each landscape type in four biological quality bands

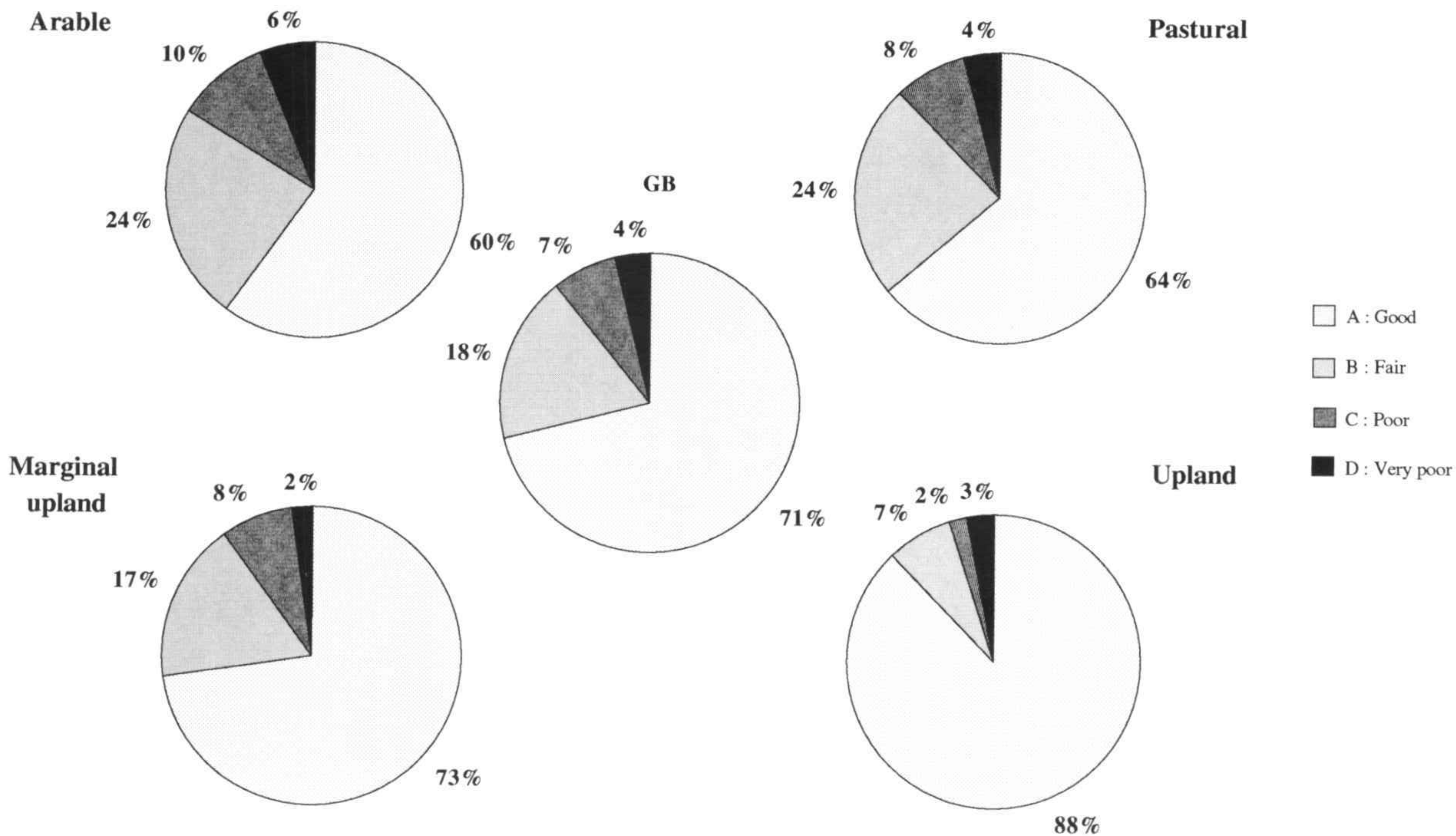


Table 6.7. The percentage frequency of sites in each ASPT quality band

Quality band	% frequency of sites
A - 'good' quality	71
B - 'fair' quality	18
C - 'poor' quality	9
D - 'very poor' quality	4

predicted biotic index values to be considered unpolluted and therefore of 'good' environmental quality.

6.2.27 The lowest frequency of band A sites (60%) and highest frequencies of bands C (10%) and D (6%) were in the arable landscapes (Figure 6.1). Sites in the pastural landscapes were of slightly better quality but there was a more marked improvement in average quality in marginal upland landscapes, and an even greater improvement in the uplands. In the latter case, 88% of sites were band A and only 2% and 3% bands C and D respectively.

6.2.28 The index values of sites and the bands derived from them may be used, together with the individual taxa present, as a basis for determining future change in the environmental quality of sites in the different Land Classes.

The fauna

6.2.29 A total of 479 distinct taxa were found in at least one of the 361 sites. Of these taxa, 338 were found in the 81 sites of the arable landscapes, 361 in the 110 sites of pastural landscapes, 246 in the 66 sites in marginal upland landscapes, and 228 in the 104 upland landscapes.

6.2.30 Overall frequencies of occurrence of individual taxa act as a baseline for comparison with future surveys, whilst breakdown by quality class provides an insight into the types of taxa which may increase or decrease in frequency as watercourse quality improves or declines.

Table 6.8 The mean number and standard error of taxa present in watercourses in each landscape type. Comparisons are made for each biological quality band and for all bands combined

	Arable		Pasture		Marginal upland		Upland	
Site type	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Band A sites	28.9	1.6	27.5	1.3	22.9	1.8	16.3	0.9
Band B sites	20.9	1.92	2.9	1.9	19.5	3.0	12.2	1.5
Band C sites	16.4	3.1	11.1	1.9	13.8	2.6	10.2	2.6
Band D sites	6.4	2.5	2.8	0.9	0.0	-	2.3	0.9
All sites	24.1	1.3	24.3	1.1	20.5	1.4	15.2	0.8

6.2.31 The mean numbers of taxa per sample in arable (24.1) and pastural (24.3) landscapes were similar and higher than for marginal upland (20.5) or upland (15.2) landscapes. A more detailed analysis is given in Table 6.8.

6.2.32 When the complicating effects of differential rates of pollution in the different landscapes are removed, by considering only B and A sites, the number of taxa in samples from arable landscapes (28.9) is higher than the other three landscape types. As expected, numbers of taxa per sample decrease with decreasing quality band in each landscape type.

6.2.33 More information on the distribution of individual taxa within and between landscape types is provided in the Countryside Information System (CIS).

6.3 Related surveys and data bases

6.3.1 For reasons outlined in Chapter 2, CS1990 sampling was confined to generally small watercourses. Rivers greater than third-order and large canals were excluded. For a more comprehensive analysis of the distribution of aquatic macro-invertebrates in relation to landscape type, it is necessary to draw on equivalent data from other sources.

6.3.2 The extensive IFE data base contains information on over 2500 samples from approximately 1200 sites. These include the samples collected during both the 1988 feasibility survey and CS1990. Sites in these surveys were sampled only once between late May and November of the respective year. Most of the other sites in the IFE data base were sampled on three distinct occasions during a single calendar year between 1978 and 1991.

6.3.3 Further analyses, and consideration of the relationship between data from CS1990 and those from other complementary sources are to be the subject of a separate report. Analyses of the results of the 1990 River Quality Survey will also be included.

6.4 Summary of Chapter 6

6.4.1 All 508 squares surveyed in 1990 were considered for sampling for running-water macro-invertebrate assemblages. A total of 361 squares had suitable watercourses and a single pond-net sample was taken from each of these squares. Most watercourses sampled were small channels within 2 km of their source

6.4.2 Analyses were undertaken and results are presented at the landscape level. The numbers of samples from each landscape varied between 66 (marginal upland) and 110 (pastural).

6.4.3 Squares lacking flowing watercourses were divided into two types, those without running water channels and those in which all channels were dry. Comparison between squares sampled for aquatic macro-invertebrates in 1988 and re-surveyed in 1990 showed that an average of 9% of squares with flowing water in 1988 were dry in 1990. In all cases, the rate of drying-up was highest in the arable landscape and lowest in the upland landscapes.

6.4.4 Environmental characteristics of sites in each landscape type were compared. A decreasing altitudinal gradient existed from upland landscapes, through marginal upland and pastural, to arable. Slope, velocity and coarseness of substratum decreased along the same gradient, whilst degree of siltation and aquatic macrophyte cover increased.

6.4.5 Sites in the arable and pastural landscapes were more shaded and had more frequent adjacent urban land than marginal upland or upland sites. Bankside trees and woods were primarily broadleaf in the lowland landscapes. Upland sites were more open, on average, than those in the marginal upland landscapes, with twice as many records of adjacent moorland. Coniferous woodland was twice as common alongside upland sites as beside sites in the marginal uplands where broadleaf predominated.

6.4.6 Sites in arable landscapes included more examples of bank maintenance, weed-cutting, channel straightening, dredging and the presence of bridges and weirs than those in any other landscapes. Indications of pollution were most frequently noted in pastural landscapes. Marginal upland and, especially, upland sites were least prone to human influences of the type being recorded.

6.4.7 On average, the poorest environmental quality (determined using the IFE RIVPACS system) was recorded at sites in arable landscapes, with successive improvements through pastural and marginal upland to upland sites. Overall, 71% of sites were assigned to the highest-quality band A ('good' quality), 18% to band B ('fair'), 9% to band C ('poor'), and band D ('very poor').

6.4.8 A total of 479 distinct taxa (mainly at species level) were found in at least one of the sites. The total numbers found in arable and pastural landscape sites were each approximately 50% higher than the total numbers found at marginal upland and at upland sites.

6.4.9 When unpolluted sites only were compared, the mean number of taxa per site was highest at arable sites, closely followed by those in the pastural landscape. Mean numbers per site showed a marked decrease between pastural and marginal upland sites, and again between marginal upland and upland sites.

6.4.10 The data given in the present report act as a baseline against which future change may be measured. More detailed analysis of the results of CS1990, and other complementary data sets, will be included in a separate report. Appropriate data will also be included in the CIS.

Chapter 7 THE RESULTS (V): SOIL SURVEYS

7.1 Introduction

7.1.1 During Countryside Survey 1990 (CS1990), improved soil data was obtained both from existing data bases held by the Soil Survey and Land Research Centre (SSLRC) and the Macaulay Land Use Research Institute (MLURI) and from detailed soil surveys of each of the 508 1 km sample squares. The additional soil data was sought so that the ITE Land Classes could be more fully characterised and to facilitate modelling studies which required soils data as one of the input parameters.

7.1.2 The soil data collected as part of the 1978 survey were used to determine the distribution of soils in the Land Classes and have been used in a number of subsequent studies based on the ITE Land Classification. However, it was always intended that improved data would be linked to the Classification as and when it became available.

7.2 Characterisation of the landscape types

Data from soil survey maps

7.2.1 Analysis of the data sets shows clear variation in the most common soils between Land Classes and between the landscape types. Thus, the arable landscape is dominated by brown soils and surface water gleys, with brown soils occurring in 38% of the squares and surface water gleys in 26% of the squares (Table 7.1). Variations in soil characteristics within the landscape types are given in the Countryside Information System (CIS).

7.2.2 There are, however, interesting variations within the arable landscapes; thus, calcareous soil subgroups are particularly common in southern central England, the east Midlands and the southern Pennines. The eastern lowlands of Scotland are also distinctive, with podzols occurring in about 20% of the squares in this region. In 38% of the squares around the Wash, bordering the east Midlands, (groundwater) gleys occur and the soils are formed in marine clays.

7.2.3 Like the arable landscapes, the pastural landscapes are dominated by brown soils and surface water gleys; brown soils occur in 43% of the 1 km squares and surface water gleys in 33%. Again, there are interesting variations within the landscapes. Thus, the south-west of England includes podzols in 19% of the 1 km squares and land in the coastal areas of England has gleys in 14% of the squares.

7.2.4 Compared to the arable and pastural landscapes, the marginal upland landscapes have a much smaller proportion of squares in which brown soils occur; from c 40% in the lowland landscapes to 27% in the marginal uplands. Surface water gleys are still widespread, occurring in 33% of the squares, but 57% of these gleys are stagnohumic gleys (peaty gleys) compared with c 8% in the lowland landscapes (Table 7.2). There is also a sharp increase in podzolic soils and peats from the lowland landscapes to the marginal uplands. In much of Wales and north-west England there are interesting combinations of brown soils, peats and stagnopodzols, reflecting the marginal status of these areas between the lowlands and uplands. The marginal uplands are, therefore, dominated by podzolic soils.

Table 7.1 Percentage occurrence of major soil groups in the four landscape types

Soil group	Arable %	Pastural %	Marginal upland %	Upland %
Terrestrial raw soils	-	-	<1	<1
Raw gley soils	<1	<1	<1	<1
Lithomorphic soils	10	2	3	2
Pelosols	8	3	<1	-
Brown soils	38	43	19	7
Podzolic soils	6	9	27	37
Surface water gley soils	26	33	35	24
Groundwater gleys	9	6	<1	<1
Man-made soils	<1	<1	<1	<1
Peat soils	2	2	14	28

Table 7.2 Percentage of surface water gleys which are stagnohumic gleys (peaty gleys) in the four landscape types

Landscape type	%
Arable	9
Pastural	7
Marginal upland	57
Upland	64

(peaty) surface water gleys, with peats also common.

7.2.5 The upland landscapes are dominated by acid soils: peats, (peaty) surface water gleys and podzolic soils. The podzolic soils are predominantly (63%) stagnopodzols (peaty podzols) (Table 7.3). There are, however, interesting variations within the upland landscapes; thus, ironpan stagnopodzols and podzols are common in the inland areas in the north and west of Scotland, and northern England, while peats and stagnohumic gley soils are more common in the more low-lying coastal fringes and islands of Scotland.

Comparison of data from the 1978 survey and from soil maps

7.2.6 It is not possible to carry out a rigorous comparison of these two data sets for a number of reasons. First, the 1978 soil data were collected and analysed on the basis of the initial ITE Land Classification (see Appendix 1), while the map data provided by SSLRC and MLURI, and derived from the 1:250 000 scale maps, have been analysed in terms of the revised Land Classification. The soil data collected in 1978 was also grouped on the basis of broad soil classes, essentially at the soil group level but that supplied by SSLRC and MLURI is based on soil subgroups and the more recent soil classification of Avery (1980). A broad comparison of the two soil data sets has been carried out and shows a broad similarity in the patterns of soils groups in each Land Class and landscape type.

7.3 CS1990 field surveys

7.3.1 The maps from the detailed field surveys of each of the 508 squares (undertaken by SSLRC and MLURI – see Chapter 2) are being used in two ways.

i. In order to further improve the descriptions of the Land Classes and landscape types, the proportions of soils of different types are being calculated.
ii. As a basis for ecological studies of the relationships between soils and vegetation, the soils data are being linked to other recorded attributes using Geographical Information Systems.

Table 7.3 Percentages of different types of podzolic soils occurring in the four landscape types

Soil type	Arable %	Pastural %	Marginal upland %	Upland %
Podzols and gley podzols	91	29	23	35
Brown podzolic soils	3	62	42	2
Stagnopodzols	6	9	35	63

7.4 Summary of Chapter 7

7.4.1 Soil data derived from the data bases of SSLRC and MLURI, and based primarily on the 1:250 000 national soil maps, have been used to determine the dominant soils in each 1 km square in GB and in the landscape types used as a framework for this report. In addition, detailed soil maps were produced by field survey of each of the 508 1 km squares.

7.4.2 Brown soils and surface water gleys dominate the arable and pastural landscapes. The marginal upland landscapes contain a smaller proportion of brown soils but a larger proportion of podzolic soils than the lowland landscapes; surface water gleys are still important but are dominated by types which have a peaty surface. The upland landscapes are dominated by peaty surface water gleys, peats and podzolic soils, with peaty surfaced podzols being widespread.

7.4.3 The similarities in the proportions of soils within the landscape types broadly agrees with the grouping of Land Classes used to derive the landscape types (see Chapter 1). More detailed examination of the data shows clear variations in the proportions of different soils between Land Classes and these are available through use of the CIS.

7.4.4 The data from the detailed soil maps and from the existing SSLRC and MLURI data bases show similar proportions of the major soil groups in the Land Classes and landscapes types.

7.4.5 The combined soil data provide a greatly improved characterisation of the landscape in terms of soils and the data now available provide a sound basis for modelling exercises which require soil data.

Chapter 8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Main conclusions

Methods

8.1.1 Countryside Survey 1990 (CS1990) has been the first fully integrated survey of the countryside of Great Britain (GB) incorporating the detail of field survey with the synoptic coverage of satellite imagery. In this respect it is innovative and unique. It provides a snapshot view of a wide range of information at one point in time and sets a new baseline against which future changes in land cover, vegetation, soils and freshwater biota may be assessed.

8.1.2 Much of the effort to date has been concerned with the collection, validation and summation of individual data sets. However, ways in which information from these different sources can be integrated, to give enhanced information and understanding of the countryside, have been demonstrated. Examples include the prediction of different types of woodland and grassland using a combination of the census information from satellite data, with the probabilistic but more detailed data from field survey (see section 3.7). Similarly, another project has used land cover, vegetation plot data and soils information to examine the vegetation types which were likely to be most affected by afforestation of moorlands (Pietx 1992).

Land cover map from satellite data

8.1.3 CS1990 has included the use of satellite data to give the first complete land cover map of GB since the 1950s. Data at 25 m pixel resolution are held in machine-readable form, for each of the c 240 000 1 km squares in GB. These data have been aggregated at three different levels for reporting purposes, but individual users may require the classes (and even sub-classes) to be aggregated in different ways for different purposes.

8.1.4 The 17 key satellite land cover types can be combined with detailed ecological information on individual species, obtained from field survey, thus utilising the strengths of both approaches.

Field survey of land cover and vegetation

8.1.5 The field survey information, collected from only a very small sample of 1 km squares (0.2% of GB), produced estimates of land cover which were close to those derived from satellite imagery. This is due to the efficient dispersal of samples through use of the ITE Land Classification system. Reasons for any differences between the two estimates ranged from the inherent statistical error associated with using a sample, to the inability of each survey approach to record certain features consistently. For example, the satellite interpretation cannot distinguish between moorland and newly planted forest; the field survey cannot record accurate boundaries between semi-natural vegetation types.

8.1.6 One of the more precise aspects of CS1990 has been the recording of plant species data from plots. Statistics on change in plant species, within plots, have been collated for the first time at the national level. Although the data summarised and presented here are from c 1280 plots which were recorded in both 1978 and 1990, one of the major achievements of CS1990 was to record and permanently mark a total of c 11 500 plots. This has formed a very valuable and detailed baseline for monitoring the more subtle changes that may take place in future years.

Other data collected as part of CS1990

8.1.7 The collection, identification and documentation of freshwater biota from the CS1990 squares provide an extremely useful addition to the Institute of Freshwater Ecology's national data base, as well as forming an important scientific resource in its own right

8.1.8 Similarly, the detailed mapping of soil data in the CS1990 field squares is an important addition to the data base, helping to build a better understanding of the sample sites, particularly in relation to changes in plant species and as a basis for agricultural modelling.

Uses of CS1990 data

8.1.9 The importance of the full CS1990 data base, and its use in the Countryside Information System (CIS), should not be underestimated. It is a unique information base which is of equal importance to policy-makers and to environmental scientists, forming an interface between these two groups.

8.1.10 The statistics on changes in hedgerow length have already influenced Government policy on support for hedgerow maintenance. The data on land cover, habitats and plant species will contribute to the UK Biodiversity Action Plan and the UK Strategy for Sustainable Development. It is clear that the CS1990 data set has the potential to contribute information and understanding to a variety of rural environmental policy issues.

8.1.11 Now that the data from CS1990 have been assembled, the scientific community will wish to examine the data and the inherent relationships that exist between the different components.

8.2 Links to other studies

Northern Ireland Countryside Survey

8.2.1 For historical reasons, the countryside surveys of 1978, 1984 and 1990 were of GB only (but including the Isle of Man). However, comparable work has been undertaken in Northern Ireland.

8.2.2 The Northern Ireland Countryside Survey (NICS), funded by the Department of the Environment for Northern Ireland and carried out by the University of Ulster, used a similar approach of land classification and field survey to CS1990. The survey was based on a sample of 628 25 ha (0.25 km²) grid squares surveyed between 1986 and 1991. Only land cover and field boundary data were collected and, because this was the first such survey in Northern Ireland, no change statistics are available. The recording categories used were broadly comparable with those used in CS1990, but the data have been aggregated in a different way for reporting purposes. A summary of the main results, for aggregated categories which are broadly comparable with CS1990, is given in Table 8.1. Definitions of the survey categories are given in Murray *et al.* (1992) and a

Table 8.1 Areas ('00 km²) of broadly comparable land cover categories, by country and UK (+ = presence <1)

Cover type	England Area	England %	Scotland Area	Scotland %	Wales Area	Wales %	N Ireland Area	N Ireland %	UK Area	UK %	NI as % UK
Urban/other	175	13	38	5	18	9	12	9	244	10	5
Tilled land	403	31	59	7	19	9	6	4	487	20	1
Intensively managed grass	328	25	98	12	68	33	42	31	535	22	8
Other managed grass	84	6	73	9	29	14	38	28	225	9	17
Fallow/disturbed	53	4	14	2	3	1	2	1	72	3	3
Wetland vegetation	12	1	20	3	5	2	6	4	43	2	14
Bracken	12	1	15	2	9	4	-	+	37	2	+
Grass moorland	29	2	73	9	17	8	1	1	119	5	+
Open heath	30	2	107	14	9	4	8	6	154	6	5
Dense heath	13	1	28	4	4	2	3	2	48	2	6
Bog	15	1	149	19	3	1	6	4	172	7	3
Broadleaved/mixed woodland	88	7	21	3	12	6	3	2	124	5	2
Scrub	6	+	2	+	1	+	1	1	10	-	10
Conifer woodland	45	3	85	11	7	3	5	4	142	6	4
Coastal vegetation	4	+	5	1	1	+	-	+	9	+	+
Total	**1297**	**100**	**787**	**100**	**205**	**100**	**134**	**100**	**2421**	**100**	

NB i. The NICS recording categories were not identical to those used in CS1990

ii. The Table summarises comparable cover types as given in the Land Cover Definitions report (Wyatt *et al* in prep.)

iii. The following definitions show how CS1990 categories have been aggregated for comparison with categories in the Table

- Intensively managed grass – recreational, recently sown, pure rye-grass, and well-managed grass
- Other managed grass – weedy swards, non-agriculturally improved grassland, calcareous grassland and upland grass
- Fallow/disturbed – non-cropped arable, unmanaged grassland, felled woodland, waste and derelict land
- Grass moorland – 'purple moor grass' and 'other moorland grass'
- Coastal vegetation – saltmarsh, maritime vegetation, dune grassland

Table 8.2 Lengths ('000 km) of aggregated boundary types, by country and UK

Boundary type	England	Scotland	Wales	N Ireland	UK	NI as %UK
Hedge (H, HB, HF, HFB, HW, HWB, HWF, HWFB*)	378	33	54	27	492	5
Relict hedge (R, RB, RF, RFB)	62	8	13	98	181	54
Wall (W, WB, WF, WFB)	73	91	28	14	205	7
Bank (B, FB)	32	4	16	45	97	46
Fence (F)	385	221	70	52	728	7

NB See Table 4.1 for explanation of abbreviations (ie B = Bank, F = Fence; G = Grass strip, H = Hedge, R = Relict hedge, W = Wall)

comparison with CS1990 is included in Wyatt *et al.* (in prep.) and in the CIS.

8.2.3 Points to note from Table 8.1 are the dominance of grassland categories in NI, such that Northern Ireland contains over 10% of the UK stock of permanent grassland, scrub and wetland vegetation.

8.2.4 The data for boundaries can similarly be aggregated for comparative purposes, as shown in Table 8.2. Northern Ireland has more than three times the average UK density of hedges and relict hedges (about 9 km per km^2 in Northern Ireland compared with about 3 km per km^2 in the UK overall). According to these aggregations, Northern Ireland has about half the UK stock of relict hedges and of banks. High proportions of hedges and walls in Northern Ireland are relict/ruined.

Land Cover Definitions (LCD) project

8.2.5 A framework for comparison between surveys is provided by the Department of the Environment (DOE) Land Cover Definitions project (LCD) (Wyatt *et al.* in prep.). Within this project, a dictionary is provided of land cover and land use classifications and surveys. Numerical comparisons were made between four major data sets (CS1990 field survey; CS1990 satellite land cover map; Monitoring Land Use Change project; and Ministry of Agriculture, Fisheries and Food June census), but others such as the National Countryside Monitoring Scheme (NCMS), National Land Use Classification and the Co-ordinated Environmental Information in the European Community system (CORINE) were compared in terms of definitions only. Subsequent analyses can use these studies as the basis for further interpretation of CS1990 results as and when required. The dictionary of land cover definitions and a facility for comparing definitions in different surveys are provided in the CIS.

Changes in key habitats

8.2.6 The sampling approach used in the field survey of CS1990 provides reliable information about the more commonly occuring habitats but there is less information about the rarer habitats, such as lowland heath, calcareous grassland, moorland, coastal vegetation and wetlands. To improve the data available for these 'key habitats' in England, the DOE has commissioned ITE to adapt the CS1990 methodology and undertake a more focussed study. Field work was completed in the field seasons of 1992 and 1993. The project is due for completion in October 1994.

Processes of countryside change

8.2.7 Many of the changes in land cover and vegetation recorded in CS1990 are the result of land use and management decisions made by farmers. The Economic and Social Research Council (ESRC) and DOE are funding a study by Wye College into the socio-economic processes of countryside change. The study involves a questionnaire survey of farmers in 256 of the 1 km squares form CS1990. In the analysis it will be possible to link the ecological changes observed with the activity and attitudes of farmers. Bringing together the disciplines of ecology and socio-ecnomics in this way is a great challenge.

Modelling studies

8.2.8 The data collected in CS1990 will form the basis for a variety of modelling studies. Land cover, soils and freshwater invertebrate data can be used in hydrological models to predict water quality in river catchments. Detailed data on the species composition of plots can be used in models of ecological succession and vegetation development in different management regimes. Land cover data from CS1990 will be used to update the

Land Use Allocation Model (LUAM) developed by the Centre for Agricultural Strategy, University of Reading.

8.3 Recommendations for further work

8.3.1 In each of the component parts of the project, opportunities for further work have been recognised:

- The satellite land cover map has a wide range of potential applications for resource assessment and is currently being developed for this purpose. There is a range of potential GIS developments linking the map to other spatial data bases. There is also a possibility of monitoring change from the existing map at regional or national levels. The application of mathematical procedures for pattern analysis has a high scientific potential.

- The digitised land cover data base, from each 1 km square in the field survey, could be used for spatial analysis in order to relate the land cover to the composition of the detailed vegetation plots. The relationship of linear features and their associated vegetation also deserves further study. The different types of pattern analysis, developed in the Ecological Consequences of Land Use Change (ECOLUC) project (Bunce *et al.* 1993), could reveal important information providing relationships between patches of vegetation and animal distribution. The analytical overlaying power of Geographical Information Systems means that the data base is ideal for looking at scenarios of potential change in the landscape.

- One principal area of future work that has been identified is the development of an understanding of the processes of change, since currently these can only be inferred. A range of hypotheses has been developed which need to be tested in order to develop adequate predictive models; these can then be used to aid land management. Further analysis is required of the patterns of diversity and their relationship with the spatial arrangement of land cover elements.

- The freshwater studies form a fundamental baseline for assessing future changes in freshwater fauna and water quality, relating these to changes in land use and land cover. An integrated approach would identify important information on sensitive taxa and the relationships between change and management of the land.

- The soils information will be an important element of studies of vegetation and change and could provide links to work on critical loads and pollution levels at local and national scales.

8.3.2 In addition, a number of suggestions for future work have arisen as a result of a meeting held in Edinburgh (organised by the Land Use Research Coordinating Committee (LURCC), March 1993), which was called specifically to discuss work that might develop from CS1990 (LURCC 1993). The main areas for future work, recognised by the meeting, were as follows:

- **Expansion of the data base** – integration of the CS1990 data with other national data bases on agriculture, climate pollution and biology.

- **Availability of data** – development of the CIS and its wider availability for research and application.

- **Spatial scales** – rigorous assessment of the application of results at national, regional and local scales and development of analysis (or synthesis) to express distinct zones of influence.

- **Causal relationships** – exploration of correlative relationships to assess causality, eg by application of theory, field experiments, detailed case studies or testing predictive models against observed spatial and temporal patterns.

- **Policy targeting and analysis** – use of the CS1990 data base to establish objectives, to target policy in terms of spatial locations or subject, and to test the effectiveness of policies (adoption dynamics).

8.3.3 The LURCC report of the meeting states: 'It was generally accepted that the combination of information which had been incorporated into CS1990 constitutes a major benchmark for future biological research, for integration with social and economic research, and for exploration of important policy issues such as conservation of biodiversity and the effects of the Common Agricultural Policy.'

GLOSSARY OF TERMS, ABBREVIATIONS AND ACRONYMS

1990 River Quality Survey - chemical and biological survey of the quality of watercourses in 1990, undertaken by the Institute of Freshwater Ecology (IFE) and commissioned by the National Rivers Authority (England and Wales), the River Purification Boards (Scotland) and the Department of Economic Development (N. Ireland).

Aerial photographic interpretation (API) - the use of aerial photographs to update and enhance base maps prior to field survey (see section 2.3.9).

Aquatic macrophytes - higher plants which are growing in, or on, water

Arable landscapes - one of the four landscape types into which ITE Land Classes have been aggregated to present results from CS1990 (see Appendix 1 - section A1.7).

ARC/INFO - proprietary Geographical Information System (GIS) written by the Environmental Systems Research Institute, Redlands, California, and used at both the ITE Monks Wood and Merlewood sites.

ASPT - average score per taxon - the total site score divided by the number of taxa contributing to that score (see section 2.5.17).

Biotic index values - simple numeric representations of complex biological information, normally used to indicate some aspect of environmental quality (see BMWP score, number of scoring taxa and ASPT).

BMWP - Biological Monitoring Working Party - responsible for devising a scoring system relating freshwater biota to their tolerance of organic pollution (see section 2.5.16 and Armitage *et al.* 1983)

BNG - British National Grid - as shown, for example, on Ordnance Survey maps.

BNSC - British National Space Centre - based in London, the BNSC was formed in 1985 as a partnership between UK Government departments and the research councils (eg NERC) to form the focus for Britain's non-military space interests. A contributor of funding to CS1990.

Boundary plots - one of the linear plot types recorded during the field survey, placed alongside field boundaries (see section 2.3.11).

Buffer zone - used in classification of satellite imagery to define an area of user-selected width surrounding features of a defined type (see section 2.2.30).

Category 1 species - plant species which were used in the analysis of botanical data, having few taxonomic or identification difficulties and which were consistently recorded by field surveyors (see Appendix 2).

Census data - data collected from every unit/member of a population, eg a complete inventory of land use information (cf sample data).

Changes in Key Habitats - a DOE-funded project to collect data from specific habitats which have a limited representation in CS1990 and to examine the effects of designations on these.

CIS - Countryside Information System - a computer-based system to display and integrate CS1990 data and other environmental information.

CORINE - Co-ordinated Information on the European Environment - a joint European initiative which includes the aim of mapping the land cover of all CEC countries using satellite imagery.

DAFS - Department of Agriculture and Fisheries for Scotland - responsible for the promotion of agriculture and the fishing industry in Scotland (now **SOAFS - Scottish Office Agriculture and Fisheries Department**).

DECORANA - Detrended Correspondence Analysis - a FORTRAN computer program which produces an ordination (gradient) of species and plots, using an improved version of Correspondence Analysis.

Digital data base - usually referring to a data base comprised of digitised map co-ordinates (see Digitising).

Digitising - the process of capturing information from maps in the form of points, lines or areas, and converting these into computer-readable co-ordinates (grid references).

DOE - Department of the Environment - one of the principal funders of CS1990 and the commissioners of this report.

DRA - Directorate of Rural Affairs - division of DOE responsible for CS1990.

DTI - Department of Trade and Industry - one of the principal funders of CS1990, especially in relation to the land cover map.

ECOLUC - Ecological Consequences of Land Use Change - ITE research project, completed in 1989 and funded by DOE (see Bunce et al. 1993)..

EQI - Environmental Quality Index - an expression of the extent to which the freshwater fauna of a site matches that to be expected in the absence of environmental stress (see section 2.5.18).

Error terms - (eg standard error) measures of the reliability of an estimate which has been based on a sample (eg when extrapolating from a sample of 1 km squares to a national or regional estimate).

GIS - Geographical Information System - a computer package which handles spatial information (usually as computerised maps) and which allows analysis of, for example, area, length and overlay.

Habitat plots - 4 m^2 plot recorded within areas of semi-natural vegetation during the field survey element of CS1990. Up to five were recorded in each 1 km square (see section 2.3.11).

IFE - Institute of Freshwater Ecology - one of the research institutes of the Natural Environment Research Council.

IIS - International Imaging Systems (also I^{2}S) - image analysis software/hardware for processing satellite images.

IR - infra-red - wavelength used in satellite imagery.

ISA - Indicator Species Analysis - a computer program from which TWINSPAN was developed.

ITE - Institute of Terrestrial Ecology - one of the research institutes of the Natural Environment Research Council.

ITE Land Classification - the system developed by ITE to classify each of the c 240 000 1 km squares in Great Britain into one of 32 Land Classes, depending on its environmental affinities Used to stratify the CS1990 field survey (see Appendix 1).

Land Classes - 32 strata produced by the ITE Land Classification (see Appendix 1).

Land cover - the composition of the land surface, being described in terms of **land cover classes** (eg arable crops, trees, buildings, bare rock)

Land cover map - map of GB showing the principal land cover classes and derived from interpretation of satellite imagery by staff at ITE Monks Wood, as part of CS1990.

Landscape type - one of the four aggregations of the ITE Land Classes (into arable, pastural, marginal upland and upland types) (see Appendix 1).

Laserscan GIS - proprietary Geographical Information System, developed by Laser-Scan Laboratories Ltd, Cambridge.

Linear plots - 10 m x 1 m plots placed alongside field boundaries, streamsides and road verges in the 1 km field survey sites from which vegetation data were recorded (see section 2.3.11).

LUAM - **Land Use Allocation Model** - the product of research project carried out by the Centre of Agricultural Strategy, Reading University (with input by ITE), which links national agricultural statistics to the ITE Land Classes.

LURCC - **Land Use Research Coordinating Committee** - a national committee under the auspices of NERC, with membership from Departments, Agencies and academia, and a remit to encourage collaboration and dissemination of land use research.

MAFF - **Ministry of Agriculture, Fisheries and Food** - responsible for administering Government policy for agriculture horticulture and fisheries in England.

Main plot classes - outputs from TWINSPAN classification of all Main (vegetation) plots (29 in number).

Main plots - 200 m^2 plots placed at random in each 1 km field sample square (5 in each) from which vegetation data were recorded.

Majority filter - filtering procedure, used to smooth out 'noise' in classification of satellite data, to produce generalised images

Marginal upland landscape - one of the four landscape types into which ITE Land Classes have been aggregated to present results from CS1990 (see Appendix 1 - section A1.7).

Minimum mappable area (0.04 ha) - smallest area of land to be mapped as a homogeneous unit (using a consistent coded description) within the field survey part of CS1990.

Minimum mappable length (20 m) - shortest length of any linear feature to be mapped as a homogeneous unit (using a consistent coded description) within the field survey part of CS1990.

MLC[1] - **Maximum likelihood classifier** - statistical procedure used in the classification of satellite imagery to extrapolate from sample data and to allocate pixels in a remotely sensed image to the most appropriate classes, based on the spectral reflectances recorded by the sensor.

MLC² - **Monitoring Landscape Change** (project) - 1984 sample survey of the countryside of England and Wales carried out by Huntings Technical Services on behalf of the DOE and the Countryside Commission.

MLURI - **Macaulay Land Use Research Institute** - based in Aberdeen, MLURI was subcontracted to carry out the soil survey element of CS1990 in Scotland (see section 2.6.1).

MSS - **Multispectral Scanner** - instrument carried on all Landsat satellites, offering an 80 m spatial resolution and four wavebands.

Multiple-element category - used in describing physical boundaries which have more than one element (eg wall with a wire fence)

Multivariate statistical technique - statistical analysis using more than one variable (characteristic) at a time to classify members of a statistical population.

National Remote Sensing Centre - (now **National Remote Sensing Centre Limited**) - home of the Earth Observation Data Centre and British agents for the supply of Landsat data.

NCC - **Nature Conservancy Council** - until 1992, the Government agency with responsibility for nature conservation in Britain. now undertaken by the Countryside Council for Wales, English Nature, the Joint Nature Conservation Committee and Scottish Natural Heritage. A contributer of funding to CS1990.

NCMS - **National Countryside Monitoring Scheme** - developed by the former Nature Conservancy Council (NCC) to record changes in GB using aerial photography on a county-by-county basis. Currently being used in Scotland.

NERC - **Natural Environment Research Council** - responsible for planning, support and encouragement of research in those sciences that relate to man's natural environment and its resources.

Northern Ireland Countryside Survey (NICS) - field survey adopting similar approach to CS1990, funded by the Department of the Environment for Northern Ireland, carried out between 1986 and 1991 (see section 8.2.2).

NRA - **National Rivers Authority** - formed in 1989 as an independent body with statutory responsibilities for the management of such things as water resources, flood defence, fisheries and pollution control for all inland waters, estuaries, coastal waters and natural underground water in England and Wales

ORACLE - data base management system, widely used in CS1990.

OS - **Ordnance Survey** - based in Southampton and responsible for the official survey and mapping of Great Britain.

Pastural landscape - one of the four landscape types into which ITE Land Classes have been aggregated to present results from CS1990 (see Appendix 1 - section A1.7)

Patch size - used in landscape ecology and pattern analysis as a measure of the area of a unit of vegetation, habitat or land cover type.

Pattern analysis - general term to describe the measurement of elements in the landscape, such as area of fields, lengths of boundaries and edges, and the relationships between them.

Pixel - area of ground surface which is the unit of classification used in satellite image interpretation (eg 25 m x 25 m in CS1990).

Plot classes - outputs from classification of vegetation plots and determined by the plant species present in the plot - plots in the same class will generally have the same species present

Polygon data - data derived from multi-sided figures representing distinct areas on a field survey map or satellite image.

Polynomial model - mathematical expression which, in this report, expresses how the geometry of the original satellite image relates to that of the earth's surface and which is used to alter the image geometrically to match the desired map scale and projection.

Primary codes - used in the field mapping part of CS1990 to define the general nature of a feature (eg woodland, lake, field of grass) (cf secondary codes which describe the feature in more detail).

Principal vegetation gradient - name given to the first axis resulting from a TWINSPAN analysis of the vegetation data - generally interpreted as being from plots which are characteristic of highly managed lowland vegetation, often with high levels of nutrients, to those of unmanaged upland vegetation with low nutrient levels

Proximity analysis - measurement of the closeness of one land cover type to another.

Quality assessment - means of measuring the quality of work, eg by repeat sampling of vegetation plots (see Appendix 4).

Quality Assurance Exercise - partial resurvey carried out in 1990 and 1991 to assess consistency and reliability of CS1990 field survey (see Appendix 4).

Raster data - data which relate to areas rather than lines (vector data) - raster maps may be made up of a grid of cells, each having a separate value.

Reflectances - light values reflected from the earth's surface and recorded by satellites.

Relict hedges - boundaries recorded in the field survey which at some point in the past have been hedges but are something else at the time of survey (eg line of trees).

Remote sensing - a general term to include observation of the land surface from a distance, usually applied to aerial photography and satellite imagery.

RIVPACS - a software package devised by IFE for assessing the biological quality of rivers.

RPB - River Purification Boards - have similar responsibilities in Scotland as the National Rivers Authority in England and Wales.

Sample data - data which have been collected from only some members of a statistical population and which are usually assumed to be representative of the whole population.

Satellite image - general term used to refer to data aquired by remote sensing; also used to refer to the visual display of such data on a screen or as printed paper products

Satellite imagery - process of collecting satellite images.

SE - standard error - estimated standard deviation of an estimate of a parameter (see Appendix 3 and 3a).

Secondary codes - used in the field mapping part of CS1990 to define the characteristics of mapped features in detail (eg tree species in woodland, size of lake, species present in grass field) (cf primary codes).

Semi-natural vegetation - generally, vegetation which has not been created by human activity (management) although it may have been influenced by it.

Soil group - division of soils into one of ten major groups, eg podzolic soils.

Soil subgroups - division of major soil group into more detailed classes, as supplied by SSLRC and MLURI for CS1990

Spatial recording - recording the position of features (eg fields, trees) using a co-ordinate (grid reference) system.

Spatial scales - data recorded at one scale applied at national, regional or local levels.

Species cover values - estimates of the ground area covered by a plant species.

Species groups - groupings of plant species resulting from DECORANA analysis of the whole CS1990 vegetation data set (see section 2.3.25).

Spectral characteristics - reflectances in different wavebands, from different surfaces on the ground, measured at sensor, and peculiar to a particular cover type.

SSLRC - Soil Survey and Land Research Centre - based at Silsoe, Bedfordshire, SSLRC was subcontracted to carry out the soil survey element of CS1990 in England and Wales (see section 2.6.1)

Stock - the amount of any feature present at a point in time.

Stratified sample - sample drawn from different divisions (strata) of the whole data set - intended to increase the chances of the sample being truly representative of the whole population.

Stratified random sample - sample drawn at random from within each of the different strata of a data set (eg the CS1990 1 km field sample squares were drawn at random from each of the 32 ITE Land Classes (strata))

Stream order - classification of streams/rivers where a first-order stream is one which runs from a source to the first confluence; second-order streams run from the confluence of two first-order streams to a confluence with another second-order stream, and so on.

Streamside plots - one of the linear plot types, placed alongside flowing watercourses (see section 2.3.11).

Student's t-test - statistical procedure to test for significant differences between two sets of data.

Suburban - land cover class shown on the land cover map (see Appendix 2).

Target land cover classes - one of the classifications of land cover data produced from the land cover map (being 25 in number)

Taxa - any group of organisms that is sufficiently distinct from any other group to be distinguished by name at one or other level of classification.

Thematic Mapper (TM) - scanner on board the Landsat satellite, which provided the reflectance data used in mapping land cover: the scanner offers seven wavebands of data for relectances from 30 m ground cells.

TWINSPAN - Two-way Indicator Species Analysis - a FORTRAN program used in CS1990 to classify plot data into vegetation classes (see Hill 1979).

Unsurveyed urban land - a census estimate of urban land from all 1 km squares not surveyed (see Appendix 3 - section A3.46).

Upland landscape- one of the four landscape types into which ITE Land Classes have been aggregated to present results from CS1990 (see Appendix 1 - section A1.7).

Vascular plants - all plants excluding mosses, liverworts and algae (ie ferns, conifers and flowering plants).

Vector-digitising - entering the spatial co-ordinates of features (eg fields lines of trees) from a map to a GIS using continuous lines in order to represent the feature as exactly as possible (cf raster data)

Vegetation gradient - see principal vegetation gradient

Vegetation plots - three types of plot, **Main**, **Habitat** and **linear**, recorded in each 1 km field survey square for vegetation analysis (see section 2.3.11).

Verge plots - one of the linear plot types, placed alongside roads/tracks (see section 2.3.11).

Ward's minimum variance clustering - statistical technique to group species which have similar distributions (see section 5.1.4)

REFERENCES

Armitage, P.D., Moss, D., Wright, J.F. & Furse, M.T. 1983 The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running water sites *Water Research*, 17, 333–347

Avery, B.W. 1980 *System of soil classification for England and Wales (higher categories)* (Technical Monograph no 14) Harpenden Soil Survey

Barr, C.J. 1990 Mapping the changing face of Britain *Geographical Magazine*, 62(9), 44–47

Barr, C.J. 1990 *Field handbook* Grange-over-Sands Institute of Terrestrial Ecology

Barr, C.J., Ball, D.F., Bunce, R.G.H. & Whittaker, H.A. 1985 Rural land use and landscape change. *Annual Report of the Institute of Terrestrial Ecology 1984*, 133–135

Barr, C.J., Benefield, C.B., Bunce, R.G.H., Ridsdale, H.A. & Whittaker, M. 1986 *Landscape changes in Britain* Abbots Ripton, Huntingdon Institute of Terrestrial Ecology

Barr, C.J., Howard, D.C., Bunce, R.G.H., Gillespie, M.K. & Hallam, C.J. 1991 *Changes in hedgerows in Britain between 1984 and 1990* NERC contract report to the Department of the Environment, Grange over-Sands Institute of Terrestrial Ecology.

Bunce, R.G.H. 1979 Ecological survey of Britain. *Annual Report of the Institute of Terrestrial Ecology 1978*, 74–75

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

Bunce, R.G.H., Barr, C.J. & Whittaker, H.A. 1983 A stratification system for ecological sampling In *Ecological mapping from ground, air and space* edited by R M Fuller 39–46 (ITE symposium no 10) Cambridge Institute of Terrestrial Ecology

Bunce, R.G.H., Howard, D.C., Hallam, C.J., Barr, C.J. & Benefield, C.B. 1993 *Ecological consequences of land use change* London Department of the Environment

Burnham, K.P., Anderson, D.R., White, G.C., Brownie, C. & Pollock, K.H. 1987 *Design and analysis methods for fish survival experiments based on release-capture* (Monograph no 5) Bethesda, Maryland American Fisheries Society

Clapham, A.R., Tutin, T.G. & Moore, D.M. 1987 *Flora of the British Isles* Third edition Cambridge Cambridge University Press

Clarke, R.T., Furse, M.T. & Wright, J.F. 1992 *Testing and further development of RIVPACS A comparison of single, paired and 3 season combined macro-invertebrate samples for the biological banding of river quality* (NERC contract report to the National Rivers Authority) Wareham Institute of Freshwater Ecology

Cochran, W.G. 1977 *Sampling techniques* 3rd ed Wiley New York

Coleman, A. 1961 The second land use survey progress and prospect *Geographical Journal*, **127** 168–186

Cummins, R.C., French, D., Bunce, R.G.H., Howard, D.C. & Barr, C.J. 1992 *Diversity in British hedgerows* (NERC contract report to the Department of the Environment) Grange-over-Sands Institute of Terrestrial Ecology

Fuller, R.M., Brown, N.J., Ullyett, J.M., Sanders, M.E., Groom, G.B., Howard, D.C. & Gillespie, M.K. 1993 *Countryside Survey 1990 mapping the land cover of Great Britain using Landsat imagery a demonstrator project in remote sensing. Final report on pattern analysis and GIS* (NERC contract report to the Department of the Environment) Abbots Ripton, Huntingdon Institute of Terrestrial Ecology

Fuller, R.M. & Parsell, R.J. 1990 Classification of TM imagery in the study of landuse in lowland Britain practical considerations for operational use *International Journal of Remote Sensing* **11**, 1901–1917

Fuller, R.M., Parsell, R.J., Oliver, M. & Wyatt, G. 1989a Visual and computer classifications of remotely-sensed images A case study of grasslands in Cambridgeshire *International Journal of Remote Sensing* 10, 193–210

Fuller, R.M., Jones, A.R. & Wyatt, B.K. 1989b Remote sensing for ecological research problems and possible solutions In *Remote sensing for Operational Applications technical contents of the 15th Annual Conference of the Remote Sensing Society, 1989*, compiled by E C Barrett & K A Brown, 155–164. Reading Remote Sensing Society.

Furse, M.T., Moss, D., Wright, J.F. & Armitage, P.D. 1987 Freshwater site assessment using multivariate techniques In *The use of invertebrates in site assessment for conservation*, edited by M L Luff Newcastle-upon-Tyne Agricultural Environment Research Group, University of Newcastle upon Tyne

Furse, M.T., Clarke, R.T., Blackburn, J.H., Gunn, R.J.M., Symes, K.O., Winder, J.M. & Harrison, S.N. In prep *Countryside Survey 1990 running-water studies* Wareham Institute of Freshwater Ecology

Gates, S., Gibbons, D.W., Fuller, R.M. & Hill, D.A. 1993 The influence of habitat diversity, measured by remote sensing, on avian species richness in Eastern England *Journal of Animal Ecology* In press

Griffiths G.H. & Wooding, M.G. 1989 *Use of satellite data for the preparation of land cover maps and statistics* Final report to the National Remote Sensing Centre contract report to Department of the Environment Volume 1, main report Unpublished

Hill, M.O. 1979 *TWINSPAN – a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes* Ithaca, N Y Section of Ecology and Systematics, Cornell University

Hill, M. O., Bunce, R. G. H. & Shaw, M. W. 1975 Indicator species analysis, a divisive polythetic method of classification, and its application to a survey of native pinewoods in Scotland *Journal of Ecology*, 63, 597–613

Hopkins, A. & Wainwright, J. 1989 Changes in botanical composition and agricultural management in enclosed grasslands in England and Wales 1970–1986 and some conservation implications *Biological Conservation*, **47**, 219–235

Jones, A.R. & Wyatt, B.K. 1988 Improved automated classification of upland environments utilizing high resolution satellite data In *Ecological change in the uplands* edited by M B Usher & D B A Thompson, 109–118 (BES Special Publication no 7 Oxford Blackwell Scientific

Jones, A.R., Settle, J. & Wyatt, B.K. 1988 Use of digital terrain data in the interpretation of SPOT-1 HRV multispectral imagery *International Journal of Remote Sensing*, **9**, 669–682

Kershaw, C.D. & Fuller, R.M. 1992 Statistical problems in the discrimination of land cover from satellite images a case study in lowland Britain *International Journal of Remote Sensing*, **13**, 3085–3104

Land Use Research Coordinating Committee. 1993. *Countryside survey 1990 a preview* Newcastle-upon-Tyne LURCC

Moss, D., Furse, M.T., Wright, J.F. & Armitage, P.D. 1987 The prediction of the invertebrate fauna of unpolluted running-water sites in Great Britain using environmental data *Freshwater Biology*, **17**, 41–52.

Murray, R., McCann, T. and Cooper, A. 1992 *A land classification and landscape ecological study of Northern Ireland* (University of Ulster contract report to the Department of the Environment (NI)) Coleraine University of Ulster

Nilsson, I.N. & Nilsson, S.G. 1985 Experimental estimates of census efficiency and pseudo turnover on islands error trend and between observer variation when recording vascular plants. *Journal of Ecology* **73** 65–70.

Pietx i Colom, J. 1992 *Conifer afforestation in upland Britain a model of impact assessment for soil types and heather* (Calluna vulgaris) *vegetation* MSc thesis, Institute of Environmental and Biological Sciences, University of Lancaster

Pitcairn, C.E.R., Fowler, D. & Grace, J. 1991. *Changes in species composition of semi-natural vegetation associated with the increase in atmospheric inputs of nitrogen* (NERC contract report to the Nature Conservancy Council) Penicuik, Midlothian Institute of Terrestrial Ecology

Prosser, M.V. & Wallace, H.L. 1992 *1990 Countryside Survey. Quality Assurance Exercise* Report to Institute of Terrestrial Ecology, Ecological Surveys, Bangor

Schowengerdt, R.A. 1983 *Techniques for image processing and classification in remote sensing* London. Academic Press

Stamp, L.D. 1962 *The land of Britain its use and misuse*. 3rd ed London Longman

Sweeting, R.A., Lowson, D., Hale, P. & Wright, J.F. 1992 1990 biological assessment of rivers in the UK In *River water quality*, edited by P J Newman, M A Piavaux & R A Sweeting, 319–326 *Ecological assessment and control*. Luxembourg Commission of the European Communities

Townshend, J.R.G., Gayler, J.R., Hardy, J.R., Jackson, M.J. & Baker, J.R. 1983. Preliminary analysis of Landsat 4 Thematic Mapper products. *International Journal of Remote Sensing*, **4**, 817–828.

Usher, M.B. 1991. Biodiversity – a scientific challenge for resource managers in the 1990s. In *Biological diversity*, edited by F D. Pineda *et al*, 33–40 Madrid Fundación Ramón Areces

Watson, A. 1988 Land use, reduction of heather and natural tree regeneration in open land *Annual Report of the Institute of Terestrial Ecology. 1988*, 25–27

Wright, J.F., Armitage, P.D., Furse, M.T., Moss, D. & Gunn, R.J.M. 1988 *Analysis of natural and polluted river communities in Great Britain. Report for the period April 1984 – March 1988* (NERC contract report to the Department of the Environment) Wareham. Institute of Freshwater Ecology

Wright, J.F., Furse, M.T., Clarke, R.T. & Moss, D. 1991 *Testing and further development of RIVPACS* (NERC contract report (R&D 243/1/Y) to the National Rivers Authority) Wareham Institute of Freshwater Ecology

Wyatt, B.K., Greatorex-Davies, N., Bunce, R.G.H, Fuller, R.M. & Hill, M.O. In prep *Comparison of land cover definitions* (NERC contract report to the Department of Environment) Abbots Ripton, Huntingdon Institute of Terrestrial Ecology

Appendix 1 THE ITE LAND CLASSIFICATION AND THE FOUR LANDSCAPE TYPES

Description of the ITE Land Classification

A1.1 The term 'Land Classification' has been used to describe a range of methods variously concerned with splitting or grouping land cover, land use and landscape. The techniques are based on the assumption that the land surface can be divided through objective mathematical classification of defined environmental parameters. The function of the ITE Land Classification is to stratify the land so that it can be sampled efficiently to provide estimates of cover and distribution of landscape elements, which cannot be easily or cost-effectively determined by direct census. A carefully applied stratified sample can provide both reliable population estimates and descriptions of the patterns of variability. The major assumption is that the character of a landscape is determined by physical environmental factors, although these factors may have been modified by the influence of man. The patterns visible today reflect both the management history and current physical conditions; analysis of ecological change relies on the identification of the causative factors which must either be measured directly or replaced by surrogate variables.

A1.2 The ITE Land Classification uses the 1 km squares of the Ordnance Survey National Grid as its sampling unit. One km squares are grouped into 32 'Land Classes' on the basis of a wide range of environmental parameters. Such standard, regular sampling units have the advantages of being easy to handle and objective, removing some of the subjectivity involved in attempting to define boundaries of natural units. The heterogeneity within the squares is an integral part of the approach and is used to distinguish Classes. The development of the ITE Land Classification system has been in two phases.

A1.3 Initially, in 1977 the Land Classes were derived from a statistical classification of a nationally distributed sample of 1228 1 km squares, each of which was situated at the intersection of a 15 km x 15 km grid. For each sample square, 282 environmental attributes were recorded from maps, covering climate, topography, geology, and man-made artefacts (such as roads and railways). On the basis of these data, the sample squares were classified into 32 Land Classes using Indicator Species Analysis (ISA – Hill *et al.* 1975). This technique generates a subset of 'indicator' attributes which can subsequently be used as a key to allocate further sample squares into classes. The Land Classes from this classification were used as strata for the 1978 national field survey of 256 squares (eight from each Land Class), and the 1984 survey of the same squares plus an additional four squares from each class.

A1.4 The second phase of development, in 1989, classified all 240 000 squares in GB into Land Classes. Since 1977, advances in computer power and the availability of Geographical Information Systems (GIS) made it possible to automate some data capture and to analyse collectively this quantity of data. It was decided at the outset to simulate the initial classification as closely as possible. Whilst in theory, the ISA key derived from the first classification might have been used simply to allocate squares to Classes, in practice the acquisition of the necessary detailed data for the key for every GB square was logistically impossible within the limitations of resources. Instead, a reduced set of some 70 attributes, selected to represent as closely as possible the variability in the initial classification, were recorded for each of the 240 000 GB squares and used in the classification process. These attributes can be grouped under seven broad headings: topography, climate, solid geology, drift geology, man-made features, island status and distance from coasts. The technique (logistic discrimination) used the 1228 squares of the initial classification as a 'training set', so maintaining a close correspondence between the two classifications. This latest classification of all 240 000 GB squares into 32 Land Classes forms the stratification system used to select sample squares for the Countryside Survey 1990.

A1.5 The ITE Land Classification thus provides a system which describes GB, and its constituent parts, in terms of their underlying environmental characteristics. Further, it provides a representative framework for sampling features which are likely to be associated with these underlying environmental parameters, and, together with its use of a standard spatial unit (the 1 km square), it provides a useful system for integrating information.

Table A1.1 Relative distribution of mapped elements amongst the four landscape types (% of mapped element in each landscape type – source Bartholomew)

	Arable	Pastural	Marginal upland	Upland
Water – sea and tidal	9	34	16	41
Water – inland	18	12	14	56
Woodland	29	18	26	28
Built up – towns	51	46	3	+
Built up – villages	48	40	8	5
Motorways	40	57	3	+
A-roads	44	41	9	6
B-roads	45	38	11	6
Minor roads	45	41	11	3
Canals	43	53	3	+
Railways	41	49	6	4
Rivers	27	29	18	26
Open countryside	34	29	16	21

Table A1.2 The average and maximum altitude (m) for the different landscape types. The figures are based on the mean altitude per 1 km square drawn from a 100-point matrix based over each square

	Mean altitude (m)	Maximum altitude (m)
Arable	76	280
Pastural	87	340
Marginal upland	244	985
Upland	313	1225

Table A1.3 Climate in the landscape types, describing the average hours of bright sunshine per day in July, the mean minimum temperature (in °C) in January and the average number of days with snow falling in each year (source. 1941–70 Air Ministry data)

	Sun (hrs)	Temp (°C)	Snow (days)
Arable	5.8	0.7	26.0
Pastural	5.7	1.4	22.1
Marginal upland	4.9	0.9	36.9
Upland	4.4	0.3	48.0

Table A1.4 Landscape composition of each county (% of county in each landscape type)

County/Region	Arable	Pastural	Marginal upland	Upland
England				
Avon	15	85	0	0
Bedford	98	2	0	0
Berkshire	61	39	0	0
Buckinghamshire	70	30	0	0
Cambridgeshire	98	2	0	0
Cheshire	12	82	6	0
Cleveland	41	51	8	0
Cornwall	+	100	+	0
Cumbria	12	34	35	18
Derbyshire	22	38	39	+
Devon	3	87	10	0
Dorset	61	39	0	0
Durham	20	34	12	34
East Sussex	88	12	0	0
Essex	95	5	0	0
Gloucestershire	46	49	5	0
Greater London	42	58	0	0
Gtr Manchester	3	77	20	0
Hampshire	77	23	0	0
Hereford & Worcester	20	75	5	0
Hertford	90	10	0	0
Humberside	55	45	+	0
Isle of Wight	67	33	0	0
Kent	86	14	0	0
Lancashire	2	67	31	+
Leicestershire	82	18	0	0
Lincoln	95	5	0	0
Merseyside	2	98	0	0
Norfolk	95	5	0	0
North Yorkshire	18	47	26	10
Northampton	96	4	0	0
Northumberland	36	26	11	27
Nottinghamshire	82	18	0	0
Oxfordshire	71	29	0	0
Shropshire	34	43	22	0
Somerset	23	67	10	0
South Yorkshire	26	55	19	0
Staffordshire	22	66	12	0
Suffolk	99	0	0	0
Surrey	83	17	0	0
Tyne & Wear	50	49	1	0
Warwick	37	63	0	0
West Midlands	58	42	+	0
West Sussex	88	12	0	0
West Yorkshire	13	53	34	0
Wiltshire	72	28	0	0
Scotland				
Borders	17	20	16	47
Central	36	6	12	46
Dumfries & Galloway	20	35	23	23
Fife	72	21	5	2
Grampian	38	10	13	39
Highland	6	1	17	75
Lothian	54	16	25	5
Orkney	1	0	85	13
Shetland	0	0	52	48
Strathclyde	17	14	26	43
Tayside	22	14	6	57
Western Isles	+	0	9	91
Wales				
Clwyd	7	41	51	+
Dyfed	1	74	25	0
Gwent	9	66	25	0
Gwynedd	0	49	49	0
Mid Glamorgan	+	48	52	0
Powys	9	6	84	+
South Glamorgan	3	97	0	0
West Glamorgan	0	79	21	0
Isle of Man	0	77	23	0

Table A1.5 Geological characteristics of the four landscape types (% of the 1 km squares in each landscape type in which each rock type is dominant)

Rock formation	Arable	Pastural	Marginal upland	Upland
Quaternary, Tertiary and Cretaceous clays	8	2	0	0
Oolitic and friable limestones	9	3	3	+
Mesozoic mudstones and Lias	18	28	2	1
Jurassic clay	4	2	0	0
Cretaceous clay	13	6	0	0
Devonian sandstones	7	13	14	4
Chalk	23	3	+	0
Massive limestones	4	5	8	4
Carboniferous and non calcareous shales, grits and sandstones	5	19	14	4
Basic and intermediate igneous rock and basic metamorphic	2	2	8	9
Acid igneous and metamorphic rock	4	3	21	60
Silurian and Ordovician	3	11	26	8
Metamorphic slates and phyllite	+	+	1	4
Metamorphic limestones	+	+	+	1
Cambrian grits and sandstones	+	2	2	5

The four landscape types

A1.6 The hierarchical nature of the ITE Land Classification allows Land Classes to be aggregated into broad landscape types. For the purposes of the present report, results have been described in terms of: 'arable', 'pastural', 'marginal upland', and 'upland' landscapes. The geographical distribution, Land Class composition and environmental characteristics of the four landscape types are shown in Figure 1.1 (Chapter 1) and Tables A1.1–5.

A1.7 In summary, the **arable** landscapes are composed of 1 km squares that occur in counties in the south and east of GB, at low altitude, having low winter temperatures, high sunshine hours and below-average snow lie. The geology is dominated by calcareous rocks, clays and other sedimentary types. Characteristic map features include built-up areas and main roads.

A1.8 The **pastural** landscapes are typical of counties in the south and west of England, much of the lower land in Wales and of southern Scotland, at low altitude, having moderate winter temperatures, high sunshine hours and little snow lie. The geology is variable but is dominated by sedimentary and metamorphic rocks. All map features occur widely in this type, but especially coastal features, built up areas and mainroads.

A1.9 The **marginal upland** landscapes occur on the fringes of the uplands in all areas of north and west Britain, especially in Wales, at medium altitude, having low winter temperatures, medium sunshine hours and average snow lie. The geology is dominated by metamorphic rocks, with some igneous rocks present. Characteristic map features include minor roads and woodlands.

A1.10 The **upland** landscapes are mainly in Scotland and northern England, at high altitude, having very low winter temperatures, low sunshine hours and above-average snow lie. The geology is dominated by igneous and metamorphic rocks. Characteristic map features are inland water, woodland and open countryside, with few buildings or roads.

Appendix 2 CODE LISTS

Category 1 species for analysis

Plant species names which were used in the analysis of botanical data, having few taxonomical or identification difficulties and which were consistently recorded by field surveyors.

Acer campestre (Field maple)
Achillea millefolium (Yarrow)
Achillea ptarmica (Sneezewort)
Acinos arvensis (Basil thyme)
Adoxa moschatellina (Moschatel)
Aethusa cynapium (Fool's parsley)
Agrimonia eupatoria (Agrimony)
Agrimonia procera (Fragrant agrimony)
Agrostis capillaris (Common bent)
Agrostis curtisii (Bristle bent)
Agrostis gigantea (Black bent)
Agrostis stolonifera (Creeping bent)
Aira caryophyllea (Silver hair grass)
Aira praecox (Early hair grass)
Ajuga reptans (Bugle)
Alchemilla alpina (Alpine lady's mantle)
Alisma plantago-aquatica (Water plantain)
Alliaria petiolata (Garlic mustard)
Allium ursinum (Ramsons)
Allium vineale (Wild onion)
Alnus glutinosa (Alder)
Alopecurus aequalis (Orange foxtail)
Alopecurus geniculatus (Marsh foxtail)
Alopecurus myosuroides (Black grass)
Alopecurus pratensis (Meadow foxtail)
Ammophila arenaria (Marram)
Anacamptis pyramidalis (Pyramidal orchid)
Anagallis arvensis (Scarlet pimpernel)
Anagallis minima (Chaffweed)
Anagallis tenella (Bog pimpernel)
Anchusa arvensis (Bugloss)
Andromeda polifolia (Bog rosemary)
Anemone nemorosa (Wood anemone)
Angelica sylvestris (Wild angelica)
Antennaria dioica (Mountain everlasting)
Anthemis arvensis (Corn chamomile)
Anthemis cotula (Stinking mayweed)
Anthoxanthum odoratum (Sweet vernal grass)
Anthriscus caucaulis (Bur chervil)
Anthriscus sylvestris (Cow parsley)
Anthyllis vulneraria (Kidney vetch)
Apium graveolens (Wild celery)
Apium inundatum (Lesser marshwort)
Apium nodiflorum (Fool's water cress)
Aquilegia vulgaris (Columbine)
Arabidopsis thaliana (Thale cress)
Arabis hirsuta (Hairy rock cress)
Arctostaphylos alpinus (Alpine bearberry)
Arctostaphylos uva-ursi (Bearberry)
Arenaria serpyllifolia (Thyme-leaved sandwort)
Armeria maritima (Thrift)
Arrhenathrum elatius (False oat grass)
Artemisia absinthium (Wormwood)
Artemisia campestris (Field southernwood)
Artemisia maritima (Sea wormwood)
Artemisia vulgaris (Mugwort)
Arum maculatum (Lords-and-ladies)
Asparagus officinalis (Asparagus)
Asperula cynanchica (Squinancywort)
Asplenium adiantum-nigrum (Black spleenwort)
Asplenium marinum (Sea spleenwort)
Asplenium ruta-muria (Wall rue)
Asplenium scolopendrium (Hart's tongue)
Asplenium trichomanes (Maidenhair spleenwort)
Asplenium viride (Green spleenwort)
Aster tripolium (Sea aster)
Athyrium filix-femina (Lady fern)
Atrichum undulatum (Wavy-leaved thread moss)
Atropa belladonna (Deadly nightshade)
Aulacomnium palustre (Bog thread moss)
Avena fatua (Wild oat)
Avena strigosa (Black oat)
Avenula pratensis (Meadow oat grass)
Avenula pubescens (Downy oat grass)
Ballota nigra (Black horehound)
Barbarea vulgaris (Winter cress)
Bellis perennis (Daisy)
Berula erecta (Lesser water parsnip)
Bidens cernua (Nodding bur marigold)
Bidens tripartita (Trifid bur marigold)
Blackstonia perfoliata (Yellow-wort)
Blechnum spicant (Hard fern)
Botrychium lunaria (Moonwort)
Brachypodium pinnatum (Tor grass)
Brachypodium sylvaticum (False brome)
Breutelia chrysocoma (moss)
Briza media (Quaking grass)
Bromus commutatus (Meadow brome)
Bromus erectus (Upright brome)
Bromus hordeaceus (Soft brome)
Bromus racemosus (Smooth brome)
Bromus ramosus (Hairy brome)
Bromus rigidus - No English name
Bromus sterilis (Barren brome)
Bryonia cretica (White bryony)
Butomus umbellatus (Flowering rush)
Calamagrostis epigejos (Wood small reed)
Calamintha ascendens (Common calaminth)
Calluna vulgaris (Heather)
Caltha palustris (Marsh marigold)
Calystegia sepium (Hairy bindweed)
Calystegia soldanella (Sea bindweed)

Campanula glomerata (Clustered bellflower)
Campanula latifolia (Giant bellflower)
Campanula rotundifolia (Harebell)
Campanula trachelium (Nettle-leaved bellflower)
Capsella bursa-pastoris (Sheperd's purse)
Cardamine amara (Large bitter cress)
Cardamine impatiens (Narrow-leaved bitter cress)
Cardamine pratensis (Cuckooflower)
Carduus acanthoidies (Welted thistle)
Carduus nutans (Musk thistle)
Carduus tenuiflorus (Slender thistle)
Carex acutiformis (Lesser pond sedge)
Carex aquatilis (Water sedge)
Carex arenaria (Sand sedge)
Carex bigelowii (Stiff sedge)
Carex binervis (Green-ribbed sedge)
Carex capillaris (Hair sedge)
Carex caryophyllea (Spring sedge)
Carex curta (White sedge)
Carex demissa (Common yellow sedge)
Carex diandra (Lesser tussock sedge)
Carex dioica (Dioecious sedge)
Carex distans (Distant sedge)
Carex disticha (Brown sedge)
Carex divisa (Divided sedge)
Carex divulsa (Grey sedge)
Carex echinata (Star sedge)
Carex extensa (Long bracted sedge)
Carex flacca (Glaucous sedge)
Carex hirta (Hairy sedge)
Carex hostiana (Tawny sedge)
Carex humilis (Dwarf sedge)
Carex laevigata (Smooth-stalked sedge)
Carex lepidocarpa (Long-stalked yellow sedge)
Carex limosa (Bog sedge)
Carex muricata agg (Prickly sedge)
Carex nigra (Common sedge)
Carex otrubae (False fox sedge)
Carex ovalis (Oval sedge)
Carex pallescens (Pale sedge)
Carex panicea (Carnation sedge)
Carex paniculata (Greater tussock sedge)
Carex pauciflora (Few-flowered sedge)
Carex pendula (Pendulous sedge)
Carex pilulifera (Pill sedge)
Carex pseudocyperus (Cyperus sedge)
Carex remota (Remote sedge)
Carex riparia (Great pond sedge)
Carex rostrata (Bottle sedge)
Carex serotina (Small-fruited yellow sedge)
Carex strigosa (Thin-spiked wood sedge)
Carex sylvatica (Wood sedge)
Carex vesicaria (Bladder sedge)
Carex vulpina (True fox sedge)
Carlina vulgaris (Carline thistle)
Carpinus betulus (Hornbeam)
Carum verticillatum (Whorled caraway)
Catabrosa aquatica (Water whorlgrass)
Centaurea calcitrapa (Red star thistle)
Centaurea nemoralis (Slender knapweed)
Centaurea nigra (Common knapweed)
Centaurea scabiosa (Greater knapweed)
Centaurium erythraea (Common centaury)
Cerastium alpinum (Alpine mouse ear)
Cerastium arcticum (Arctic mouse ear)
Cerastium arvense (Field mouse ear)
Cerastium diffusum (Sea mouse ear)
Cerastium fontanum (Common mouse ear)
Cerastium glomeratum (Sticky mouse ear)
Cerastium semidecandrum (Little mouse ear)
Ceratophyllum demersum (Soft hornwort)
Chaenorhinum minus (Small toadflax)
Chaerophyllum temulentum (Rough chervil)
Chamaemelum nobile (Chamomile)
Chamaenerion angustifolium (Rosebay willowherb)
Chelidonium majus (Greater celandine)
Chrysanthemum segetum (Corn marigold)
Chrysosplenium alternifolium (Alternate-leaved golden saxifrage)
Chrysosplenium oppositifolium (Opposite-leaved golden saxifrage)
Cichorium intybus (Chicory)
Circaea alpina (Alpine echanter's nightshade)
Circaea lutetiana (Enchanter's nightshade)
Cirsium acaule (Dwarf thistle)
Cirsium arvense (Creeping thistle)
Cirsium dissectum (Meadow thistle)
Cirsium eriophorum (Woolly thistle)
Cirsium helenioides (Melancholy thistle)
Cirsium palustre (Marsh thistle)
Cirsium vulgare (Spear thistle)
Cladium mariscus (Great fen sedge)
Cladonia arbuscula (lichen)
Cladonia furcata (lichen)
Cladonia impexa (lichen)
Cladonia uncialis (lichen)
Clematis vitalba (Traveller's joy)
Clinopodium vulgare (Wild basil)
Cochlearia officinalis (Common scurvygrass)
Coeloglossum viride (Frog orchid)
Colchicum autumnale (Autumn crocus)
Conium maculatum (Hemlock)
Conopodium majus (Pignut)
Convallaria majalis (Lily of the valley)
Convolvulus arvensis (Field bindweed)
Cornus sanguinea (Dogwood)
Cornus suecica (Dwarf cornel)
Coronopus didymus (Lesser swine cress)
Coronopus squamatus (Swine cress)
Corydalis claviculata (Climbing corydalis)
Corylus avellana (Hazel)
Crataegus laevigata (Midland hawthorn)
Crataegus laevigata x monogyna (Hawthorn hybrids)
Crataegus monogyna (Hawthorn)
Crepis biennis (Rough hawk's beard)
Crepis capillaris (Smooth hawk's beard)
Crepis paludosa (Marsh hawk's beard)
Crepis vesicaria (Beaked hawk's beard)
Crithmum maritimum (Rock samphire)
Cruciata laevipes (Crosswort)

Cryptogramma crispa (Parsley fern)
Cuscuta epithymum (Dodder)
Cynoglossum officinale (Hound's tongue)
Cynosurus cristatus (Crested dog's tail)
Cystopteris fragilis (Brittle bladder fern)
Cytisus scoparius (Broom)
Dactylis glomerata (Cock's foot)
Danthonia decumbens (Heath grass)
Daphne laureola (Spurge laurel)
Daphne mezereum (Mezereon)
Daucus carota (Wild carrot)
Deschampsia cespitosa (Tufted hair grass)
Deschampsia flexuosa (Wavy hair grass)
Desmazeria rigida (Fern grass)
Dicranella heteromalla (Silky fork moss)
Dicranum majus (Greater fork moss)
Dicranum scoparium (Lesser fork moss)
Digitalis purpurea (Foxglove)
Diphasiastrum alpinum (Alpine clubmoss)
Diplotaxis muralis (Annual wall rocket)
Diplotaxis tenuifolia (Perennial wall Rocket)
Dipsacus fullonum (Fuller s teasel)
Drosera anglica (Great sundew)
Drosera intermedia (Oblong-leaved sundew)
Drosera rotundifolia (Round-leaved sundew)
Dryas octopetala (Mountain avens)
Echium vulgare (Viper's bugloss)
Eleocharis multicaulis (Many-stalked spike rush)
Eleocharis palustris (Common spike rush)
Eleocharis quinqueflora (Few-flowered spike rush)
Eleocharis uniglumis - No English name
Eleogiton fluitans (Floating clubrush)
Elymus farctus (Sand couch grass)
Elymus pycnanthus (Sea couch)
Empetrum nigrum (Crowberry)
Epilobium anagallidifolium (Alpine willow herb)
Epilobium hirsutum (Great willowherb)
Epilobium palustre (Marsh willowherb)
Epipactis helleborine (Broad helleborine)
Equisetum arvense (Field horsetail)
Equisetum fluviatile (Water horsetail)
Equisetum palustre (Marsh horsetail)
Equisetum pratense (Shady horsetail)
Equisetum sylvaticum (Wood horsetail)
Equisetum telemateia (Great horsetail)
Erica cinerea (Bell heather)
Erica tetralix (Cross-leaved heather)
Erigeron acer (Blue fleabane)
Eriophorum angustifolium (Common cottongrass)
Eriophorum vaginatum (Hare's tail cottongrass)
Erodium cicutarium (Common stork's bill)
Erophila verna (Common whitlowgrass)
Erysimum cheiranthoides (Treacle mustard)
Euonymus europaeus (Spindle)
Eupatorium cannabinum (Hemp agrimony)
Euphorbia amygdaloides (Wood spurge)
Fallopia convolvulus (Black bindweed)
Festuca altissima (Wood fescue)
Festuca arundinacea (Tall fescue)
Festuca gigantea (Giant fescue)
Festuca ovina (Sheep's fescue)
Festuca pratensis (Meadow fescue)
Festuca rubra (Red fescue)
Festuca tenuifolia (Fine-leaved sheep's fescue)
Festuca vivipara (Viviparous fescue)
Festulolium hybrid (Hybrid fescue)
Filago lutescens (Common cudweed)
Filago minima (Small cudweed)
Filago vulgaris (Cudweed)
Filipendula ulmaria (Meadowsweet)
Filipendula vulgaris (Dropwort)
Fragaria vesca (Wild stawberry)
Fraxinus excelsior (Ash)
Fumaria bastardii (Tall ramping fumitory)
Fumaria capreolata (White ramping fumitory)
Fumaria officinalis (Common fumitory)
Galeopsis angustifolia (Red hemp nettle)
Galeopsis segetum (Downy hemp nettle)
Galeopsis speciosa (Large-flowered hemp nettle)
Galeopsis tetrahit (Common hemp nettle)
Galium aparine (Cleavers)
Galium boreale (Northern bedstraw)
Galium mollugo (Hedge bedstraw)
Galium odoratum (Woodruff)
Galium palustre (Common marsh bedstraw)
Galium pumilum (Slender bedstraw)
Galium saxatile (Heath bedstraw)
Galium sterneri (Limestone bedstraw)
Galium tricornutum (Corn cleavers)
Galium uliginosum (Fen bedstraw)
Galium verum (Lady's bedstraw)
Genista anglica (Petty whin)
Genista tinctoria (Dyer's greenweed)
Gentianella amarella (Autumn gentian)
Gentianella campestris (Field gentian)
Geranium columbinum (Long-stalked crane's bill)
Geranium dissectum (Cut-leaved crane's bill)
Geranium lucidum (Shining crane's bill)
Geranium molle (Dove's-foot crane's bill)
Geranium pratense (Meadow crane's bill)
Geranium pusillum (Small-flowered crane's bill)
Geranium pyrenaicum (Hedgerow crane's bill)
Geranium robertianum (Herb Robert)
Geranium sanguineum (Bloody crane's bill)
Geranium sylvaticum (Woody crane's bill)
Geum rivale (Water avens)
Geum urbanum (Wood avens)
Geum x *intermedium* (Hybrid avens)
Glaucium flavum (Yellow horned poppy)
Glaux maritima (Sea milkwort)
Glechoma hederacea (Ground ivy)
Glyceria declinata (Small sweet grass)
Glyceria fluitans (Floating sweet grass)
Glyceria maxima (Reed sweet grass)
Glyceria plicata (Plicate sweet grass)
Gnaphalium supinum (Dwarf cudweed)
Gnaphalium sylvaticum (Heath cudweed)
Gnaphalium uliginosum (Marsh cudweed)
Goodyera repens (Creeping lady's tresses)
Gymnadenia conopsea (Fragrant orchid)

Gymnocarpium dryopteris (Oak fern)
Halimione portulacoides (Sea purslane)
Hedera helix (Ivy)
Helianthemum nummularium (Common rock rose)
Heracleum sphondylium (Hogweed)
Hieracium pilosella (Mouse ear hawkweed)
Hippocrepis comosa (Horseshoe vetch)
Hippuris vulgaris (Mare's tail)
Holcus lanatus (Yorkshire fog)
Holcus mollis (Creeping soft grass)
Honkenya peploides (Sea sandwort)
Hordelymus europaeus (Wood barley)
Hordeum murinum (Wall barley)
Hordeum secalinum (Meadow barley)
Humulus lupulus (Hop)
Huperzia selago (Fir clubmoss)
Hyacinthoides non-scripta (Bluebell)
Hydrocharis morsus-ranae (Frogbit)
Hydrocotyle vulgaris (Marsh pennywort)
Hylocomium splendens (Glittering feather moss)
Hypericum androsaemum (Tutsan)
Hypericum calycinum (Rose of Sharon)
Hypericum elodes (Marsh St John's wort)
Hypericum hirsutum (Hairy St John's wort)
Hypericum humifusum (Trailing St John's wort)
Hypericum maculatum (Imperforate St John's wort)
Hypericum montanum (Pale St John's wort)
Hypericum perforatum (Perforate St John's wort)
Hypericum pulchrum (Slender St John's wort)
Hypericum tetrapterum (Square-stalked St John's wort)
Hypericum undulatum (Wavy St John's wort)
Ilex aquifolium (Holly)
Inula conyza (Ploughman's spikenard)
Inula crithmoides (Golden samphire)
Iris foetidissima (Stinking iris)
Iris pseudocorus (Yellow iris)
Isoetes lacustris (Quillwort)
Isolepis cernua (Slender club rush)
Isolepis setacea (Bristle club rush)
Jasione montana (Sheep's bit)
Juncus ambiguus - No English name
Juncus bufonius (Toad rush)
Juncus bulbosus (Bulbous rush)
Juncus castaneus (Chesnut rush)
Juncus conglomeratus (Compact rush)
Juncus effusus (Soft rush)
Juncus gerardi (Saltmarsh rush)
Juncus inflexus (Hard rush)
Juncus maritimus (Sea rush)
Juncus squarrosus (Heath rush)
Juncus subnodulosus (Blunt-flowered rush)
Juncus tenuis (Slender rush)
Juncus trifidus (Three-leaved rush)
Juncus triglumis (Three-flowered rush)
Juniperus communis (Juniper)
Kickxia elantine (Sharp-leaved fluellen)
Kickxia spuria (Round-leaved fluellen)
Knautia arvensis (Field scabious)
Koeleria macrantha (Crested hair grass)
Lactuca saligna (Least lettuce)
Lactuca serriola (Prickly lettuce)
Lamiastrum galeobdolon (Yellow archangel)
Lamium album (White dead nettle)
Lamium amplexicaule (Henbit dead nettle)
Lamium hybridum (Cut-leaved dead nettle)
Lamium purpureum (Red dead nettle)
Lapsana communis (Nipplewort)
Lathyrus montanus (Bitter vetch)
Lathyrus nissolia (Grass vetchling)
Lathyrus pratensis (Meadow vetchling)
Legousia hybrida (Venus's looking glass)
Lemna minor (Common duckweed)
Lepidium campestre (Field pepperwort)
Lepidium heterophyllum (Smith's cress)
Lepidium latifolium (Dittander)
Leucanthemum vulgare (Ox eye daisy)
Leucobryum glaucum (White fork moss)
Leymus arenarius (Lyme grass)
Ligusticum scoticum (Scots lovage)
Ligustrum vulgare (Wild privet)
Lilium martagon (Martagon lily)
Limonium humile (Lax-flowered sea lavender)
Limonium vulgare (Common sea lavender)
Linaria vulgaris (Common toadflax)
Linum bienne (Pale flax)
Linum catharticum (Fairy flax)
Liparis loeselii (Fen orchid)
Listera cordata (Lesser twayblade)
Listera ovata (Common twayblade)
Lithospermum arvense (Corn gromwell)
Litorella uniflora (Shore weed)
Lobelia dortmanna (Water lobelia)
Loiseleuria procumbens (Trailing azalea)
Lolium perenne (Perennial rye grass)
Lonicera periclymenum (Honeysuckle)
Lotus corniculatus (Common bird's foot trefoil)
Lotus subbiflorus (Hairy bird's foot trefoil)
Lotus tenuis (Narrow-leaved bird's foot trefoil)
Lotus uliginosus (Greater bird's foot trefoil)
Luzula pilosa (Hairy wood rush)
Luzula spicata (Spiked wood rush)
Luzula sylvatica (Great wood rush)
Lychnis flos-cuculi (Ragged Robin)
Lycopodium clavatum (Stag's-horn clubmoss)
Lycopsis arvensis (Bugloss)
Lycopus europaeus (Gipsywort)
Lysimachia nemorum (Yellow pimpernel)
Lysimachia nummularia (Creeping Jenny)
Lysimachia vulgaris (Yellow loosestrife)
Lythrum portula (Water purslane)
Lythrum salicaria (Purple loosestrife)
Malus sylvestris (Crab apple)
Malva moschata (Musk mallow)
Malva neglecta (Dwarf mallow)
Malva sylvestris (Common mallow)
Marrubium vulgare (White horehound)
Matricaria matricarioides (Pineappleweed)
Matricaria recutita (Scented mayweed)
Meconopsis cambrica (Welsh poppy)
Medicago arabica (Spotted medick)

Medicago lupulina (Black medick)
Melampyrum pratense (Common cow wheat)
Melica uniflora (Wood melick)
Melittis melissophyllum (Bastard balm)
Menyanthes trifoliata (Bogbean)
Mercurialis perennis (Dog's mercury)
Milium effusum (Wood millet)
Minuartia verna (Vernal sandwort)
Mnium hornum (Swan s neck thread moss)
Moehringia trinervia (Three-nerved sandwort)
Molinia caerulea (Purple moor grass)
Moneses uniflora (One-flowered wintergreen)
Montia fontana (Blinks)
Mycelis muralis (Wall lettuce)
Myosoton aquaticum (Water chickweed)
Myrica gale (Bog myrtle)
Myriophyllum alterniflora (Alternate-flowered water milfoil)
Myriophyllum spicata (Spiked water milfoil)
Mysotis arvensis (Field forget-me-not)
Nardus stricta (Mat grass)
Narthecium ossifragum (Bog asphodel)
Nasturtium microphyllum (Winter cress)
Nasturtium officinale (Water cress)
Nuphar lutea (Yellow water lily)
Nymphaea alba (White water lily)
Odontites verna (Red bartsia)
Oenanthe crocata (Hemlock water dropwort)
Oenanthe fistulosa (Tubular water dropwort)
Ononis repens (Common restharrow)
Ononis spinosa (Spiny restharrow)
Ophioglossum vulgatum (Adder's tongue)
Ophrys apifera (Bee orchid)
Orchis mascula (Early-purple orchid)
Oreopteris limbosperma (Lemon-scented fern)
Origanum vulgare (Marjoram)
Ornithopus perpusillus (Bird's foot)
Orobanche minor (Common broomrape)
Osmunda regalis (Royal fern)
Oxalis acetosella (Wood sorrel)
Oxyria digyna (Mountain sorrel)
Papaver dubium (Long-headed poppy)
Papaver rhoeas (Common poppy)
Parapholis strigosa (Hard grass)
Parentucellia viscosa (Yellow bartsia)
Parietaria judacia (Pellitory-of-the-wall)
Parnassia palustris (Grass of Parnassus)
Pastinaca sativa (Wild parsnip)
Pedicularis palustris (Marsh lousewort)
Pedicularis sylvatica (Lousewort)
Peltigera canina (lichen)
Petasites hybridus (Butterbur)
Petroselinum segetum (Corn parsley)
Phalaris arundinacea (Reed canary grass)
Phalaris canariensis (Canary grass)
Phalaris minor (Lesser canary grass)
Phegopteris connectilis (Beech fern)
Phragmites australis (Common reed)
Phyteuma orbiculare (Round-headed rampion)
Picris echioides (Bristly ox tongue)
Picris hieraciodes (Hawkweed ox tongue)
Pimpinella major (Greater burnet saxifrage)
Pimpinella saxifraga (Burnet saxifrage)
Pinguicula lusitanica (Pale butterwort)
Pinguicula vulgaris (Common butterwort)
Plagiomnium undulatum (moss)
Plagiothecium denticulatum (Sharp fern-like feather moss)
Plagiothecium undulatum (moss)
Plantago coronopus (Buck's-horn plantain)
Plantago lanceolata (Ripwort plantain)
Plantago major (Greater plantain)
Plantago maritima (Sea plantain)
Plantago media (Hoary plantain)
Platanthera bifolia (Lesser butterfly orchid)
Platanthera chlorantha (Greater butterfly orchid)
Pleurozium schreberi (Red stemmed feather moss)
Poa angustifolia (Narrow-leaved meadow grass)
Poa annua (Annual meadow grass)
Poa compressa (Flattened meadow grass)
Poa pratensis (Smooth meadow grass)
Poa subcaerulea (Spreading meadow grass)
Polygala calcarea (Chalk milkwort)
Polygonatum multiflorum (Solomon's seal)
Polygonum amphibium (Amphibious bisort)
Polygonum arenastrum (Small-leaved knotgrass)
Polygonum aviculare (Knotgrass)
Polygonum bistorta (Common bistort)
Polygonum hydropiper (Water pepper)
Polygonum lapathifolium (Pale persicaria)
Polygonum mite (Tasteless water pepper)
Polygonum persicaria (Redshank)
Polygonum viviparum (Alpine bistort)
Polypodium vulgare (Polypody)
Populus tremula (Aspen)
Potamogeton natans (Broad-leaved pondweed)
Potamogeton polygonifolius (Bog pondweed)
Potentilla anglica (Trailing tormentil)
Potentilla anserina (Silverweed)
Potentilla erecta (Tormentil)
Potentilla palustris (Marsh cinquefoil)
Potentilla reptans (Creeping cinquefoil)
Potentilla sterilis (Barren strawberry)
Primula elatior (Oxlip)
Primula veris (Cowslip)
Primula vulgaris (Primrose)
Prunella vulgaris (Selfheal)
Prunus avium (Wild cherry)
Prunus padus (Bird cherry)
Prunus spinosa (Blackthorn)
Pseudorchis albida (Small-white orchid)
Pseudoscleropodium purum (Neat meadow feather moss)
Pteridium aquilinum (Bracken)
Puccinellia distans (Reflexed saltmarsh grass)
Puccinellia fasciculata (Borrer's saltmarsh grass)
Puccinellia maritima (Common saltmarsh grass)
Pulicaria dysenterica (Common fleabane)
Pulmonaria officinalis (Lungwort)
Pyrola minor (Common wintergreen)
Ranunculus acris (Meadow buttercup)
Ranunculus aquatilis (Common water crowfoot)

Ranunculus arvensis (Corn crowfoot)
Ranunculus auricomus (Wood crowfoot)
Ranunculus bulbosus (Bulbous buttercup)
Ranunculus ficaria (Lesser celandine)
Ranunculus flammula (Lesser spearwort)
Ranunculus fluitans
Ranunculus hederaceus (Ivy-leaved crowfoot)
Ranunculus lingua (Great spearwort)
Ranunculus omiophyllus - No English name
Ranunculus parviflorus (Small-flowered buttercup)
Ranunculus peltatus - No English name
Ranunculus penicillatus - No English name
Ranunculus repens (Creeping buttercup)
Ranunculus sardous (Hairy buttercup)
Ranunculus sceleratus (Celery-leaved buttercup)
Ranunculus trichophyllus - No English name
Raphanus maritimus (Sea radish)
Raphanus raphanistrum (Wild radish)
Reseda lutea (Wild mignonette)
Rhacomitrium lanuginosum (Woolly fringe moss)
Rhamnus catharticus (Buckthorn)
Rhizomnium punctatum (moss)
Rhynchospora alba (White beak sedge)
Rhytidiadelphus loreus (moss)
Rhytidiadelphus squarrosus (Drooping-leaved feather moss)
Rhytidiadelphus triquetrus (Triangular-leaved feather moss)
Ribes uva-crispa (Gooseberry)
Rorippa amphibia (Great yellow cress)
Rorippa islandica (Northern marsh yellow cress)
Rorippa palustris (Common marsh yellow cress)
Rorippa sylvestris (Creeping yellow cress)
Rubia peregrina (Wild madder)
Rubus caesius (Dewberry)
Rubus chamaemorus (Cloudberry)
Rubus idaeus (Rasberry)
Rubus saxatilis (Stone bramble)
Rumex acetosa (Common sorrel)
Rumex acetosella (Sheep s sorrel)
Rumex crispus (Curled dock)
Rumex hydrolapathum (Water dock)
Rumex longifolius (Northern dock)
Rumex maritimus (Golden dock)
Rumex obtusifolius (Broad-leaved dock)
Rumex palustris (Marsh dock)
Rumex pulcher (Fiddle dock)
Rumex rupestris (Shore dock)
Ruscus aculeatus (Butcher's broom)
Sagittaria sagittifolia (Arrowhead)
Sambucus nigra (Elder)
Samolus valerandi (Brookweed)
Sanguisorba minor (Salad burnet)
Sanguisorba officinalis (Great burnet)
Sanicula europaea (Sanicle)
Sarcocornia perennis - No English name
Saxifraga aizoides (Yellow saxifrage)
Saxifraga granulata (Meadow saxifrage)
Saxifraga hypnoides (Mossy saxifrage)
Saxifraga oppositifolia (Purple saxifrage)
Saxifraga stellaris (Starry saxifrage)
Scabiosa columbaria (Small scabious)
Schoenoplectus lacustris (Common club rush)
Schoenus nigricans (Black bog rush)
Scilla autumnalis (Autumn squill)
Scilla verna (Spring squill)
Scirpus maritimus (Sea club rush)
Scirpus sylvaticus (Wood club rush)
Scrophularia auriculata (Water figwort)
Scrophularia nodosa (Common figwort)
Scutellaria galericulata (Skullcap)
Scutellaria minor (Lesser skullcap)
Sedum album (White stonecrop)
Sedum forsteranum (Rock stonecrop)
Sedum rosea (Roseroot)
Sedum telephinum (Orpine)
Sedum villosum (Hairy stonecrop)
Selaginella selaginoides (Lesser clubmoss)
Senecio aquaticus (Marsh ragwort)
Senecio congestus (Marsh fleawort)
Senecio erucifolius (Hoary ragwort)
Senecio integrifolius (Field fleawort)
Senecio jacobaea (Common ragwort)
Senecio sylvaticus (Wood groundsel)
Senecio viscosus (Sticky groundsel)
Senecio vulgaris (Groundsel)
Serratula tinctoria (Saw wort)
Seseli libanotis (Moon carrot)
Sesleria albicans (Blue moor grass)
Sherardia arvensis (Field madder)
Sibthorpia europaea (Cornish moneywort)
Silaum silaus (Pepper saxifrage)
Silene dioica (Red campion)
Silene latifolia (White campion)
Silene maritima (Sea campion)
Silene vulgaris (Bladder campion)
Sison amomum (Stone parsley)
Sisymbrium altissimum (Tall rocket)
Sisymbrium officinale (Hedge mustard)
Smyrnium olusatrum (Alexanders)
Solidago virgaurea (Goldenrod)
Sonchus arvensis (Perennial sow thistle)
Sonchus asper (Prickly sow thistle)
Sonchus oleraceus (Smooth sow thistle)
Sonchus palustris (Marsh sow thistle)
Sorbus aria (Common whitebeam)
Sorbus aucuparia (Rowan)
Sorbus torminalis (Wild service tree)
Sparganium emersum (Unbranched bur reed)
Sparganium erectum (Branched bur reed)
Spergularia marginata (Greater sea spurrey)
Spergularia marina (Lesser sea spurrey)
Spergularia rubra (Sand spurrey)
Spiranthes spiralis (Autumn lady's tresses)
Stachys x *ambigua* (hybrid, probably Hedge woundwort)
Stachys arvensis (Field woundwort)
Stachys officinalis (Betony)
Stachys palustris (Marsh woundwort)
Stachys sylvatica (Hedge woundwort)

Stellaria alsine (Bog stitchwort)
Stellaria graminea (Lesser stitchwort)
Stellaria holostea (Greater stitchwort)
Stellaria media (Common chickweed)
Stellaria neglecta (Greater chickweed)
Stellaria nemorum (Wood stitchwort)
Stellaria palustris (Marsh stitchwort)
Suaeda maritima (Annual sea blite)
Suaeda vera (Shrubby seablite)
Subularia aquatica (Awlwort)
Succisa pratensis (Devils'-bit scabious)
Symphytum officinale (Common comfrey)
Symphytum tuberosum (Tuberous comfrey)
Symphytum uplandicum (Russian comfrey)
Tamus communis (Black bryony)
Tanacetum vulgare (Tansy)
Taxus baccata (Yew)
Teucrium scorodonia (Wood sage)
Thesium humifusum (Bastard toadflax)
Thlaspi arvense (Field penny cress)
Thuidium tamariscinum (moss)
Tilia cordata (Small-leaved lime)
Tilia platyphyllos (Large-leaved lime)
Tofieldia pusillata (Scottish asphodel)
Torilis japonica (Upright hedge parsley)
Torilis nodusa (Knotted hedge parsley)
Tragopogon pratensis (Goat's beard)
Trichophorum caespitosum (Deergrass)
Trientalis europaea (Chickweed wintergreen)
Trifolium arvense (Hare's-foot clover)
Trifolium campestre (Hop trefoil)
Trifolium dubium (Lesser trefoil)
Trifolium fragiferum (Strawberry clover)
Trifolium medium (Zigzag clover)
Trifolium micranthum (Slender trefoil)
Trifolium pratense (Red clover)
Trifolium repens (White clover)
Trifolium squamosum (Sea clover)
Trifolium striatum (Knotted clover)
Triglochin maritima (Sea arrowgrass)
Triglochin palustris (Marsh arrowgrass)
Trisetum flavescens (Yellow oat grass)
Tussilago farfara (Colt's foot)
Typha angustifolium (Lesser bulrush)
Typha latifolia (Bulrush)
Ulex europaeus (Gorse)
Umbilicus rupestris (Navelwort)
Urtica dioica (Common nettle)
Urtica urens (Small nettle)
Utricularia intermedia (Intermediate bladderwort)
Utricularia minor (Lesser bladderwort)
Vaccinium myrtillus (Bilberry)
Vaccinium oxycoccus (Cranberry)
Vaccinium uliginosum (Bog bilberry)
Vaccinium vitis-idaea (Cowberry)
Valeriana dioica (Marsh valerian)
Valeriana officinalis (Common valerian)
Verbascum nigrum (Dark mullein)
Verbascum thapsus (Great mullein)
Veronica agrestis (Green field speedwell)
Veronica anagallis-aquatica (Blue water speedwell)
Veronica arvensis (Wall speedwell)
Veronica beccabunga (Brooklime)
Veronica catenata (Pink water speedwell)
Veronica chamaedrys (Germander speedwell)
Veronica filiformis (Slender speedwell)
Veronica hederifolia (Ivy-leaved speedwell)
Veronica montana (Wood speedwell)
Veronica officinalis (Heath speedwell)
Veronica persica (Common field speedwell)
Veronica polita (Grey field speedwell)
Veronica scutellata (Marsh speedwell)
Veronica serpyllifolia (Thyme-leaved speedwell)
Viburnum lantana (Wayfaring tree)
Viburnum opulus (Guelder rose)
Vicia bithynica (Bithynian vetch)
Vicia cracca (Tufted vetch)
Vicia hirsuta (Hairy tare)
Vicia sativa (Common vetch)
Vicia sepium (Bush vetch)
Vicia sylvatica (Wood vetch)
Vicia tetrasperma (Smooth tare)
Vinca minor (Lesser periwinkle)
Viola arvensis (Field pansy)
Viola canina (Heath dog violet)
Viola hirta (Hairy violet)
Viola lutea (Mountain pansy)
Viola odorata (Sweet violet)
Viola palustris (Marsh violet)
Viola tricolor (Wild pansy)
Viscum album (Mistletoe)
Vulpia bromoides (Squirrel tail fescue)
Vulpia myuros (Rat's tail fescue)
Wahlenbergia hederacea (Ivy-leaved bellflower)
Wolffia arrhiza (Rootless duckweed)
Zannichellia palustris (Horned pondweed)

1990 Mapping code list

PHYSIOGRAPHY/INLAND WATER/COASTAL

1 Cliff > 30m high
2 Cliff 5-30m high
3 Rock outcrop & cliff < 5m
4 Scree
5 Surface boulders
6 Limestone pavement
7 Peat hags
8 Current peat workings
9 Old peat workings
10 Soil erosion
11 Ground levelling
12 100% rock
13 > 50% rock
14 10-50% rock
15 100% peat
16 > 50% peat
17 10-50% peat
31 Cliff > 30m high
32 Cliff 5-30m high
33 Rock outcrop and cliff < 5m
34 Rocky/boulder shore
35 Pebble/gravel shore
36 Sandy shore (or dune)
37 Bare mud
38 Sea
51 Lake - natural
52 Lake - artificial
53 River
54 Canalised river
55 Canal
56 Stream
57 Roadside ditch
58 Other ditch
59 Spring
60 Well
61 Signs of drainage
62 Waterfall
63 Gorge
64 Levee
65 Bank < 1m
66 Bank 1-5m
67 Bank > 5m

AGRICULTURE/NATURAL VEGETATION

101 Lowland agricultural grass
102 Upland grass
103 Moorland - grass
104 Moorland - shrub heath
105 Calcareous grassland
106 Maritime vegetation
107 Lowland heath
108 Aquatic macrophytes
109 Aquatic marginal vegetation
110 Raised bog
111 Blanket bog
112 Valley bog
113 Fen
114 Marsh
115 Flush
116 Saltmarsh
117 Wheat
118 Barley
119 Oats
120 Sugar beet
121 Turnips/swedes/roots
122 Kale
123 Potatoes
124 Field beans
125 Peas
126 Maize
127 Rye
128 Oilseed rape
129 Other crop
130 Flowers
131 Commercial horticulture
132 Orchard
133 Unmanaged grass
134 Tall herb vegetation
136 Ley
137 Unimproved grass
138 Forbs 10-25% (grass)
139 Forbs 25-50% (grass)
140 Forbs > 50% (grass)
141 Neglected
142 Abandoned
143 Ploughed
144 Burnt
145 Mown
146 Lolium multiflorum
147 Lolium perenne
148 Trifolium repens
149 Dactylis glomerata
150 Anthoxanthum odoratum
151 Phleum pratense
152 Cynosurus cristatus
153 Holcus lanatus
154 Agrostis tenuis
155 Festuca ovina
156 Pteridium aquilinum - dense
157 Pteridium aquilinum - scattered
158 Juncus effusus
159 Deschampsiaflexuosa
160 Nardus stricta
161 Calluna vulgaris
162 Vaccinium myrtilus
163 Molinia caerulea
164 Eriophorum angustifolium
165 Eriophorum vaginitum
166 Trichorophorum caespitosum
167 Sphagnum spp.
168 Juncus squarrosus
175 25-50%
176 50-75%
177 75-95%
178 95-100%
179 < 10cm
180 10-30cm
181 30-50cm
182 0.5-1m
183 1-1.5m
184 > 1.5m
185 Beef
186 Dairy
187 Breeders
188 Dual purpose
189 Sheep
190 Goats (with no.)
191 Horses (with no.)
192 Pigs
193 Silage
194 Hay
195 Deer
196 Grouse
197 No apparent use

FORESTRY/WOODLAND/TREES

201 Individual trees
202 Scattered trees
203 Line of trees
204 Belt of trees
205 Clump of trees
206 Woodland/forest
207 Individual scrub species
208 Scattered scrub
209 Line of scrub
210 Patch of scrub
215 Closed canopy
216 Canopies not touching
217 Hedgerow
218 Parkland
236 Elder
237 Elm
221 Fir - Douglas
222 Larch
223 Pine - Corsican
224 Pine - Lodgepole
225 Pine - Scots
226 Spruce - Norway
227 Spruce - Sitka
228 Unspecified conifer
231 Alder
232 Ash
233 Beech
234 Birch
235 Bramble
238 Field maple
239 Gorse
240 Hawthorn
241 Hornbeam
242 Lime
243 Oak
244 Poplar
245 Rowan
246 Sweet chestnut
247 Sycamore
248 Willow
250 Mixed broadleaf
251 Mixed conifer
252 Unspecified broadleaf
256 25-50%
257 50-75%
258 75-95%
259 95-100%
261 1-4 years
262 5-20 years
263 20-100 years
264 > 100 years
266 Timber production
267 Landscape
268 Sporting/game
269 Public recreation
270 Nature conservation
271 Shelter
275 Well managed
276 Unmanaged - thriving
277 Unmanaged - improvable
278 Declining
281 Felling/stumps
282 Natural regeneration
283 Underplanting
285 Ploughed land
286 Staked trees
287 Tree protectors
288 Fenced (single trees)
289 Windblow
290 Dead standing trees
291 Regrowth - cut stump
292 Grazing (stock)
293 Ride/firebreak
294 Bracken - dense
295 Bracken - scattered

BOUNDARIES AND RECREATION

301 Dry-stone wall
302 Mortared wall
303 Other wall
311 Fence - wood only
312 Fence - iron only
313 Fence - wire on posts
314 Other fence
321 Hedge > 50% hawthorn
322 Hedge > 50% other species
323 Mixed hedge
331 Stone bank
332 Earth bank
333 Grass strip only
341 > 2m high
342 1-2m high
343 < 1m high
351 Stockproof
352 Not stockproof
353 Filled gaps < 10%
354 Filled gaps > 10%
355 Signs of replacement
356 Signs of removal
357 Trimmed
358 Uncut
359 Derelict
360 Line of relict hedge
361 Laying
362 Flailing
363 Regrowth from stumps
364 Bracken present

BUILDINGS/STRUCTURES/COMMUNICATIONS

401 Building
402 Garden/grounds with trees
403 Garden/grounds without trees
404 Public open space
405 Amenity grass > 1ha
406 Allotments
407 Car park
408 Glasshouse
409 Garden centre/nursery
410 Embankment
411 Other land
421 Residential
422 Commercial
423 Industrial
424 Public service & facilities
425 Institutional
426 Educational/cultural
427 Religious
428 Agricultural
429 Sporting/recreational
430 Waste - domestic
431 Waste - industrial
432 Quarry/mine
433 Gravel pit
441 New
442 Vacant
443 Derelict
451 Railway track/land
452 Road (tarmac)
453 Verge < 1m
454 Verge 1-5m
455 Verge > 5m
456 Constructed track
457 Unconstructed track
458 Footpath (exclusive)
459 Footpath (other)
460 Satisfactory throughout
461 Parts in poor condition
462 Impassable/difficult
463 Difficult stile/gate
464 Difficult bridge
465 Difficult fence/wall
466 Ploughed/crops
467 Natural vegetation
468 Muddy/flooded
469 Fallen trees/rock
470 Bull(s)
471 Other difficulty
501 School playing fields
502 Other playing fields
503 Golf course
504 Race track
505 Tennis courts
506 Boating area
507 Static caravan(s)
508 Touring caravan park
509 Camp site
510 Launch site
511 Other designated area
521 Horsiculture
522 Angling
523 Boat - inland water
524 Other recreation

UNIVERSAL CODES

888 New to map
999 No longer on map

1984 Mapping code list

PHYSIOGRAPHY/INLAND WATER/COASTAL

1 Cliff > 30m high
2 Cliff 5-30m high
3 Rock outcrop &cliff < 5m high
4 Scree
5 Surface boulders
6 Isolated boulders
7 Limestone pavement
8 100% rock
9 > 50% rock
10 10-50% rock
11 Stable raw peat
12 Eroding raw peat
13 Current domestic peat workings
14 Current commercial peat work's
15 Old peat workings
16 Soil erosion
17 Ground leveling
26 Cliff > 30m high
27 Cliff 5-30m high
28 Rocky shore
29 Pebble/gravel shore
30 Sandy shore
31 Sand dune
32 Bare mud
36 Lake natural
37 Lake artificial
38 Pond natural
39 Pond artificial
40 River
41 Canalised river
42 Canal
43 Stream
44 Roadside ditch
45 Other ditch
46 Spring
47 Well
48 Signs of Drainage
51 Rock
52 Sand/Gravel
53 Mud
54 Peat
55 Lake shore
56 Riverbank
57 River substrate
58 Stream substrate
59 Waterfall
60 Rapids
61 Gorge
62 Levee

AGRICULTURE/NATURAL VEGETATION

100 Amenity grass > 1ha
101 Ley
102 Permanent Pasture
103 Upland Grassland
104 Moorland - grass
105 Moorland - shrub heath
106 Herb-rich grassland
107 Maritime grass
108 Lowland heath
109 Aquatic macrophytes
110 Aquatic marginal veg.
111 Bog
112 Fen
113 Marsh
114 Flush - calcareous
115 Flush - non-calcareous
116 Saltmarsh
117 Wheat
118 Barley
119 Oats
120 Mixed grain
121 Sugar beet
122 Turnips/Swedes/Roots
123 Kale
124 Potatoes
125 Field beans
126 Peas
127 Lucerne
128 Maize
129 Rye
130 Oilseed rape
131 Other crop ....
132 Flowers
133 Commercial horticulture
134 Commercial glasshouse
135 Soft fruit...........
136 Garden Centre/Nursery
137 Ploughed
138 Vacant
139 Abandoned/Neglected
140 Burnt
141 Fallow
151 Lolium multiflorum
152 Lolium perenne
153 Dactylis glomerata
154 Cynosurus cristatus
155 Holcus lanatus
156 Agrostis tenuis
157 Festuca ovina
158 Pteridium aquilinum
159 Juncus effusus
160 Deschampsia flexuosa
161 Nardus stricta
162 Calluna vulgaris
163 Vaccinium myrtillus
164 Molinia caerulia
165 Eriophorum angustifolium
166 Eriophorum vaginatum
167 Tricophorum cespitosum
168 Sphagnum spp.
169 Juncus squarrosus
171 Beef
172 Dairy
173 Dual purpose
174 Sheep
175 Goats (with no.)
176 Horses (with no.)
177 Pigs
178 Farmyard Poultry
179 Commercial Poultry
180 Silage
181 Hay
182 Bailed straw
183 Produce for sale
184 Fish farm...........
190 25-50%
191 50-75%
192 75-95%
193 95-100%
194 < 10cm
195 < 30cm
196 < 50cm
197 < 1m
198 < 1.5m
199 > 1.5m

FORESTRY/WOODLAND/TREES

200 Scattered trees
201 Woodland/Forest
202 Coppice
203 Scrub
204 Copse
205 Gillside
206 Shrub
207 Line of trees
208 Belt
209 Individual trees
210 Hedgerow tree
211 Corsican pine
212 Scots pine
213 Lodgepole pine
214 Norway spruce
215 Sitka spruce
216 Douglas fir
217 Larch
218 Western hemlock
219 Western red cedar
220 Other conifer
221 Elm
222 Oak
223 Beech
224 Ash
225 Sycamore
226 Birch
227 Poplar
228 Alder
229 Lime
230 Willow
231 Hawthorn
232 Gorse
233 Bramble
234 Other broadleaf
235 Mixed softwoods
236 Mixed hardwoods
241 Commercial
242 Domestic
243 Timber production
244 Fuelwood production
245 Conservation
246 Amenity
247 Recreation
248 Grazing - agricultural
249 Shelter
250 Game/Sporting
255 25-50%
256 50-75%
257 75-95%
258 95-100%
261 Unmanaged
262 Cutting/Brashing
263 Felling/Stumps
264 Natural regeneration
265 Underplanting
266 Plantation
267 Planted
268 Ploughed land
269 Staked trees
270 Tuley tubes
271 Fenced single trees
272 Windblow
273 Dead standing trees
274 Re-growth - cut stump
281 1-4 yrs.
282 5-20 yrs.
283 >20 yrs.
284 >100 yrs.

BOUNDARIES AND RECREATION

301 Dry stone
302 Mortared
303 Other............
304 Wood only
305 Iron only
306 Wire
307 Other
310 >50% Hawthorn
311 >50% Beech
312 >50% Willow
313 >50% Gorse
314 >50% Other
315 Mixed hedge
316 Hedge trimmed
317 Hedge uncut
318 Hedge derelict
319 Line of relict hedge
320 Laying
321 Flailing
322 Stone
323 Earth
331 >2m high
332 <2m high
333 <1m high
335 Stockproof
336 Not stockproof
337 Filled gaps < 10%
338 Filled gaps > 10%
339 Signs of replacement
340 Signs of removal
341 No longer present
342 Derelict
343 Burnt
351 School playing-fields
352 Other playing-fields
353 Golf course
354 Race track............
355 Tennis courts
356 Boating area
359 Static informal Caravans
360 Static formal Caravans
361 Touring Caravan Park
362 Camp site
371 Horse jumps
372 Other horse accessories
373 Angling notice
374 Angling platform
375 Boat-house
376 Boat - inland water
378 Nature trail
379 Information point

BUILDINGS/STRUCTURES/COMMUNICATIONS

401 Building
402 Garden/Grounds with trees
403 Garden/Grounds without trees
405 Public Open space
406 Allotments
407 Car park
408 Other land...........
411 Residential
412 Commercial
413 Industrial
414 Public Service & facilities
415 Institutional
416 Educational/Cultural
417 Religious
418 Agricultural
419 Forestry
420 Sporting/Recreational
421 Waste domestic
422 Waste industrial
423 Quarry/Mine
431 New
432 Vacant
433 Derelict
441 Bridge
442 Tunnel
443 Dam
444 Pipeline (above)
445 Pylon
446 Other pole...........
447 Silo
448 Silage pit/clamp
449 Other agricultural store
450 Snow-fence
451 Speed restriction
461 Road (tarmac)
462 Verge <1m
463 Verge <5m
464 Verge >5m
465 Constructed track
466 Unconstructed track
467 Footpath (exclusive)
468 Footpath (other)
469 Railway track
470 Other railway land
471 Embankment
472 Airport/Aerodrome
473 Informal barrier

UNIVERSAL CODES

888 New to map

Descriptions of land cover/use categories from the field survey

1 **Wheat**

2 **Barley** .... Includes winter and spring barley

3 **Oats**

4 **Mixed and other cereals** ... Includes rye,triticale and mixed corn

5 **Maize**

6 **Turnips/swedes**

7 **Kale**

8 **Oil-seed rape**

9 **Crucifer crops** .... Includes mustard but not OSR

10 **Peas**

11 **Field beans**

12 **Legumes** .... Includes sainfoin,lucerne,lupin but not peas or field beans

13 **Sugar beet**

15 **Root crops** .... Not turnip/swede/potato

14 **Potatoes**

16 **Other field crops** .... Other non-horticultural field crops such as linseed, sunflower

17 **Horticulture** .... Characterised by small plots of widely differing crop types within a small area. Includes flowers.

18 **Non-cropped arable** .... Ploughed and fallow , includes rotational Set-aside

19 **Perennial crops** .... Woody perennial crops such as orchards,vineyards,hops and soft fruit

20 **Recreational (mown) grass**. Non-agricultural grass. includes amenity grass, playing fields, golf courses, touring caravan parks and campsites

21 **Recently sown grass** .... Includes short term agricultural grass which has been reseeded in the last five years. Characterised by evidence of ploughing, bare soil between grass tillers, scarcity of broad leaf species and usually dominated by single planted grass species

22 **Pure rye-grass** .... Established ryegrass swards with 50 to 95% cover of *Lolium* and up to 25% cover of *Trifolium repens* (white clover) or other planted grass species.

23 **Well-managed grass** ....Mixtures of *Lolium* (ryegrass) and *Trifolium repens* (white clover) where *Lolium* cover does not exceed 50% or cover dominated by other planted grass (eg *Dactylis glomerata* (cocksfoot) or *Phleum pratense* (timothy))

24 **Weedy swards with >25% rye-grass** .... Swards with 25 to 50% *Lolium* cover and more than 25% cover of non-sown grasses, broadleaf weeds or rushes

25 **Non-agriculturally improved grass** .... Unimproved or little improved grassland in an enclosed situation. Contains many palatable grasses but sward composition has not been altered by treatment with fertilisers, pesticides, drainage or re-seeding. Excludes calcareous grass, acid grass and moorland.

26 **Calcareous grass** .... Unimproved, often unenclosed, grasslands found on calcareous soils (pH >7.0). Contains a high proportion of calcicole species found on limestone, chalk, dunes and machair.

27 **Upland grass** .... Unimproved natural grassland, most frequently in an upland situation, usually on mineral soils (pH <5.5). Contains a high proportion of palatable grasses including *Festuca ovina, Agrostis capillaris, Anthoxanthum odoratum and Galium saxatile.*

28	**Dense bracken**	Herbaceous vegetation dominated by *Pteridium aquilinum*. Excludes woodland with *Pteridium* dominated ground flora.
29	**Purple moor grass-dominated moorland**	Coarse unimproved upland grass in a moorland setting. Areas are usually unenclosed, often little grazed, on soils with a peaty top. Cover of *Molinia* (purple moor grass) exceeds 50%.
30	**Moorland grass (other than purple)**	Coarse upland grass in a moorland setting, usually dominated by species such as *Nardus stricta*, *Deschampsia flexuosa* and *Juncus squarrosus*.
31	**Unmanaged grassland and tall herb**	Semi-natural vegetation, often in wet or disturbed positions and dominated by tall herbs (eg *Artemisia vulgaris*, *Anthriscus sylvestris*, and *Epilobium hirsutum*). Contains areas of vegetation typical of the margins of water bodies (eg *Phalaris arundinacea*, *Eupatorium cannabinum* and *Mentha aquatica*)
32	**Dense heath**	Heathland with >75% cover of *Calluna* and/or *Erica*. Includes dune heath which occurs on consolidated and flattened dunes.
33	**Open-canopy heath**	Heathland with 25 to 75% cover of *Calluna* and/or *Erica*, in a mosaic with grassy herbaceous vegetation. Includes lowland wet heath, where the ericoid element is high.
34	**Berry-bush heath**	Heathland with >25% cover of *Vaccinium* + *Empetrum* + *Arctostaphylos* and <25% cover of *Calluna* + *Erica*
35	**Drier northern bogs**	Mostly with *Eriophorum vaginatum* and often *Vaccinium myrtillus*.
36	**Wet heaths and saturated bogs**	Includes very wet heaths with low ericoid cover. Vegetation characterised by *Trichophorum* and *Eriophorum angustifolium*
37	**Conifer woodland**	Woodland where 80% or more of the tree canopy is of coniferous species, including Larch
38	**Mixed woodland**	Mixture of coniferous and broadleaved species (semi-natural or planted), where both comprise >20% of the canopy cover.
39	**Broadleaved woodland**	Woodland where 80% or more of the tree canopy is of broadleaved species
40	**Shrub**	Consists predominantly of shrubby species, often with tree generation and brambles. Includes species such as *Crataegus monogyna*, *Prunus spinosa* and *Salix*.
41	**Felled woodland**	Areas of felled woodland in which woody regeneration is less than 1 m high; includes felled coppice
42	**Inland rocks and screes**	Area where >50% of the land surface is covered by rock; includes cliffs, rock outcrops, limestone pavements and screes.
43	**Still water**	Lake, pond, mere, reservoir
44	**Running water**	River, canal
45	**Wetland**	Includes fen, marsh and flush.
46	**Intertidal soft coast without vegetation**	Includes intertidal mud flat and sand flat, sandy shore and pebble/gravel shore.
47	**Saltmarsh**	Intertidal sand-, silt- or mud-based habitats, colonised by halophytic grasses such as *Puccinellia* spp and *Spartina* spp, rushes such as *Juncus gerardi* and herbs such as *Limonium* spp.
48	**Dune**	Onshore wind-carried sand deposits arranged in cordons of ridges parallel to the coast. Also inland wind blown sand deposits. Either open or with semi-natural grassland.
49	**Hard coast with no vegetation**	Includes intertidal seaweed covered boulders, rocky boulder shore (not vegetated), rocks and cliffs
50	**Maritime vegetation**	Vegetation found in coastal situations, usually herb-rich with halophytic species present due to salt spray.

51 **Railway** .... Includes all track and associated land

52 **Road** .... Includes any road, whether private or not, which is totally tarmac or concrete across its width.

53 **Agricultural buildings** .... Includes sheds,barns and silos as well as commercial glasshouses.

54 **Residential buildings** .... Dwellings and associated land

55 **Other buildings** .... Includes commercial, industrial, public service and other facilities

56 **Waste and derelict land** ..... Includes domestic and industrial waste land as well as allotment land

57 **Hard areas without buildings** .... Unvegetated derelict land, building sites, car parks, ungrassed recreational grounds and public spaces.

58 **Quarries and extractive industries** ..... Gravel pit, quarry, opencast mine

Descriptions of satellite target cover classes

0 **Unclassified**: Cover types which did not fit into the 25 'target' classes

1 **Sea/estuary**: Sea, coastal waters and estuaries, inland to the first bridging point or barrier.

2 **Inland water**: Inland freshwaters and estuarine waters above the first bridging point or barrier.

3 **Coastal bare ground (beach/mudflats/cliffs)**: Bare coastal mud, silt, sand, shingle and rock, including coastal accretion and erosion features above high water.

4 **Saltmarsh**: Intertidal seaweed beds and saltmarshes up to normal levels of high water spring tides

5 **Grass heath**: Semi-natural, mostly acid, grasslands of dunes, heaths and lowland/upland margins.

6 **Mown/grazed turf**: Pastures and amenity swards, mown or grazed, to form a turf throughout the growing season.

7 **Meadow/verge/semi-natural swards**: Meadows, verges, low-intensity amenity grasslands and semi-natural cropped swards, not maintained as a short turf.

8 **Rough grass/marsh**: Lowland marsh/rough grasslands, mostly uncropped and unmanaged, forming grass and herbaceous communities, of mostly perennial species, with high winter-litter content.

9 **Moorland grass**: Montane/hill grasslands, mostly unenclosed *Nardus/Molinia* moorland.

10 **Open shrub moor**: Upland, dwarf shrub/grass moorland.

11 **Dense shrub moor**: Upland evergreen dwarf shrub-dominated moorland.

12 **Bracken**: Bracken-dominated herbaceous communities.

13 **Dense shrub heath**: Lowland evergreen shrub-dominated heathland.

14 **Scrub/orchard**: Deciduous scrub and orchards.

15 **Deciduous woodland**: Deciduous broadleaved and mixed woodlands.

16 **Coniferous/evergreen woodland**: Conifer and broadleaved evergreen trees

17 **Upland bog**: Upland herbaceous wetlands with permanent or temporary standing water.

18 **Tilled land (arable crops)**: Arable and other seasonally or temporarily bare ground

19 **Ruderal weed**: Ruderal weeds colonising natural and man-made bare ground

20 **Suburban/rural development**: Suburban and rural developed land comprising buildings and/ or roads but with some cover of permanent vegetation.

21 **Urban development**: Industrial, urban and any other developments, lacking permanent vegetation.

22 **Inland bare ground**: Ground bare of vegetation, surfaced with 'natural' materials.

23 **Felled forest**: Felled forest, with ruderal weeds and rough grass.

24 **Lowland bog**: Lowland herbaceous wetlands with permanent or tempory standing water.

25 **Open shrub heath**. Lowland, dwarf shrub/grass heathland

Appendix 3 STATISTICAL ASPECTS OF THE FIELD SURVEYS

A3.1 This summary provides details of the statistical rationale and methodology used to estimate land cover and change in the countryside surveys carried out in 1978, 1984 and 1990. It includes brief background statistical details on the 1 km square classification used to provide the stratified sampling frame and of the formulae used to derive field survey stock and change estimates and their errors ('stock' here being the amount at one point in time).

A3.2 To ensure consistency, exactly the same estimation methods have been used in deriving the published field survey results as input and used in the associated Countryside Information System (CIS).

A3.3 The statistical definitions and mathematical formulae are given in Appendix 3a. Nearly all the basic statistical rationale and methods of estimation used are based by Cochran (1977).

Stratification into Land Classes

A3.4 All three field surveys were based on a stratified random sampling scheme using a 1 km square classification into 32 ITE Land Classes as the strata. In this context, the terms 'Land Class' and 'stratum' are equivalent. The original ITE classification was based on classifying a systematic grid of *c* 1200 1 km squares spread throughout Great Britain (GB), using Ordnance Survey (OS) map-derived land characteristics (Appendix 1). This initial classification was used as the stratification for the 1978 and 1984 surveys

A3.5 For the 1978 field survey, because interest was in all the Land Classes themselves as ecological types, equal numbers (n=8) of 1 km squares were sampled from each Land Class irrespective of their estimated relative areas in GB. In 1984, these squares were nearly all resurveyed together with an additional four new randomly selected squares from each Land Class, giving a total sample size of 384 1 km squares.

A3.6 In 1990, the classification was revised using multivariate discrimination techniques on a reduced set of environmental attributes to enable all 240 000 1 km squares in GB to be classified. This has eliminated any estimation error due to not knowing the true sizes of each Land Class.

A3.7 However, it has meant that some squares in the original classification and earlier field surveys have now moved Land Classes, because all 1 km squares were assigned to a Land Class using the revised classification key. Strictly speaking, the original strata sample sizes should have been proportional to original stratum total areas to permit their re-allocation to the revised classification, as a form of post or retrospective stratification (Cochran, pp134–135). However, the Land Classification is only a dissection of what is really a continuum in environmental variation. Moreover, nearly all of the changes in Land Class are between 'neighbouring' similar Land Classes in the sense of the hierarchical divisive tree structure of the original classification. The general interpretation of the Land Classes has not changed.

A3.8 Therefore, in practice, the field squares of all three surveys can be treated as stratified random samples from the revised classification (Table A3.1), and estimates of both stock and change in stock derived accordingly.

A3.9 This will, however, lead to slightly revised estimates of cover for the previously published 1978 and 1984 surveys. But it does enable cover, and change up to 1990, to be estimated from within each of the same set of Land Classes.

A3.10 The extra 124 1 km squares sampled in Countryside Survey 1990 (CS1990) were selected from the Land Classes to make the overall Land Class sampling rate as near as possible proportional to Land Class areas.

Estimating cover and linear features

A3.11 The basic sampling unit for any statistical estimate of the area, length or frequency of any attribute is the 1 km square. Each 1 km square gives one value.

A3.12 Variation between squares within each Land Class represents the natural variation and is used to derive estimates of error for our population estimates. Inadequate sampling would lead to estimates and the estimated precision of those estimates (eg their standard error (SE)) both being imprecise.

A3.13 There are many attributes which can be derived for each square from the detailed information in the field survey. These range from areal estimates of single or combinations of recorded field sheet attributes, to lengths of hedgerow types, to the presence and richness of species in the quadrats. Different types of attribute may require different methods of estimation.

A3.14 The ITE Land Classification is effective as a means of providing a stratification for the field surveys, in that it restricts the occurrence of any individual attribute to a fraction of the Land Classes, and it is absent (or at least not found) in the other Land Classes. However, in those Land Classes where the attribute does occur, it is still absent from a proportion of the sample squares and the statistical distribution of values is skewed and highly non-normal. The median is often still zero in many Land Classes where the attribute does occur.

A3.15 To obtain unbiased estimates of a population mean or total, regardless of the statistical distribution, we first need to estimate the arithmetic mean (m) for each Land Class, rather than, say, the median or (bias-corrected) geometric mean. This is a simple but important point.

A3.16 To give some indication of the precision of estimates, their SE will often be given. In some cases the SE may be presented as a percentage of the estimate itself, in which case it is known as the percentage coefficient of variation (%CV) of the estimate (eg an estimate of 60, with SE of 15, has %CV of 25%).

A3.17 However, the skewed distribution and relatively small sample sizes within each Land Class mean that the sample stratum means (m) are probably not symmetrically or normally distributed, so that (m ± 2 SE(m)) does not provide reasonable estimates of 95% confidence limits. (SE(m) = standard error of sample mean m.) Therefore, if 95% confidence limits are required for estimates of the stratum means (or totals), it is thought that they would be

Table A3.1 Symmetric and asymmetric confidence limits for different coefficients of variation

%CV	Symmetric limits Lower	Upper	Asymmetric limits Lower	Upper
5	0.90	1.10	0.90	1.11
10	0.80	1.20	0.82	1.22
20	0.60	1.40	0.67	1.49
30	0.40	1.60	0.56	1.80
40	0.20	1.80	0.46	2.16
50	0.00	2.00	0.39	2.57

better represented by asymmetric confidence limits assuming a log-normal distribution.

These multiplicative confidence limits were estimated as follows:

lower limit = m / k; upper limit = $m \cdot k$

where $k = \exp(1.96 \sqrt{\{var(\log_e m)\}})$

$var(\log_e m)$ = variance of $\log_e m$

which can be estimated by:

$v_2 = \log_e\{1+[CV(m)]^2\}$

where $CV(m) = SE(m) / m$ = coefficient of variation of m.

A3.18 This method of estimating the variance of $\log_e m$ is taken from Burnham *et al.* (1987). Table A3.1 indicates the difference between using these limits and the usual symmetrical limits given by {m ± 1.96 SE(m)}. (For clarity of illustration 2.00 is used instead of 1.96, and all limits are expressed as a ratio of the estimate m.)

A3.19 In practical terms, this implies we are less sure about the upper limit for the area, say, of the attribute than the lower limit. It also ensures we do not get any negative lower confidence limits for poorly estimated attributes, so that, if %CV is 50% for poorly estimate attributes, the limits are not zero to double the estimate, but the more plausible range of 0.39–2.57 x the estimate.

A3.20 The total area of an attribute in the whole population (A_T) and its variance $Var(x_T)$ are estimated by weighted summations over the strata, as detailed in Appendix 3a. Because the population total estimate is based on 32 strata and many more samples, it is more likely to be normally distributed, so (x_T ± 2 SE) may be used to give reasonable 95% confidence limits for widespread attributes. However, for many detailed attributes of low overall percentage cover, absent from a high proportion of all sample squares, the true limits could still be

Table A3.2 Numbers of squares sampled in the three countryside surveys

Year of survey	New squares in 1978	1984	1990	Total
1978	256	-	-	256
1984	253	131	-	384
1990	252	129	127	508

asymmetric. Because the symmetric and asymmetric methods of estimating confidence limits give very similar results when %CV is small, it was recommended that asymmetric limits simply be used throughout for ALL estimates of stock, including for regions and countries.

A3.21 Following the approach of section A3.16, the 95% confidence limits for the estimate A_T of the population total stock are given by:

$A_T/k,\ A_T \cdot k$

where $k = \exp(1.96\sqrt{v_3})$, and

$v_3 = \log_e\{1+[CV(A_T)]^2\}$

where $CV(A_T) = SE(A_T) / A_T$ = coefficient of variation of A_T.

Estimating change in area or length between surveys

A3.22 The approach in CS1990 has been that the most reliable way to estimate change is to resurvey the same areas wherever possible. This is not only likely to lead to more accurate estimates of net change, but provides some detailed information on actual change between land feature categories (what has changed to what!). It is also assumed that the ITE Land Classes provide an effective stratification for change as well as stock; ie any particular change is likely to be relatively more consistent within the Land Classes.

A3.23 In the 1984 and 1990 surveys, it was possible to resurvey nearly all the previously sampled squares. The exact pattern of sampling over the three surveys is shown in Table A3.2.

A3.24 Over the three surveys, 514 1 km squares have been surveyed at least once. There is still a core of 252 squares which have been surveyed in all three surveys, and 381 squares which were surveyed in both 1984 and 1990.

A3.25 Change was estimated between any two surveys in two ways: first, by analysing the observed change in just the squares surveyed both times, and, second, by using all the squares available on each occasion. The two estimates will differ! However, their differences and their errors may be informative in themselves and in deciding which approach, on balance, provides the most accurate estimates.

A3.26 Estimating change from just the resurveyed squares is likely to give more precise estimates than independent survey squares if the general change has been small, and/or if the time between surveys is 'short'. In the extreme, a repeat survey of the same squares the next day would show the truth that there had been little or no change throughout the country, whereas completely independent surveys on consecutive days would provide no accurate information of the change. In the countryside surveys, the more accurate estimates of change, between 1984 and 1990, are provided by just the 381 squares surveyed at both times rather than by the difference between the total areas estimated by all 384 squares in 1984 and all 508 in 1990.

A3.27 If the sample units change so much from survey to survey that there is on average no correlation between the value (amount of land cover) of Y in successive surveys on the same sample unit (1 km square), then no gain in precision is obtained by re-sampling the same squares rather than taking a completely new random sample. However, there is no loss of precision either when compared to using two independent samples of the same size.

A3.28 Change using just the resurveyed squares is estimated by first calculating the change in cover, or change from cover type A to B, as required, in each individual square, and then estimating Land Class and total population change as for total stock in any one survey.

A3.29 When change is estimated from all the available sample squares in each survey, the estimate is simply the difference between the two population totals based on all available squares. However, because a proportion of the squares are the same in both surveys, there is a correlation between the two individual survey population estimates, which must be included in the estimation of the SE of the estimate of change., as detailed in section A3a.9 of Appendix 3a.

Estimates for regions of GB

A3.30 Separate estimates are provided for Scotland, England, and Wales in addition to GB as a whole.

A3.31 The estimates of stock and change for any region or country in both the published reports and the Countryside Information System (CIS) are based on using the overall GB means for each Land Class. Ideally, the estimates for any region should be based only on the Land Class means estimated from sample squares within the region. Although the ITE Land Classification is an 'environmental', and not regional, classification, it is still possible that land use and cover within a Land Class may differ between geographic regions for historical and economic reasons. Therefore, estimates for England, Scotland and Wales might also be made using just the Land Class means for the sample survey squares in each country. These should be compared with the corresponding estimates based on the GB Land Class means. (Any between-country differences in Land Class means can be assessed by non-parametric statistical tests.)

A3.32 It is best not to use within-region estimates of Land Class means for small regions because the estimates will be based on inadequate numbers of sampled squares, and any gain through reduction in bias will be outweighed by loss of precision. Using the GB estimates of Land Class means, in any region, does assume no significant regional differences of land stock within any Land Class.

A3.33 Standard errors and confidence limits will not therefore be very reliable estimates of the accuracy of estimates for English county-size regions, and in the CIS no errors will be given for such small regions of less than 5000 km^2.

Non-sampling of 'mostly sea' squares

A3.34 The sampling frame for each of the three field surveys was the population of all 1 km squares, referenced to the OS National Grid, which contained any land in GB. However, since the surveys aim to estimate countryside land statistics, any 1 km squares randomly selected from each ITE Land Class which were more than 90% sea, as measured from OS maps, were not included in the sample squares and field survey. They are referred to as 'mostly sea' squares. In practice, only one initially selected square had over 90% sea, but several others were rejected because they were mostly a combination of sea and built-up land, again as measured from OS maps.

A3.35 The small area of land in any ITE Land Class that is in 1 km squares with more than 90% sea (as measured on 1:250 000 OS maps) was assumed to have the same average composition of land cover types as any other part of that Land Class.

Estimating the total area of land in each Land Class

A3.36 The simplest approach for estimating the total area of an attribute in a Land Class is just to estimate the mean percentage of (the whole of) each 1 km square covered by the attribute in the Land Class, and then multiply by the total area (including sea) of all 1 km squares in the Land Class.

A3.37 Since the basic sampling unit is the 1 km square referenced to the National Grid, some 'coastal' sample field survey squares will include an area of sea, as only squares which were 'mostly sea' (see section A3.34) were excluded. This mainly affects ITE Land Classes 7 and 8 (mostly SW England and Wales), and 14, and 29, 30 and 31 (mostly Scottish islands). Deriving cover as a percentage of land removes the sample variation in attribute areas due simply to the differing amount of land in the sampled squares. Also, since the actual area of land, rather than the total area, in all the 1 km squares of a Land Class has been measured, it seems sensible to use this 'known' land area to try to improve the precision of cover estimates.

A3.38 Therefore, both the 1990 field survey analyses and the related CIS computer system used a second approach which is more complex. As part of the ITE Land Classification of every 1 km square in the whole of GB, the area of sea of every 1 km square was measured by digitisation from 1:250 000 OS maps. This means we have a 'census' figure for the total area of land in each Land Class. The field survey estimate of the proportion of land in a Land Class covered by a particular attribute was then multiplied by the census figure for total land area in that Land Class to estimate the total area of the attribute in the Land Class.

A3.39 The proportion of land covered by an attribute in a Land Class was estimated as the ratio of total attribute area to total land area from the field sample squares in that Land Class, and hence it, and its standard error, were calculated using standard statistical methods for 'Ratio estimators' (Cochran 1977). The computational details are given in Appendix 3a. If the census values for the total area of land in each Land Class were exact, then this second method would provide more precise estimates of total attribute areas and provide more accurate spatial estimates of cover for individual coastal squares in the CIS.

A3.40 The complication is that the field survey estimates of sea area are based on 1:10 000 scale maps which are more accurate than the 1:250 000 scale maps. Analysis of a set of squares for both 1:250 000 map area of sea (SM) and 1:10 000 field survey area of sea (SF) showed that there was a general tendency for SM to overestimate SF, but this varied between Land Classes, being much more pronounced in the 'lowland' Land Classes. Detailed analysis of the sample relationships between SF and SM suggested that these discrepancies could be adequately allowed for by simply dividing all squares into two major Land Class groups (Land Classes 1–16 and 17–32) and deriving one correction factor for each Land Class group.

A3.41 From the set of squares from each Land Class group (1–16 or 17–32) with both SM and SF measured, the following ratio estimate conversion factor B (with SE(B)) was derived, based on the ratio of mean SF to mean SM:

for Land Classes 1–16

$B = 0.487$. $SE(B) = 0.073$; $r=0.50$; $SD_r=12.5$

for Land Classes 17–32

$B = 0.825$, $SE(B) = 0.056$; $r=0.95$; $SD_r= 6.0$

where r measured the correlation between SM and SF, while SD_r indicated the average error (in hectares) in using B x SM to estimate the 'true' 1:10 000 field survey area of sea in any one 1 km square. It was seen that the estimates were not particularly accurate for individual 'coastal' squares (which might be selected in the CIS), especially in Land Classes 1–16 (mostly classes 7 and 8), where estimates for individual 1 km squares could be out by up to 20 hectares, so users of the CIS should beware.)

A3.42 The following procedure was used to estimate the total area of land in each Land Class, h.

- Calculate the total area (X_{hT}), including sea, of all 1 km squares in the Land Class
- Calculate the total area of sea (X_{hS}) (as defined from the 1:250 000 maps) of all squares in the Land Class that are recorded as having some sea (again as derived from the 1:250 000 maps).
- Then, estimate the total area of land (X_h) in Land Class, h, as:

$$X_h = X_{hT} - X_{hS}.B$$

and the variance of X_h by:

$$Var(X_h) = (X_{hS}.SE(B))^2$$

A3.43 For any whole Land Class or large region involving several Land Classes, the percentage error (%CV) in estimating the total land area will usually be small compared to the %CV for the proportional cover of attributes; and hence can usually be ignored.

A3.44 There were also a few squares which did have some sea (as defined by field survey 1:10 000 maps), but which were recorded as having no sea from the 1:250 000 map digitisation. However, analysis of the samples squares with both SM and SF, indicated that the amount of sea missed and hence the amount of land overestimated was less than 0.1% of the total area of land in all the 1 km squares calculated to have no sea from the 1:250 000 maps, and hence unimportant.

A3.45 For Land Classes or regions with little (or no) sea, the above procedure produced the same estimates as the simpler approach given in section A3.36.

Allowing for 'urban' 1 km squares

A3.46 Squares were only included in CS1990 if they were less than 75% built-up or urban land, as measured from 1:250 000 OS maps. Such squares are termed 'rural' squares, while the built-up squares are referred to as 'urban' squares. The built-up or urban land

Table A3.3 Number of squares sampled in each field survey from each of the 32 Land Classes of the revised classification. Also given is the total area of each Land Class in each of England, Wales, Scotland and GB as a whole

Land Class	No. of squares surveyed			Total area of Land Class (km²)			
	1978	1984	1990	England	Scotland	Wales	GB
1	8	15	28	12 466	0	1 049	13 515
2	10	12	24	14 059	0	4	14 063
3	11	18	30	15 344	0	91	15 435
4	4	6	10	8 279	0	54	8 333
5	3	4	6	2 428	0	1 325	3 753
6	9	13	23	7 228	348	2 670	10 246
7	8	13	13	1 682	412	430	2 524
8	9	12	14	3 222	543	481	4 246
9	13	16	21	9 249	1 211	699	11 159
10	12	17	22	10 999	2 428	134	13 561
11	13	19	22	8 712	4	0	8 716
12	5	9	10	3 322	14	0	3 336
13	9	14	17	4 208	1 948	635	6 791
14	4	6	6	342	522	22	886
15	5	7	9	1 227	397	2 430	4 054
16	8	10	11	2 270	479	321	3 070
17	10	16	28	3 698	300	9 001	12 999
18	6	9	13	1 952	3 796	928	6 676
19	2	4	7	2107	3 272	42	5 421
20	2	4	4	912	1 351	245	2 508
21	9	16	19	9	9 708	0	9 717
22	11	16	25	2 648	9 898	3	12 549
23	10	14	17	688	6 222	41	6 951
24	8	12	15	195	7 012	0	7 207
25	12	18	24	1 978	8 570	0	10 548
26	8	14	15	899	5 462	0	6 361
27	8	12	15	1 401	5 323	0	6 724
28	8	12	14	894	6 563	0	7 457
29	9	11	11	0	5 456	0	5 456
30	9	14	14	0	4 249	0	4 249
31	7	11	11	0	3 017	0	3 017
32	6	10	10	0	3 779	0	3 779
Total	**256**	**384**	**508**	**12 2518**	**92 284**	**20 605**	**235 307**

(as defined from the 1:250 000 map digitisation) is referred to as 'map-urban' land. Land in the 'urban' squares which is not 'map-urban' is referred to as 'unclassified urban fringe'. Account must be taken of the effect of not including 'urban' squares in the field survey.

A3.47 The 1:250 000 digitisation of every 1 km square in GB was done after both the 1978 and 1984 surveys. Cross-checking has verified that with, just one exception, every square selected as having less than 75% urban land in both the 1978 and 1984 surveys also had less than 75% cover values from the 1:250 000 digitisation. By 1990, the 1:250 000 digitisation of all squares was available, so the extra 122 squares added to the 1990 field survey were selected to have less than 75% urban land. Together, this means that the 1:250 000 digitisation was used to subdivide all squares within a Land Class into 'rural' squares (with less than or equal to 75% 1:250 000 map-urban) and 'urban' squares (with more than 75% map-urban).

A3.48 The total area of land in each Land Class was estimated separately for the 'rural' type squares and the 'urban' type squares.

A3.49 The field survey data strictly relate only to the 'rural' type squares. Ratio estimates (as described in sections A3.38–A3.40) were therefore used to estimate the total area (or length) of each survey attribute in 'rural' squares and hence for 'rural' square areas of regions or countries.

A3.50 Because there are no detailed field survey data for the 'unclassified urban fringe' part of the 'urban' squares for each of the surveys, the known total 'urban' square area for any Land Class, region or country is simply subdivided into the known total areas of 'map-urban' and 'unclassified urban fringe' land.

A3.51 In the CIS the 'urban' squares and/or areas of 'map-urban' or 'unclassified urban fringe' can be indicated on visual displays separately from the 'rural' square information.

A3.52 Although any squares with more than 75% 'map-urban' were classed as 'urban' squares, the total area of 'unclassified urban fringe' is only 8% of the total area of all the 'urban' squares.

A3.53 The 'urban' squares themselves form only 2.3% of the total area of land in GB. Therefore, in GB as a whole, the 'unclassified urban fringe' is less than 0.2% of the total area of land.

A3.54 Where it is required to derive field survey stock and change estimates for all land in a region or country, including the area of 'urban' squares, the following procedure was adopted.

- The 'map-urban' part of the 'urban' squares was treated as a separate cover attribute and its area identified for each square, Land Class or region, as required. (By its definition, it has no error.)

- For the (usually) relatively small area of 'unclassified urban fringe' in the 'urban' squares of any particular Land Class in a region, the relative proportional cover and distribution of the 'rural' field survey attributes was assumed to be the same as in the 'rural' squares in that Land Class. The total area, X_h, of land in the 'rural' squares and the 'unclassified urban fringe' in that Land Class h was calculated for the region concerned. If q_h was the estimate of the proportion of land in that Land Class covered by this attribute, then the estimate of the attribute's total area in that Land Class was calculated for the region as $(X_h q_h)$, using the formulae to calculate errors described in sections A3.11–A3.21 and given in Appendix 3a, sections A3a.10–A3a.12).

A3.55 The above procedure ignores the fact that some of the area in the 'rural' squares is made up of attributes which probably represent the 'map-urban' part of squares. Therefore, the simple approach above may tend to underestimate the areas of rural attributes in the 'unclassified urban fringe'. However, we have no detailed information on the true composition of the 'unclassified urban fringe' and it is usually only a very minor part of the total area concerned. The proportional and total area of 'unclassified urban fringe' in a region should always be indicated, and a warning given that this proportion of the total area of any attribute is from 'unclassified urban fringe' in 'urban' squares, and hence must be treated with extreme caution.

Appendix 3a STATISTICAL FORMULAE

A3a.1 The change in the mean value of a population attribute X between time 1 and time 2 can be estimated by taking samples at each time. There are several options available. At one extreme, independent separate samples could be taken on the two occasions, and, at the other extreme, the same sample units could be used in both sample surveys. The ITE field surveys used an intermediate approach whereby (nearly) all of the sample 1 km squares surveyed at time 1 were resurveyed at time 2, together with a number of new randomly selected units. A few of the 1 km squares surveyed in 1978 and/or 1984 could not be resurveyed because permission could not be obtained. In statistical terms, this means the ITE sampling scheme for change is effectively a 'partial replacement' scheme, with only a proportion of the sample units surveyed in both of any two surveys (Cochran 1977, pp344–358).

A3a.2 The choice of resampling scheme affects the estimator of change and its sampling variance or precision. Details of how to estimate cover (or lengths) and change for the field surveys are given below.

A3a.3 Suppose the whole population has been divided into L strata, and each stratum has been randomly sampled separately. For the ITE countryside surveys, the L strata are the 32 ITE Land Classes. Throughout this Appendix, 'stratum' and Land Class' are synonymous.

A3a.4 Then, the following section (A3a.5) must first be applied and calculated independently for each stratum in turn, and section (A3a.10) then used to multiply up Land Class statistics to obtain population estimates.

WITHIN ANY ONE STRATUM (LAND CLASS), h

A3a.5 Definitions

Let Y = the measured variable of interest.

A 'rural' square is defined to be a 1 km square which when digitised from a map was less than 75% built-up land. All other 1 km squares are referred to as 'urban' squares, as defined in sections A3.46–A3.55. The field survey only sampled 'rural' squares.

n_{h1}, n_{h2} = number of squares sampled at time 1 and 2 respectively in Land Class h

Y_{htj} = value of attribute Y in the jth sampled square of Land Class h at time t, $j=1...n_{ht}$, $t=1,2$

In any particular sampled square, the value of Y_{htj} will usually be either the proportion of the square covered by the attribute, or its total length in the square if it is a linear attribute.

Let X_{hj} = proportion of the jth sampled square in Land Class h which is land; $j=1...n_h$
(as measured directly from the 1:10 000 maps for the field survey).

Let X_h = 'census' figure of total area of land of all 1 km 'rural' squares in Land Class h, including correction of 'map' sea (SM) to more accurate field 'survey' sea (SF) – see section A3.40 for details.

$Q_{htj} = Y_{htj} / X_{hj}$ = proportion of land in the jth sampled square of Land Class h which is covered by attribute Y; $j=1...n_{ht}$

Assume (if necessary after suitable re-ordering) that the first n_{hc} of these sample squares were sampled at both times 1 and 2. This means that the first n_{hc} sampled units for this stratum in each survey are the same units (but obviously not necessarily with the same values), ie:

n_{hc} = number of 'overlap' sample units

$P_{h1} = n_{hc}/n_{h1}$ = proportion of the squares sampled at time 1 that were re-sampled at time 2

$P_{h2} = n_{hc}/n_{h2}$ = proportion of the units sampled at time 2 that were also sampled at time 1

$n_{hc} <= n_{h1}$, $n_{hc} <= n_{h2}$; $P_{h1} <= 1$, $P_{h2} <= 1$

$y_{ht} = \sum_{j=1}^{n_{ht}} Y_{htj}/n_{ht}$ = sample mean of Y in Land Class h at time t, $t=1,2$

$x_{ht} = \sum_{j=1}^{n_{ht}} X_{hj}/n_{ht}$ = sample mean of X in Land Class h at time t, $t=1,2$

(Σ means sum over the squares indicated)

$q_{ht} = y_{ht} / x_{ht}$ = sample 'ratio estimate' of the proportion Q_{ht} of land in Land Class h which is covered by this attribute at time t; t=1,2

The estimated variance of the estimator q_{ht} is:

$$Var(q_{ht}) = \sum_{j=1}^{n_{ht}} (Y_{htj} - q_{ht}X_{hj})^2 / (n_{ht}(n_{ht}-1)X_h^2),\ t=1,2$$

(At this stage, the possible (small) error in the 'census' figure X_h for the total area of land is ignored.)

The standard error of q_{ht} is $SE(q_{ht}) = \sqrt{Var(q_{ht})}$

NB In many Land Classes there are no 'coastal' squares with sea. In such cases, X_{ij} is always unity and $Q_{htj} = Y_{htj}$, so the ratio estimator and its SE are just the usual sample mean (y_{ht}) and $SE(y_{ht})$, as one would expect. This general procedure enables us also to cope with the Land Classes with sea in some 1 km squares.

A3a.6 Covariance between values in two surveys – precision of estimates of change

The tendency for the values of Y in the same sample unit to be similar at times 1 and 2 is quantified by the (auto) covariance of Y over time. This covariance between the values of Y in the two surveys in this stratum must be estimated from the n_{hc} 'overlap' squares sampled from this Land Class h in BOTH surveys, as follows.

Calculate the 'overlap' sample means m_{h1c}; m_{h2c} for each survey based on just the n_{hc} 'overlap' squares, as:

$$y_{htc} = \sum_{j=1}^{n_{hc}} Y_{htj} / n_{hc}$$ = 'overlap' sample mean of Y in Land Class h at time t, t=1,2

$$x_{hc} = \sum_{j=1}^{n_{hc}} X_{hj} / n_{hc}$$ = 'overlap' sample mean of X in land class h (same at times 1 and 2)

Let $q_{htc} = y_{htc} / x_{hc}$ = 'overlap' sample estimate of ratio Q at time t

The covariance between q_{h1c} and q_{h2c} is estimated by:

$$Cov(q_{h1c}, q_{h2c}) = \sum_{j=1}^{n_{hc}} \{ (Y_{h1j} - q_{h1c}X_{hj}) (Y_{h2j} - q_{h2c}X_{hj})\} / (n_{hc}(n_{hc}-1)X_h^2)$$

Because the n_{hc} 'overlap' samples are the only link between the estimates in the two surveys, their covariance determines the covariance between the ratio estimates q_{h1} and q_{h2} based on using all the samples available for each survey (see section A3a.9).

A3a.7 Estimating change within one stratum

Having calculated the above statistics, it is now possible to estimate the change in Q (the proportion of land which is a particular attribute cover) in this Land Class h, between the two surveys, by either, or both, of the following two methods (taken in part from Cochran (1977, pp180–182).

A3a.8 Estimating change using only the squares sampled in both surveys

This method is likely to be accurate for attributes whose change between the two surveys has been small and/or consistent within each Land Class.

The change in ratio Q in the stratum is simply estimated by calculating the change in mean area covered by the attribute from the n_{hc} 'overlap' survey squares (namely $m_{h2c} - m_{h1c}$). This difference is converted to a 'ratio estimator' by expressing it as a proportion m_{hdc} of:

$$m_{hdc} = m_{h2c} - m_{h1c} = (y_{h2c} - y_{h1c}) / x_{h1c} \quad (NB\ x_{h1c} = x_{h2c})$$

Let $Y_{hdj} = Y_{h2j} - Y_{h1j}$ = change in Y on j^{th} square in Land Class h

Then the estimated variance of m_{hdc} is:

$$Var(m_{hdc}) = \sum_{j=1}^{n_{hc}} (Y_{hdj} - m_{hdc}X_{hj})^2 / (n_c(n_c-1)\ X_h2)$$

A3a.9 Estimating change using ALL the squares sampled in either survey as the simple difference between the estimates for each survey

This method is likely to be better for attributes whose change is very variable between the squares within each Land Class, since, if there is little consistency between squares, it is best simply to use as large a sample as possible. (Note, however, that with large erratic changes, neither method will give very accurate estimates of change with much larger samples).

By this second method, the CHANGE in ratio Q in this Land Class h is estimated as the simple difference q_{hd} between the ratio estimates q_{h1} and q_{h2}, using all the surveyed squares in the two separate surveys to give:

$$q_{hd} = q_{h2} - q_{h1}$$

The estimated variance of q_{hd} is:

$$Var(q_{hd}) = Var(q_{h1}) + Var(q_{h2}) - 2\ Cov(q_{h1}, q_{h2})$$

where $Cov(q_{h1}, q_{h2})$ is estimated from the 'overlap' squares by:

$$Cov(q_{h1}, q_{h2}) = P_1 P_2\ Cov(q_{h1c}, q_{h2c})$$

The standard error of q_{hd} = SE(q_{hd}) = $\sqrt{\mathrm{Var}(q_{hd})}$

COMBINING STRATUM (LAND CLASS) ESTIMATES INTO AN ESTIMATE FOR A WHOLE REGION (OR COUNTRY OR GB)

The following formulae are used to combine the estimates in each Land Class of the proportional cover of any particular attribute, with the 'census' figures for the total area of land in each Land Class to derive estimates of totals for a whole region, where the phrase 'region' could mean just one Land Class, or a whole country, or all of GB.

The formulae can be applied to estimate the total area of:

- just the 'rural' squares, or
- just the 'unclassified urban fringe', or
- both the above – to give totals for both 'rural' and 'urban' squares,

simply by using the appropriate 'census' figure X_h for the total area of land – see sections A3.40 and A3.51 for further details.

X_h = appropriate 'census' figure of total area of land in Land Class h

$X_R = X_1 + X_2 + \ldots + X_{32}$ = total area of land in whole 'region' of interest.

As before, let q_{h1}, q_{h2} denote the estimators for ratio Q at times 1 and 2 for Land Class h.

Let m_{hd} = the estimator for change in ratio Q between times 1 and 2 for stratum h. (NB m_{hd} could here be the estimates based on all the squares in each survey, or just the 'overlap' squares

Similarly, Var(m_{h1}), Var(m_{h2}) and Var(m_{dh}) denote their estimated variances – calculated as detailed in section A3a.5.

A3a.10 Estimating total cover of an attribute in a 'region' in any single survey

The TOTAL area A_t for attribute Y, in the 'region', at time t, is estimated by:

$$A_t = \sum_{h=1}^{32} X_h q_{ht}, \quad t=1,2$$

The estimated variance of A_t is:

$$\mathrm{Var}(A_t) = \sum_{h=1}^{32} (X_h)^2 \mathrm{Var}(q_{ht}) + S_t$$

where S_t is the error variance on the 'census' figure for the total area of land X_R in the region. Unless the 'region' includes a high proportion of 1 km squares with sea, S_t will be negligible and can be ignored.

If required, S_t is calculated as follows (as in section A3.40).

Let X_{hS} = the total area of 'map' sea (as defined from the 1:250 000 maps) of all squares in Land Class in the 'region' that are recorded as having some sea (again as derived from the 1:250 000 maps).

Because we have two sea conversion factors B, B_1 and B_2 for Land Class groups (1–16) and (17–32) respectively, we need to calculate:

$$A_{1S} = \sum_{h=1}^{16} (X_{hS} q_{ht}) \quad \text{and} \quad A_{2S} = \sum_{h=17}^{32} (X_{hS} q_{ht})$$

Then, using the standard errors SE(B_1) and SE(B_2) of the two correction factors B from section A3.40, we have:

$$S_t = \{ A_{1S}\,\mathrm{SE}(B_1) \}^2 + \{ A_{2S}\,\mathrm{SE}(B_2) \}^2$$

A3a.11 Estimating change in cover in a 'region' between surveys

The TOTAL CHANGE A_d in area of attribute Y in the 'region' between times 1 and 2 can be estimated by:

$$A_d = \sum_{h=1}^{32} X_h q_{hd}, \quad t=1,2$$

The estimated variance of A_d is:

$$\mathrm{Var}(A_d) = \sum_{h=1}^{32} (X_h)^2 \mathrm{Var}(q_{hd}) + S_d$$

where S_d is as S_t above except q_{hd} replaces q_{ht} in the formulae for A_{1S} and A_{2S}.

The standard error A_d = SE(A_d) = $\sqrt{\mathrm{Var}(A_d)}$.

A3a.12 Estimating lengths (in contrast to areas)

All the above principles can be used in the same way to estimate the total lengths of linear attributes (such as hedgerows and roads).

The attribute Y will then be the total length of the attribute in each 1 km survey square. If X is still the proportion of the square which is land, then the same ratio estimator q=y/x ,used in section A3a.5, now estimates the length of the attribute per 1 km^2.

Therefore, multiplying by the total area of all land (in km^2) in that Land Class in the 'region' concerned and summing over the region in the same way as for areas (see sections A3a.10–A3a.11) will estimate the total length of the attribute in the 'region'.

Appendix 4 QUALITY ASSURANCE EXERCISE - SUMMARY

Introduction

It is recognised that in a field investigation on the scale of the Countryside Survey 1990 the large numbers of recorders and surveyors involved will produce an inherent degree of variation, despite the provision of a training course, a field handbook (Barr 1990) and on-site visits by supervisors (quality control). Whilst there is no reason to expect any directional bias in the records made, neither was any subsequently demonstrated, it is important to attempt to measure the consistency and reliability of the work done within the major components of the field programme (Quality Assurance Exercise).

A sample comprising 37 of the 512 squares surveyed in 1990 was selected and in each of these one quarter was resurveyed in 1991, at the same time of year as the original survey. The resurvey included one of each of the six permanently marked plot types: Main (200 m^2) plots; Habitat (4 m^2) plots; Verge plots; Hedge plots; Streamside plots: and field boundaries (all 10 m x 1 m plots) used in the main survey.

The Quality Assurance Exercise investigated

- the efficiency of plot relocation
- the reproducibility of species records made by the original surveyors
- the accuracy of percentage cover estimates of the species present
- the effect of the level of recording on the results obtained when subject to the normal techniques used to demonstrate habitat change
- the accuracy of the land use mapping of the 1 km squares.

The Quality Assurance Exercise has been fully reported (Prosser *et al.* 1992) this Appendix presents some of the key results and observations.

Plot relocation

Only 23 out of the 178 plots in the sample could not be relocated by the assessors in a brief search (5 minutes). It is considered that this 'recovery rate' (87%) justified the time taken during CS1990 to permanently mark and photograph all plots. The high relocation percentage suggests that detailed changes in the vegetation can be followed using the present survey methods. However, the relocation of plots, especially those in unenclosed land is often time-consuming and in future surveys additional manpower will be needed if all plots in a 1 km square are to be sought.

Accuracy of species records

Of *c* 5000 species records in 178 plots drawn from a subsample comprising 35 1 km squares:

- 63% were confirmed as species present by the assessors at the time of their survey;
- of the remaining 37%; 11% were clearly attributable to real differences in species composition of the plots surveyed in the two years and a further 9% were considered likely to be due to seasonal effects which could not be clearly demonstrated.

This suggests an initial recording accuracy lying between 74% at the lowest and 83% at the highest estimate, which is close to the value of 79% given as the maximum attainable efficiency between standardised searches by experienced field workers in Nilsson and Nilsson (1985).

The full report includes a detailed breakdown of the nature of species mismatches between the 1990 survey and the 1991 Quality Assurance Exercise (Prosser *et al.* 1992).

Not all plots gave equal levels of agreement. Results for Main (200 m^2) and for roadside Verge plots indicate that high levels of confidence can be attached to analyses of these sites. Those for Habitat (4 m^2) plots and Streamside plots are less reproducible; improved survey techniques could be developed to bring these up to the same standard. Recommendations for simple modifications of survey techniques are included in the full report.

Estimates of vegetation cover

When a comparison was made of the 20 most frequent species forming appreciable cover, only two (both grasses) have been recorded at significantly different levels in plots by the surveyors and the assessors. However, visual assessments of cover made over larger areas as part of the land cover mapping were more variable, and attention needs to be given to improving this aspect of countryside surveys

Direction of vegetation change

When data for changes in species composition within individual plots over time were subjected to correspondence analysis (eg DECORANA, Hill 1979), the shifts in position of plots or groups of plots could be related to changes in the environment acting on the vegetation in these plots. A series of such analyses have been performed in which the 1990 survey data and those of the 1991 Quality Assurance Exercise are compared for each individual plot type. In all cases, axis shifts have been demonstrated.

The overall axis shift between 1990 and 1991, though insufficient to be significant at this relatively small sample size, paralleled that previously demonstrated during the Ecological Consequences of Land Use Change project. To what extent the 1990–91 results reinforce the changes previously demonstrated or are evidence of a singular climatic shift between the two individual seasons cannot at present be established with certainty. The consistent direction of change shown since the surveys of 1978 and 1988 nevertheless indicate that the plot data obtained for 1990 were sufficiently reliable to be used with confidence to demonstrate environmental change.

Land cover mapping

Land cover mapping involved the use of a series of codes (see Appendix 2) which may, for the purpose of analysis, be subdivided into three groups:

- primary codes: major habitat and crop types;
- secondary descriptive codes: related to stock and variations in land management;
- cover codes: a further characterisation of a given parcel of land using a combination of the mapping of the most prevalent species together with a code denoting the cover of each.

The overall agreement found in primary coding was 84%; there was, however, a marked difference between the reliability of coding between the lowlands (95%) and the uplands (71%). The greater discrepancies identified in the unenclosed uplands relate in particular to difficulties experienced in distinctions between upland heath and bog types. Upland heath seemed to be under-recorded. This was the only instance in which there appeared to be a directional bias in coding.

It is clear that the allocation of primary codes to the commoner forms of managed and natural vegetation cover is reliable. Rarer habitats were, inevitably, represented only by a small number of samples; the reliability of information derived for these is less than for widespread habitats.

The percentage agreement found for the simpler secondary descriptive (or qualifying) codes was 78%. This figure relates to the use of codes which were unambiguous and involved simple decision-making, eg whether a hedge was stockproof or not stockproof. No satisfactory method was derived for direct comparison of strings of codes which included considerable elements of judgement. The method presented in the full report indicates the level of agreement for such qualifying codes to be approximately 49%.

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