INSTITUTE OF TERRESTRIAL ECOLOGY
(NATURAL ENVIRONMENT RESEARCH COUNCIL)

DETR Reference No. CR0175
ITE Project T02080m5

Ecological Factors Controlling Biodiversity in the British Countryside (ECOFACT)

MODULE 6 - Understanding the Causes of Change in Biodiversity in Britain (DETR) and England and Wales (MAFF)

Draft Final Report

R G H Bunce[1], P Carey[2], D C Howard[1], H M Van de Poll[1], D Roy[2], M O Hill[2], P Wilson[3], S M Smart[1], P Rothery[2], J Metcalfe[1] & J Duckworth[1]

[1] **Institute of Terrestrial Ecology**
Merlewood Research Station
Grange-over-Sands
Cumbria LA11 6JU

[2] **Institute of Terrestrial Ecology**
Monks Wood Experimental Station
Abbots Ripton
Huntingdon PE17 2LS

[3] **Unit of Comparative Plant Ecology**
Department of Botany
University of Sheffield
Western Bank
Sheffield S10 2TN

March 1998

CONTENTS

Page

Introduction 1

Impact Tables 3

Synthesis 13

Annexes

INTRODUCTION

This draft final report of Module 6 presents the final synthesis and drawing together of the information from the botanical change as well as the analysis of the causal factors. The summaries are designed to present a balanced series of arguments to answer the hypotheses set up during the process of Module 6. The impact tables are used as a means of synthesising the information which was determined during the process of the project, as they were originally intended to merely present the results. At the meeting of a sub-group in January it was decided to use the impact tables as a means of drawing the information together and providing the basis for the synthesis. They may subsequently be used to develop a computer package, in the same way as the project carried out by Nottingham University on farmland birds for DETR.

The sections on **'General evidence'** in the synthesis are drawn from broad ecological knowledge. Where possible individual references are included but these are mainly reviews. There is a potential for including a wider range of information subsequently. The sections on *'ECOFACT analysis'* is used to coordinate the case studies that have been carried out in the Module 6 and the information on botanical change. References are given in the text to the relevant sections of previous interim reports of Module 6. The **'General conclusion'** section is a presentation in terms of probabilities of the likelihood of the action causing the observed change. One of the main conclusions of the work has been that it is impossible to disaggregate many of the causal factors, because they are co-incident and synergistic in the way they operate at the landscape scale. In addition there is the problem of historical process development, for example in the development of a series of inter-related farm management practices as well as other integrated changes that have taken place over the period of the survey.

The major change in emphasis in the project from the initial design has been in the development of the indicator values for species developed by Professor Ellenberg. These have been re-calibrated for British conditions and cross referenced to independent data concerning the levels of nutrients within the appropriate species. This approach has superseded the initial idea of extracting information from individual previous studies such as the Park Grass experiment. They also replace the attempt to use logistic regression, because the information available at the site level was too general, to enable species to be correlated within environmental factors except at a gross level. The results presented in the various ECOFACT projects demonstrate that these values are the major determining factors controlling British vegetation. The shifts in vegetation composition, species composition and between classes can therefore be used to indicate change in the underlying environmental factors. Module 1 considers the inherent characteristics of the botanical composition of species as opposed to their use as environmental indicators as described in this document.

An important overriding conclusion was reached during the field work in 1996 which may be summarised as follows;

> The composition of vegetation at any given point within the landscape is determined by the management practice to which it has been subjected, given the inherent environmental character of that location.
>
> It follows that the management practices are determined using according to the objectives of land managers.
>
> Certain exceptions may occur;
> i) Atmospheric deposition
> ii) Catastrophic events eg. flooding.

It is also necessary to adopt the simplest solution which should apply to any given set of circumstances. For example, an assemblage of weeds within an intensively managed arable field where management has been directed towards the production of a crop is most likely to be the product of the management, rather than external influences, such as ozone levels.

Different types of change involve different timescales which means that some categories can be readily determined whereas others may take months and weeks to operate. There is therefore an important principle of categorical interpretation. For example there is no doubt that salt effects the edge of roads, but there is little detailed experimental evidence to support this. There is a wide difference between many of the individual cells of the impact tables, because some have very large amounts of ecological information e.g. grassland management and others such as roadside verges have very little information available from experimental or detailed case study work. The case studies carried out during ECOFACT attempted to redress this balance, but still never the less a variety of different levels of detail and certainty are involved.

The majority of the changes which have taken place are reflected in subtle differences between the categories, between the species composition within vegetation. The gross changes between the aggregate classes are usually caused by major factors such as crop rotation and these have been shown both in the initial CS90 report and in the analysis of botanical change to be relatively unimportant in comparison with the subtle changes which are taking place within a given vegetation class. The approach has been to use gross change, rather than holding the vegetation constant within any one class, except for the analysis of the functional strategies.

Another important factor which was observed during the field work, was that there was a major difference between vegetation which was present in the main plots, primarily in fields, which were generally involved in a single management practice, such as crop management, and roadsides, where several actions by be taking place within a single section of verge. Generally speaking, changes in plots that have changed greatly in their species composition were due to either changes in land cover, positive management or absence of management. Plots that were observed to be stable were mainly due to the fact that there had been lack of management as in ancient woodland, stable low inputs such as heaths on high mountains or intense management for a particular objective, such as mowing of roadsides and grassland verges. The dis-aggregation of these different influences however, is very difficult and in the interpretation of the results it has been attempted to balance the various effects but inevitably judgement is involved. One of the other general conclusions was that the number of actions were found to be complex. For example the indirect effects of afforestation are complex, involving polarisation of land use, decrease in streamwater flow, drying out of flushes, modification of nutrient flow in rivers, fragmentation of areas of semi-natural vegetation as well as the isolation of areas of high land surrounded by forestry. Similar complex factors has already been referred to in the case of roadside verges and the difficulty here is that the correlative approach can only proceed so far to explain these changes. In the report to the MAFF review of research in the wider countryside it was emphasised that one of the primary conclusions from this work is that it is necessary to carry out detailed experimental work in order to dissaggregate some of these effects. However the cost of these complex experimental projects would probably be prohibitive because of the necessity of including so many interactions. Therefore at the present time the balanced approach adopted in the present review is the best that can be done with the data which is available at a national level, although in some cases the detail experimental work which is available, for example in Park Grass, can be used to support the results where this is applicable.

IMPACT TABLES

It was originally intended that these would be constructed for the four landscapes separately but in practice sufficient objective information was not available. For example, there is no evidence other than circumstantial, that hedgerows are managed differently in different landscapes. However, if a hedge falls within Aggregate Class II (*tall grassland/herb*) it is likely to have had an inherently different history of management that one in Aggregate Class V (*lowland wooded*).

The starting points have therefore been borne in mind in determining the actions and their likely contribution to the observed changes. The first figure is the force of the action and the second, its likely involvement in the observed changes. Comments will be added in the text, if information is available between landscapes and to incorporate the information from case studies carried out in ECOFACT.

Although, in some cases the changes in Ellenberg values may involve only the loss of species, the residual population usually contains a higher proportion of generalists, and therefore represents simplification.

All tables follow the following format:

Ellenberg values

Fertility	+ = increase in fertility; - = decrease in fertility
Acidity	+ = less acidity; - = more acidity
Light	+ = more dense cover; - = more open
Moisture	+ = increase in moisture; - = decrease in moisture
Continentality	+ = increase in continentality; - = decrease in continentality

x = 1-5% significance level
xx = 1-0.1% significance level
xxx = less than 0.1 significance level

Impact Tables

●●	Will cause a major impact; probably involved in the observed change
●•	Will cause a major impact; likely to be involved in the observed change
●∙	Will cause a major impact; could be involved in the observed change
●.	Will cause a major impact; no evidence in the analysis
•∙	Will cause a significant impact; could be involved in the observed change
•.	Will cause a significant impact; no evidence in the analysis
∙∙	Will cause a minor impact; could be involved in the observed change
∙.	Will cause a minor impact; no evidence in the analysis
..	Could cause an impact; no evidence in the analysis

Shaded: not applicable

The decimal numbering system refers to sections in the final report. These will be accompanied by boxes of critical results which will in turn be linked to annexes appended to the report.

Main plots in Great Britain

	Species No.	Fertility	Acidity	Light	Moisture	Continentality
AC I	=	=	xxx	=	xxx	xxx
Weeds/crops	a	b	+		-	+
AC III	=	x	=	x	x	xxx
Fertile grassland		+		-	-	+
AC IV	xxx	xxx	x	=	=	xxx
Infertile grassland	-	+	+			+
AC V	=	=	=	=	=	x
Lowland wooded						+
AC VI	xx	=	=	=	=	=
Upland wooded	-					+
AC VII	=	=	=	x	=	=
Grass mosaics/moorland				-		
AC VIII	=	xxx	xxx	x	xx	x
Heath/bog		+	+	-	-	+

a - xx (in arable landscapes only)
b + xxx (in arable landscapes only)

Main plots on agricultural land in England Wales

	Species No.	Fertility	Acidity	Light	Moisture	Continentality
AC A (EW)	x	=	=	=	=	=
Sparse weeds/crops	-					
AC B (EW)	x	xx	xxx	=	xxx	xxx
Mixed weeds/crops	-	+	+		-	+
AC E (EW)	xxx	xx	x	=	=	xxx
Mixed grassland	-	+	+			+
AC G (EW)	=	=	=	=	=	=
Grass mosaics/moorland						
AC H (EW)	=	=	x	=	xx	=
Heath/bog						

a - xx (in arable landscapes only)
b + xxx (in arable landscapes only)

1 = Crop management: includes cultivation practice, fertiliser and herbicide use
2 = Crop change: changes between crops and associated management
3 = Lack of cultivation: involves Set-aside but this only came after 1980. Also involved in old grassland
4 = Crop rotation: an alternation between grass and crops
5 = Cultivation: ploughing up of old grassland
6 = Burning: concerned only with management for grouse
7 = Grass management: involves fertiliser, herbicide and cutting for hay/silage
8 = Drainage: tile drains/plastic drains in vegetation classes associated with wet soils
9 = Grazing (cattle): now mainly on lowland grassland
10 = Grazing (sheep): although common on lowland grass, main ecological impact is upland vegetation
11 = Recreation: involves trampling - shifts in use of fertile grassland not included
12 = Climate change: application of UK TR scenario
13 = Acid deposition: as measured by critical loads
14 = Nitrogen deposition: as measured by deposition maps
15 = Afforestation (broadleaved): virtually restricted to the lowlands
16 = Afforestation Conifer (direct): combined effect of ploughing and the canopy closure
17 = Afforestation Conifer (indirect): effect of water loss and drainage outside the forested areas
18 = Felling (broadleaved): usually small scale, localised
19 = Felling (conifer): usually large scale, effects runoff and soil

Main plots in Great Britain

	1 Crop management	2 Crop change	3 Lack of Cultivation	4 Crop rotation	5 Cultivation	6 Burning	7 Grass managemen	8 Drainage	9 Grazing (cattle)	10 Grazing (sheep)
AC I	●● 1.1	•• 2.1	●• 3.1	●• 4.1	▨	▨	▨	..	..	..
AC III	▨	▨	●• 3.2	●• 4.2	●• 5.1	▨	●• 7.1	•• 8.1	●• 9.1	•• 10.1
AC IV	▨	▨	▨	●• 4.3	●• 5.2	▨	●● 7.2	●• 8.2	●• 9.2	•• 10.2
AC V	▨	▨	▨	▨	▨	▨	▨	..	..	..
AC VI	▨	▨	▨	▨	▨	▨	▨	..	..	•• 10.3
AC VII	▨	▨	▨	▨	▨	•• 6.1	▨	●• 8.3	•. 9.3	●● 10.4
AC VIII	▨	▨	▨	▨	▨	•• 6.2	▨	●• 8.4	•. 9.4	●• 10.5

	11 Recreation	12 Climate change	13 Acid deposition	14 Nitrogen deposition	15 Afforestation (broadleaved)	16 Afforestation Conifer (direct)	17 Afforestation Conifer (indirec	18 Felling (broadleaved)
AC I	..	..	..	..	●. 15.1	▨	▨	▨
AC III	..	..	..	..	●. 15.2	▨	▨	▨
AC IV	..	•. 12.1	..	..	●. 15.3	..	..	▨
AC V	..	•. 12.2	..	•• 14.1	▨	▨	▨	▨
AC VI	..	•. 12.3	•. 13.1	•. 14.2	▨	●● 16.1	•. 17.1	● 18.1
AC VII	•. 11.1	•. 12.4	●• 13.2	●• 14.3	▨	●• 16.2	●• 17.2	●● 18.2
AC VIII	•. 11.2	•. 12.5	●• 13.3	●• 14.4	▨	●• 16.3	●• 17.3	▨

Main plots on agricultural land in England Wales

	Crop management 1	Crop change 2	Lack of Cultivation 3	Crop rotation 4	Cultivation 5	Burning 6	Grass management 7	Drainage 8	Grazing (cattle) 9	Grazing (sheep) 10
AC A (EW)	●● 1.1	●● 2.1	●• 3.1	●• 4.1	▨	▨	▨	••	••	••
AC B (EW)	●● 1.2	●● 2.2	●• 3.2	●• 4.2	▨ 5.1	▨	▨ 7.1	▨ 8.1	▨ 9.1	▨ 10.1
AC C (EW)	▨	▨	▨	●• 4.3	●• 5.2	▨	●● 7.2	●• 8.2	●● 9.2	●• 10.2
AC G (EW)	▨	▨	▨	▨	▨	●• 6.1	▨	●• 8.3	•. 9.3	●● 10.4
AC H (EW)	▨	▨	▨	▨	▨	●• 6.2	▨	●• 8.4	•. 9.4	●• 10.5

	Recreation 11	Climate change 12	Acid deposition 13	Nitrogen deposition 14	Afforestation (broadleaved) 15	Afforestation Conifer (direct) 16	Afforestation Conifer (indirect 17	Felling (broadleaved) 18
AC A (EW)	••	••	••	••	●. 15.1	▨	▨	▨
AC B (EW)	••	••	••	••	●. 15.2	▨	▨	▨
AC C (EW)	••	•. 12.1	••	••	●. 15.3	••	••	▨
AC G (EW)	•. 11.1	•. 12.4	•• 13.2	●● 14.3	▨	●. 16.2	•. 17.2	▨
AC H (EW)	•. 11.2	•. 12.5	•. 13.3	•. 14.4	▨	●. 16.3	•. 17.3	●• 18.2

Streamsides in Great Britain

	Species No.	Fertility	Acidity	Light	Moisture	Continentality
AC II	=	x	x	=	=	x
Tall grassland/herb		-	-			-
AC III	=	=	=	=	x	xx
Fertile grassland					+	-
AC IV	xxx	=	=	x	=	=
Infertile grassland	-			+		
AC V	=	=	=	x	xx	x
Lowland wooded				-	+	+
AC VI	x	=	=	x	=	x
Upland wooded	-			-		+
AC VII	x	=	=	=	x	=
Grass mosaics/moorland	-				+	
AC VIII	=	x	x	x	x	=
Heath/bog		+	+	+	-	

Streamsides in agricultural land in England Wales

	Species No.	Fertility	Acidity	Light	Moisture	Continentality
AC C (EW)	=	=	=	xx	=	x
Open wooded				-		+
AC D (EW)	=	=	=	=	=	=
Dense wooded						
AC E (EW)	x	=	=	xx	x	xx
Mixed grassland	-			+	+	-
AC F (EW)	=	=	=	=	=	=
Wet grassland						
AC G (EW)	=	=	=	=	=	=
Grass mosacis/moorland						

Key for Impact Tables (overleaf)

1 = Bank management involving flailing or cutting
2 = Neglect: absence of management in formally cut riverside
3 = Eutrophication, run off: increase in nitrogen in water plus build up of organic matter
4 = Acid run off: acid deposition on poorly buffered soils ??? ??? ??? ????
5 = Ditching: the practice of digging out ditches to improve drainage
6 = Canalisation: the practice of straightening and clearing river banks
7 = Burning: burning of heather for grouse moor management
8 = Reduction in grazing would involve management and/or fencing
9 = Increase in grazing would involve introduction of grazing
10 = Afforestation (direct): the effects of drainage, ploughing and canopy
11 = Felling (broadleaved): includes individual trees by water courses
12 = Clear felling of extensive conifer forests

Streamsides in Great Britain

	1 Bank managment	2 Neglect	3 Eutrophication run of	4 Acid run off	5 Dithcing	6 Canalisation	7 Burning	8 Grazing increase	9 Grazing decrease	10 Afforestation	11 Felling (broadleaved)	12 Felling (conifer)
AC II	●• 19.1	●• 20.1	●• 21.1	..	●. 23.1	●• 24.1	▨	●. 26.1	•. 27.1	▨	•• 29.1	▨
AC III	●. 19.2	●• 20.2	●• 21.2	..	●. 23.2	●. 24.2	▨	●• 26.2	●• 27.2	▨	..	▨
AC IV	●. 19.3	●● 20.3	●● 21.3	..	●. 23.3	●. 24.3	▨	●. 26.3	●• 27.3	..	..	▨
AC V	..	..	●. 21.4	..	..	..	▨	..	..	..	●• 29.2	▨
AC VI	..	..	..	..	..	..	▨	●. 26.4	•. 27.4	●• 28.1	●• 29.3	●• 30.1
AC VII	..	..	..	•. 22.1	●. 23.4	..	●. 25.1	•. 26.5	●• 27.5	●● 28.2	▨	▨
AC VIII	.	.	•• 21.5	●• 22.2	●. 23.5	.	●• 25.2	•. 26.6	●• 27.6	●• 28.3	▨	▨

Streamsides in agricultural land in England & Wales

	1 Bank managment	2 Neglect	3 Eutrophication run of	4 Acid run off	5 Dithcing	6 Canalisation	7 Burning	8 Grazing increase	9 Grazing decrease	10 Afforestation	11 Felling (broadleaved)	12 Felling (conifer)
AC C (EW)	▨	●• 20.1	●• 21.1	..	●. 23.1	●• 24.1	▨	●. 26.1	•. 27.1	▨	•• 29.1	▨
AC D (EW)	▨	●• 20.2	●• 21.2	..	●. 23.2	●. 24.2	▨	●• 26.2	●• 27.2	▨	..	▨
AC E (EW)	●. 19.3	●● 20.3	●● 21.3	..	●. 23.3	●. 24.3	▨	●. 26.3	▨	..	..	▨
AC F (EW)	.. 19.4	..	●. 21.4	..	..	..	▨	..	..	▨	▨	▨
AC G (EW)	..	..	..	..	..	..	●• 25.1	●. 26.4	•. 27.4	●• 28.1	▨	▨

Roadsides in Great Britain

	Species No.	Fertility	Acidity	Light	Moisture	Continentality
AC II	xxx +	=	=	=	x -	=
AC III	=	x +	xx +	x +	=	=
AC IV	=	x +	=	x +	xx +	xx +
AC VII	=	=	=	=	=	=

Roadsides on agricultural land in England Wales

	Species No.	Fertility	Acidity	Light	Moisture	Continentality
AC B (EW) *Mixed weeds/crops*	x +	=	x +	=	=	=
AC E (EW) *Mixed grassland*	=	=	=	=	=	=

Roadsides in Great Britain

	Disturbance 1	Management 2	Neglect 3	Salt 4	Mowing 5	Felling 6	Eutrophication 7	Increase in grazing 8	Decrease in grazing 9	Herbicides 10	Ditching 11
AC II	●• 31.1	●• 32.1	●• 33.1	•• 34.1	●• 35.1	●• 36.1	●• 37.1	··	··	●● 40.1	●• 41.1
AC III	●• 31.2	●● 32.2	●● 33.2	•• 34.2	●· 35.2	•· 36.2	●• 37.2	··	··	●• 40.2	●· 41.2
AC IV	●• 31.3	●● 32.3	●● 33.3	•• 34.3	●• 35.3	•· 36.3	●• 37.3	•· 38.1	●· 39.1	●• 40.3	●• 41.3
AC VII	●· 31.4	●· 32.4	●· 33.4	··	··	··	•· 37.4	•· 38.2	●· 39.2	··	●· 41.4

Roadsides on agricultural land in England & Wales

	Disturbance 1	Management 2	Neglect 3	Salt 4	Mowing 5	Felling 6	Eutrophication 7	Increase in grazing 8	Decrease in grazing 9	Herbicides 10	Ditching 11
AC B (EW)	●• 31.1	●• 32.1	●• 33.1	·· 34.1	●• 35.1	●• 36.1	●• 37.1	··	··	●● 40.1	●• 41.1
AC E (EW)	●• 31.2	●● 32.2	●● 33.2	•• 34.2	●· 35.2	•· 36.2	●• 37.2	··	··	●• 40.2	●· 41.2

1 = Disturbance: physical disturbance from vehicles, animals or excavation
2 = Management: flailing of the 1.3 m visibility strip involving cut of vegetation and deposition of dead organic materials
3 = Neglect: lack of management
4 = Salt deposition
5 = Mowing at regular intervals and removal of cuttings
6 = Felling of trees: involving remove of shade
7 = Nitrogen deposition and eutrophication from air breakdown
8 = Increase in grazing presence
9 = Decrease in grazing presence
10 = Application of herbicides
11 = Excavation of ditches by roadsides

Hedges in Great Britain

	1 Crop edge management	2 Grass management	3 Layering	4 Hedge management	5 Dereliction	6 Nigrogen depositon	7 Grazing increase	8 Grazing decrease
AC II	•• 42.1	•• 43.1	●• 44.1	⬤⬤ 45.1	⬤⬤ 46.1	•. 47.1	●. 48.1	●• 49.1
AC IV	•• 42.2	⬤● 43.2	⬤• 44.2	⬤● 45.2	⬤⬤ 46.2	•• 47.2	⬤• 48.2	⬤● 49.2
AC VII	•• 42.3	●• 43.3	⬤● 44.3	⬤● 45.3	•. 46.3	•. 47.3	●• 48.3	●. 49.3

Hedges on agricultural land in England & Wales

	1 Crop edge management	2 Grass management	3 Layering	4 Hedge management	5 Dereliction	6 Nigrogen depositon	7 Grazing increase	8 Grazing decrease
AC C (EW)	•• 42.1	•• 43.1	●• 44.1	⬤⬤ 45.1	⬤⬤ 46.1	•. 47.1	●. 48.1	●• 49.1
AC E (EW)	•• 42.2	⬤● 43.2	⬤• 44.2	⬤● 45.2	⬤⬤ 46.2	•• 47.2	⬤• 48.2	⬤● 49.2

Hedges in Great Britain

	Species No.	Fertility	Acidity	Light	Moisture	Continentality
AC II	xx -	xx +	x +	xx +	=	=
AC IV	-	x +	=	=	x +	=
AC V	=	=	=	x -	=	xxx +

Hedges on agricultural land in England Wales

	Species No.	Fertility	Acidity	Light	Moisture	Continentality
AC C (EW) *Open wooded*	=	=	=	=	=	=
AC E (EW) *Mixed grassland*	xxx -	xxx +	xxx +	=	=	x +

1 = Crop edge management: includes spray drift, fertiliser drift run off, crop influence
2 = Grass management: includes grazing, fencing
3 = Coppicing/layering: includes clear felling and traditional hedge layering practice
4 = Positive hedge management: includes removal of shrubs by flailing and mulching effect
5 = Dereliction: includes short- and long-term lack of management
6 = Nitrogen deposition
7 = Increase in grazing
8 = Decrease in grazing

CROP MANAGEMENT

1.1 AC I & AC A (EW)
1.2 AC B(EW)
General evidence

Weed management forms the subject of a major scientific journal (Weed Research) and is a major research topic in itself. An important finding is that certain species rapidly acquire resistance to some herbicides whilst others like *Bromus sterilis* became a problem because major changes in cultivation practice have favoured their persistence and expansion (Marshall, ;Firbank et al, 1996?). There is therefore a continued programme of research to eliminate these species so that the main objective of management of crop fields i.e. that of maintaining a weed free crop is continued. There is also evidence that many persistent weeds maintain large seedbanks necessitating continual control of above ground populations whilst rarer arable weeds may show less persistence, can be more seasonal in their germination requirements and have been generally disadvantaged by modern seed cleaning techniques, the efficacy of herbicides and changes in the timing of cultivation (refs). Evidence indicates that the main objective of crop management is to achieve weed free and highly productive cropping from season to season. This must therefore be a factor in the steady increase in productivity of arable systems observed over the last twenty years, as well as the longer term decline in mixed farming, the concentration of arable farming in the south and south east of Britain and the increased scarcity of rare arable plant species (Wilson, ; Rich and Woodruff, 1996; Scarce Plants Atlas; Corn Bunting study).

ECOFACT analysis

A wide range of management information was obtained from the ADAS report showing for example that nitrogen fertilizer applications in cereal fields increased by almost 25% between 1978 and 1990. This together with a shift to autumn sowing and increased efficiency of cultivations accords with the observed increase in Ellenberg fertility scores and functional analysis results which indicate eutrophication. This conclusion was supported by the results of field work carried out in ECOFACT where in the majority of cases in arable fields no other possible factor could be identified as causing the observed changes. Other potential factors such as ozone and ultra violet are still unproven in contrast with the proven relationship between management and weed populations. This strongly supports the link between management and diversity.

General conclusion

GB crop management is probably involved in the observed changes in crop/weed vegetation. EW as GB.

CROP CHANGE

2.1 AC I & AC A (EW)
2.2 AC B(EW)
General evidence

Different crops require different management regimes; for example potatoes are earthed up mechanically whereas cereals are drilled direct into the ground. There are also differences in spraying regime, fertilizer and insecticide use on different crops which will have both direct and indirect effects upon the weed population. It is also known that there has been a geographical polarisation in the distribution of arable farming in Britain (Corn Bunting study) and an associated decline in the diversity of crop species sown in rotation again owing to the influence of modern management practice. One major change has been the increase in oil seed rape at the expense mainly of cereals (CS1990 Main Report).

ECOFACT analysis

There is strong circumstantial evidence because the classes in the countryside vegetation system are related to the type of crop involved. However the relationships are rather weak and also the shifts in and out of different crops would tend to cancel each other out over the period of study. It is therefore unlikely that this change between crops is likely to have caused the observed changes and the shift towards eutrophication.

General conclusion

GB crop rotation is unlikely to have been involved in the loses of species in crop/weed vegetation.
EW. There is no evidence that this conclusion will differ from the GB trend.

LACK OF CULTIVATION
3.1 AC I & AC A(EW)
3.2 AC III & AC B(EW)

General evidence

Vegetation changes following the establishment of set-aside land usually involve a shift away from short lived ruderal species to longer lived perennial grasses with the fastest changes community composition occurring in the first three years after reversion (Critchley and Smart, 1995; AEES report to MAFF, 1998). Detailed differences in plant community changes depend on the composition of initial weed populations and the effects of management regimes prescribed by set-aside rules. However these factors are likley to exert a diminishing influence over time as succession eventually results in an established tree cover as shown by studies such as that on the Broadbalk wilderness at Rothampstead (get ref from Mark Hill). Apart from areas of vacant land near urban areas there is very little evidence of widespread dereliction of crop land in Britain.

ECOFACT analysis

The 1990 survey did pick up changes in land cover co-incident with land moving out of cropping. This was probably the first indication of set-aside but insufficient time is likely to have elapsed to have resulted in the detected decline in species. Indded dereliction following set-aside would be likely to result in an initial increase in species richness. Therefore dereliction is unlikely to be involved in the observed loss of biodiversity.

General conclusion

GB and EW: Dereliction is unlikely to been involved in the loss of species in crop/weed vegetation.

CROP ROTATION
4.1 General Evidence

The general evidence is that rotation between grass and crops has declined although not to the same degree in Scotland, as in England and Wales. As the majority of crop land is in England and Wales this suggests that this effect is not likely to be important in national changes. In addition in general it would be expected that CS90 database would involve movements in both directions which would actually cancel themselves out.

ECOFACT analysis

The matrix of change between 1978 and 1990 showed that 47 plots moved into grassland to crops and 44 from crops into grassland, therefore the balance is almost equal between them. The effect is therefore likely to be neutral because roughly equal numbers of plots were moving in and out of crops and grassland vegetation. Analysis of seed banks under EcoFact 3, showed that the seed bank of fields which have been grassland is rather different from those that have been purely crop land over the period of time so this could be an indirect effect. However again the same effect is likely to be involved in that movement in and out will cancel each other out.

General conclusion

Rotation of crops is unlikely to be observed in the observed major changes in crop/weeds vegetation.

4.2 General Evidence

Crop rotation is more likley to involve shifts in and out of the fertile grasslands. The effects of sowing high productivity cultivars of grasses such as perennial ryegrass, are likely to have the effect of producing a changed sward.

ECOFACT analysis

As with 4.1 there is no evidence of a shift and the effect is therefore likely to be neutral. New cultivars would be expected to increase the density of grass, whereas the effect was the reverse. In EW data the short term grassland is included with both the tall grassland/herb and infertile grassland of the GB dataset. This would make it unlikley that the effects of crop rotation are involved in the observed changes.

General conclusion

GB and EW: Crop rotation is unlikely to be involved in the observed changes in fertile grassland vegetation.

CULTIVATION

5.1 General Evidence

Cultivation of fertile grassland converts it to a crop and therefore involves a change in the overall species composition towards ruderal species. MAFF statistics show that the area of sown leys has declined.

ECOFACT analysis

Evidence from the analysis of functional attributes indicated that eutrophication and disturbance had taken place which maybe linked to the effects of cultivation. There is no evidence from the matrix of change of classes or from the land cover data that there is any increase in cultivation of fertile grasslands.

General conclusion

Cultivation of existing grasslands is unlikely to be involved in the observed changes in fertile grassland vegetation.

5.2/5.3 General Evidence

Cultivation in infertile grassland involves a major shift from old grasslands typified by high richness of native grasses and herbs into poorer high productivity grasslands and crop monocultures in both of which species composition is much more a reflection of comtemporary agricultural management than the longer term influence of factors such as age and soil type.

ECOFACT analysis

Evidence from the analysis of farm management practice and from fucntional analysis suggests that there is a change towards eutrophication and disturbance within this category. However, the evidence from the land cover analysis shows that this is less likely to have resulted from widespread ploughing and reseeding of old pastures but more to intensification within existing swards.

General conclusion

GB and EW: Although locally important, cultivation is unlikely to have caused the observed overall changes in infertile grassland vegetation (GB) and mixed grassland (EW).

BURNING

6.1 & 6.2 General Evidence

Burning takes place regularly within heather dominated ecosystems, mainly for grouse moor management, but occasionally for improving the quality of the herbage (Gimingham, 1995). The vegetation at the poorest end of aggregate class 7 and in the drier, better drained heathlands of aggregate class 8 are most likely to be effected by this practice. There is general agreement that heather burning combined with intensive grazing will remove the heather cover and convert heather moorland into acid or moorland grassland (Tallis, 1997; Gimingham, 1964). Furthermore the importance of burning in areas where bracken is encroaching is also important in shifting the balance towards vegetation that is dominated by species other than heather(Pakeman and Marrs,1992). Involved in this process is the progressive accumulation of nutrients since the over exploitation in Napoleonic times and since the removal of forest canopy. In England and Wales burning is restricted to the grouse moors of northern England and is less likley to be important than in GB as a whole.

ECOFACT analysis

The increase in light in both aggregate class 7 & 8 suggest that burning could be implicated in opening up the vegetation to further light and for more graminaceous species. This is confirmed by the decline in ericacious species and the increase in carices and grassland species involved. However this change is not co-incident with the eutrophication and decline in acidity that has also been observed in ECOFACT. It would however be in agreement with the increase in disturbance observed in the ECOFACT analysis of the functional strategists.

General conclusion

GB: It is likely that burning could be a contributory factor involved in the observed changes in upland vegetation but probably in combination with other more important factors.
EW: No evidence that burning is a significant factor.

GRASS MANAGEMENT

Annex A (attached) - Hopkins review

Annex B - Nitrogen levels in managed grasslands, section L. 1997 Interim Report.

7.1 General Evidence

The review by Hopkins presented in Annex emphasises that grassland management has changed significantly between 1978 and 1990. Although this is probably less marked in the already intensively managed grassland of aggregate class III there is no doubt that the increased use of fertilisers, the further expansion of slurry application and the shift from hay to silage are all likely to be contributory factors to any observed change in this category of grassland.

ECOFACT analysis

The difference between the arable and pastural landscapes suggest that there are regional differences in the shift of species number within this category and whilst overall in the table there is no national shift the ECOFACT analysis demonstrates that changes are taking place. Therefore although plots in this vegetation type were by definition already rather species poor in 1978 there is still evidence that there has been a decline in biodiversity. The increase in canopy cover, together with the eutophication and disturbance reported in the functional analysis strongly suggests that grassland management overall is likely to be an important factor in this category.

General conclusion

Grassland management is probably involved in the observed changes in fertile grassland.

7.2 General Evidence

One of the most widely observed changes in the English agricultural landscape has been the decline in herb rich meadows (Marren, 1993; Green, 1990; 1984; Fuller, 1987). There is also an extensive scientific literature summarised in the work by Smith (1987) in which he demonstrated the wide spread influence of management practices involving both fertilisation, time of cutting and traditional seasonal grazing.

ECOFACT analysis

The review by Hopkins presented in the annex (a) summarises the overall changes which have taken place in grassland management over the period of time. ECOFACT analysis of the farm management data collected by ADAS confirm the broad direction of Hopkins conclusions but further emphasise that it is not possible to dis-entangle the various processes at work. The conclusion therefore from the management information collected during ECOFACT is that there has been a major shift towards intensification of management involving direction of nutrients into the grass crop at the expense of less competitive and particularly broad leaved species. The initial analysis of CS1990 data (Barr et al, 1993) emphasised that losses of biodiversity in this category were, with the exception of upland woodlands, the most significant across the whole spectrum of the classes under consideration. This has been confirmed in the further analysis of Ellenberg scores which show that these losses in species are associated with a major increase in fertility, decline in acidification and also an increase in eutrophication and disturbance as recorded by the functional analysis. Other ECOFACT analyses have shown that this particular category is involved in a major loss of quality species regarded as significant by the conservation agencies and that it is also associated with a loss of species that provide food for butterfly larvae and bumblebees. Aggregate Class 4 encompasses vegetation that varies from chalk grassland, which over the period of time is unlikely to have been effected by this process, to other unimproved, neutral grassland types which are most tractable to agricultural improvement and make up the bulk of plots in the class. It is however, important to note that detected changes centre upon average values for the class which can be consistent with stability in, for example, chalk grassland plots whilst marked change can occurr in other groups of plots.

General conclusion

Grassland management has probably caused the obaserved changes in infertile grassland vegetation.

8.1 General evidence

The evidence is that drainage has still probably continued (Potter and Lobley, 1996), but primarily for agronomic purposes in order to produce grass earlier. Most of the species typical of wetlands situations have probably already disappeared from this aggregate class.

ECOFACT analysis

There is an observed decline in moisture levels in this class but because of the low initial of moisture level is unlikely to be involved in the loss of wetland species. The highly significant increase in continentality is also difficult to explain. The eutrophication observed in this class from the functional analysis is not likely to be co-incident with drainage, unless higher nitrogen application had take place

General conclusion

It is unlikely that drainage is involved in the observed changes in fertile grassland vegetation.

8.2 General evidence

It would be expected from general observation that drainage in infertile grassland would have still been taking place during the period 1978 to 1990 and this was confirmed by Potter and

Lobleys' (1996) survey of a sub-sample of landowners in CS sample squares. Drainage may therefore have partly contributed to detected changes in the vegetation.

ECOFACT analysis

Within aggregate class IV there is a wide range of vegetation classes from calcareous grassland which is unlikely to be effected by drainage, to the wet grasslands of river margins; for example on the Ouse washlands. However there is little evidence from ECOFACT analysis in this class that the losses of species observed are likely to be associated with moisture but rather the evidence is towards eutrophication and disturbance.

General conclusion

It is unlikely that drainage has been involved in the observed overall changes in infertile grassland but could be important in some CVS classes.

8.3 & 8.4 General evidence

It has been generally observed that drainage in moorland and upland situations has declined and especially moorland gripping is not occurring as in the late 60's and early 70's. Evidence also suggests that on deap peat grip drains only influence the vegetation in a narrow zone adjacent to the channel linked to the low hydraulic conductivity of compacted peat (Ref). However the effects of drainage on shallower peats or in combination with other impacts cannot be discounted. Neither can we rule out the delayed effects of earlier drainage operating in some CS plots.

ECOFACT analysis

The general evidence from the analysis of individual species suggested that moisture loving species are not involved. The analysis of Ellenberg values however shows that there has been a decline in moisture levels within aggregate Class VIII. There has also been evidence of eutrophication and disturbance both from ECOFACT analysis of Ellenberg values, and from the functional analysis. Neither of these changes are co-incident with drainage. It is unlikely therefore that drainage per se is likely to be involved, in a major way because of the links with eutrophication and disturbance. The indirect effect of afforestation could also be involved (16.1 - 16.3) and would be difficult to separate.

General conclusion

Drainage could be involved in the observed changes in heath/bog vegetation.

9.1 General evidence

Cattle, both dairy and beef, have a major influence on sward composition.

ECOFACT analysis

There is limited evidence of an increase in either dairy or beef cattle over the period time 1978 to 1990 as recorded in the analysis of farm management practice. The observed decreases in light and moisture are unlikely therefore to be involved in this observed change, since the broad pattern is of continued use of managed grassland by dairy and beef cattle.

General conclusion

Although absence of grazing would cause a major change, there is no evidence that shifts in cattle grazing have caused the observed change.

9.1 General evidence

Cattle grazing is an integral part of many of the ecosystems in this aggregate class and in maintaining the variability of the vegetation.

ECOFACT analysis

Although the increase in fertility could be due to increased grazing there is limited evidence that this has occurred, except indirectly on an influence of grass improvement.

General conclusion

Although absence of grazing would cause a major change, there is no evidence that shifts in cattle grazing have caused the observed change.

9.3 & 9.4 General evidence

Very few cattle are now involved in grazing acid grassland moorland, heath or bog vegetation. Although they may have an influence locally they are unlikely to be a widespread influence on the general composition of vegetation in these two aggregate classes.

ECOFACT analysis

The observed increase in eutrophication and disturbance is unlikely to be co-incident with cattle grazing in such vegetation.

General conclusion

Cattle grazing is unlikely to be involved in the observed changes.

GRAZING (SHEEP)

Annex C - Upland studies, Section A. Interim Report, 1997.

10.1 & 10.2 General evidence

Sheep grazing on intensively managed lowland swards has become more widespread in recent years owing to the increased profitability of sheep farming in lowland systems.

ECOFACT analysis

It is difficult to specifically associate the incidence of sheep grazing across the whole spectrum of the ECOFACT individual vegetation classes because they vary from chalk grassland through to intensively managed lowland grass. It is difficult therefore to associate the change in sheep grazing with the major trend to eutrophication and decrease in acidity observed across the whole of this aggregate class. Sheep grazing could be involved in the disturbance observed in the functional analysis and if extremely intensive could be involved in the eutrophication, but, it is difficult to envisage that this level of change could be caused by a shift from cattle to sheep grazing. In addition it is generally known that sheep grazing maintains diversity on chalk grassland and is likely to be involved in aftermath grazing on infertile grassland elsewhere in traditional systems and has not therefore been associated in the past with loss of biodiversity.

General conclusion

In general over the whole aggregate class it is unlikely that shifts in sheep grazing are likely to be involved in the observed changes which are primarily due to fertility.

10.3 General evidence

Upland woodlands are often grazed and it is well known that their vegetation is affected by sheep grazing (B.Wildlife, OTHERS).

ECOFACT analysis

The actual proportion of such vegetation within the upland wooded aggregate class is however small, since the very large areas of woodland involved are primarily coniferous within which grazing is not present. The observed species loss and the increase in continentality is probably because of the loss of oceanic species beneath the forest canopy, and not co-incident with any sheep grazing.

General conclusion

Sheep grazing although locally important is unlikely to be involved in the loss of species within upland wooded vegetation.

10.4 General evidence

There is a major literature associated with sheep grazing on upland vegetation. The work by Hughes (196??) showed that the overall effects are complex and relates to the individual character of the vegetation concerned. In general however there is agreement that intensive grazing in the uplands causes a shift away from *Ericaceous* vegetation dominated by dwarf shrubs to graminaceous swards dominated by species such as *Agrostis/Festuca* or *Nardus* or even in some cases *Molinia* (Welch, 1984; Welch and Scott,1995; Anderson and Yalden,1981).

ECOFACT EVIDENCE

There is strong support for the increase in sheep numbers in particular upland areas in Britain (Hudson, 1984; Anderson and Yalden, 1981). However there is doubt as to the extent to which this has on average impacted upon open fell and mountain or on the in-bye land below. Therefore, the initial suggestions that followed the CS1990 report may not be supported because of important differences in the dispersion of sheep through the landscape. However, the analysis of change of individual species showed a decline in *Ericaceous* species which would be consitent with grazing effects. This is also in agreement with the increased disturbance detected in the functional analysis of vegetation together with increases in eutrophication. This is further in agreement with the analysis of Ellenberg scores which showed an increase in light which could well be co-incident with the increase in grazing pressure. These uncertainties led to the ECOFACT case study of upland vegetation, grazing and nitrogen deposition in which it was demonstrated that there is strong evidence that the primary control is from grazing, but that these effects interact with nitrogen deposition.

General conclusion

Sheep grazing is likely to be involved in the observed changes in the balance of upland vegetation, but that this is probably coincident with and cannot be separated from the effects of nitrogen deposition.

10.5 General evidence

The evidence for grazing pressure on heath and bog is more fragmentary than on grassland mosaics/moorland. The extensive research at Redesdale and elsewhere in the uplands, points to the significance in grazing in reducing the proportion of cover of *Ericaeous* species, but again it is very much dependant upon the individual characteristics of the vegetation concerned and can vary widely between situations in areas covered by *Calluna* at different altitudes at different aspects and slopes.

ECOFACT analysis

The ECOFACT analysis showed major increases in fertility, decreases in acidity and increases in light all of which would be co-incident with grazing changes in this type of vegetation although it should be emphasised that these were not associated with a loss of species but a change of the balance of the species composition within similar vegetation. Further analysis in ECOFACT showed that the changes in aggregate class VIII were different between dry acidic heaths on podzolic soils, as opposed to those typical of saturated bogs on deep peats which becoming less acid and more fertile. This divergence was masked in the tabulation showed in the final version of the impacts table, because plots in both situations were initially analysed together. The eutrophication and disturbance observed in the functional analysis confirms that there is likely to be similar trend to that observed in the Ellenberg values. The ECOFACT case study showed the complexity of the interaction between grazing and nitrogen deposition. In general therefore the factors concerned are closely inter-related and inter-correlated and it is not possible to identify which particular factor is causing which particular change except to confirm that their co-incidence is likely to be causing the underlying changes in the vegetation involved.

General conclusion

Grazing is likely to be involved in the observed changes but in a complex way and possibly linked to nitrogen deposition.

RECREATION

Refered to in minutes of April 1997, TSG meeting.

11.1 General evidence

The drier grasslands of *Agrostis/Festuca* within aggregate Class 7 are likely to be more susceptible to trampling than the more robust *Molinia* dominated grasslands. There is a wide range of information summarised by Bayfield (1977 & others) on the impact of trampling upon upland vegetation. In summary the effect is to cause localised destruction of the vegetation and this can lead to sheet erosion in some areas on steep less stable slopes. However impacts are likely to be highly localised although visually conspicuous. Much evidence is anecdotal rather than quantitative.

ECOFACT analysis

As part of the ECOFACT upland study a method was developed to record recreational pressure. This work showed no evidence of such impacts in any of the squares visited. However this was a small sample and there is no doubt that trampling in upland areas is of great local importance. Recent work by the National Trust in England and Scotland have shown that remedial action is particularly effective on mineral soils. Whilst trampling would cause the increase in light observed in this class the ECOFACT evidence is such that it is unlikely to be involved in CS upland squares.

General conclusion

There is not evidence that recreational pressure is involved in the observed changes.

11.2 General evidence

The high mountain vegetation of the Cairngorm plateau and other mountain areas is quite susceptible to recreational impact. However this type of vegetation is only a very small part of aggregate Class 8. Other areas that have shown to be susceptible are very wet peat lands where the vegetation is very slow to recover form damage and it is often necessary to build broadwalks to relieve the recreational pressure.

ECOFACT analysis

As with the previous section, no impact was observed in the study sites. The impact of recreation is not co-incident with the observed changes and it is therefore considered not to be a causal factor.

General conclusion

There is no evidence htat recreation is involved in the observed changes.

CLIMATE CHANGE

Discussion presented in the first Interim Report, April 1996

12.1 - 12.5 General evidence

There is a broad agreement about the extent of climate warming as reflected by the progressive increases in temperature over the last century and about the associated increases in green house gasses, such as Carbon Dioxide. There is a very extensive literature on this subject and the TIGER programme of NERC has provided much evidence about the likely impacts of climate change. However there is virtually no agreement about the way in which these changes are likely to effect the vegetation, nor even to the extent that current modelling scenarios agree in their predictions. The subject is therefore very difficult to assess because of the degree of uncertainty about future changes. One important conclusion from the CLAUM project was that 'land use change was most likely to be much more important than the very gradual effects of climate change'.

ECOFACT analysis

ECOFACT analysis of Ellenberg scores showed an increase in continentality in four of the six classes for which sufficient data is available. There has also been an observed a shift towards the more widely spread species with biogeographic distributions that are very generalist in their occurrence. It is unlikely however that these major shifts have been caused directly by climate change. What is most likely is that the species which have declined in abundance are usually rather specialised species vulnerable to land-use change and an increase in more competitive species as well as to an increasingly inhospitable climate. The increase in biogeographic generalists supports this interpretation, but without further detailed analysis it is not possible to confirm this interpretation.

General conclusion

Climate change is unlikely to be involved in the observed change in species but some circumstantial evidence to that effect has been found.

ACID DEPOSITION

Discussion presented in the first Interim Report, April 1996

13.1 General evidence

There has been much discussion in the past about the effect of acid deposition and, in broad terms, the critical load project has demonstrated that impacts are likely to be greatest on poor soils in areas of high deposition. This is proven in the European situation where the majority of observed tree deaths have been on shallow acidic soils, usually on granite rocks.

ECOFACT analysis

The major loss of species observed in aggregate Class 6 is not likely to have been caused by this effect since there has been virtually no evidence of canopy damage. The strong coicidence in some plots between species loss and conifer canopy closure further confirms that this factor is not likely to be linked to the observed changes established in ECOFACT.

General conclusion

There is no evidence that Acid deposition is involved in the observed changes.

13.2General evidence

Critical load analysis has shown that such systems are likely to be under some pressure from acid deposition as they are mostly associated with nutrient poor, acidic soils.

ECOFACT analysis

Evidence of acidification would emerge from analysis of Ellenberg pH scores for dry heath dominated areas but on average there was no significant cahnge. The majority of soils within aggregate Class VII are relatively well buffered and this process is therefore unlikely to have caused the observed change. The increase in mean light score is more likely to be due to grazing.

General conclusion

Acid deposition could be involved in the overall change observed in part of the class but is unlikely to be the major factor.

13.3 General evidence

Critical load mapping has shown that upland vegetation on soils with low exchange capacity are most at risk. The CVS classes dominated by *Calluna* on podzolic soils are therefore those that fall into this category.

ECOFACT analysis

Analysis of Ellenberg scores showed that within the dry heaths there had indeed been a significant acidification whereas in the bog classes overall the opposite effect had been observed. The overall dominance of the peaty classes meant that in the impacts table a decrease in acidity had taken place. Overall results for the GB analysis show that acidification may have taken place only in vegetation on drier soils. Whether this has been caused by acid deposition or by nitrogen deposition is uncertain. The increase in light is more likely to be due to grazing.

General conclusion

Acid deposition could be synergistic with nitrogen deposition and grazing to have caused the observed acidification in dry heaths, but not in bogs.

NITROGEN DEPOSITION

Annex D - Section K, Interim Report, Dec 1997

14.1 General evidence

Lowland woodlands are efficient trappers of nitrogen. Some studies in Sweden and in East Anglia have shown an increase in eutrophic species in woodlands. This could be from aerial sources, fertiliser drift or run-off.

ECOFACT analysis

Although the analysis of Ellenberg values showed no change, the functional analysis indicated eutrophication, especially in arable landscapes. These results would support an increase in the fast growing species which would benefit from increased nitrogen levels. This is in conflict with the observed gains in species which have been shown to be in opposition to increases of cover of large fast growing species.

General conclusion

Nitrogen deposition could be involved in shifts in the balance between species in lowland woods but are not likely to be related to the observed change in species number.

14.2 General evidence

Nitrogen deposition in upland woods is likely to be lower than in the lowlands because of the lack of point sources of ammonia.

ECOFACT analysis

The species decline in upland woods is not in agreement with an increase in nitrogen level in terms of the fertility score nor of eutrophication as measured by the analysis of functional strategies.

General conclusion

Nitrogen deposition is unlikely to be observed in the changes seen in upland woodlands.

14.3 General evidence

Nitrogen deposition is at a relatively even level until north of the great glen in Scotland. There is little general evidence of any direct effect of the nitrogen deposition except that the work of Thompson (19??) showed that there was an interaction with nitrogen deposition, recreation and grazing pressure in certain specialised high mountain vegetation. There has been no observed increase in fertility in this class and the species number is relatively stable. The analysis of the case study carried out in the uplands for ECOFACT showed however that there was co-incidence between grazing pressure, nitrogen deposition and the type of vegetation involved. Therefore although there is evidence in ECOFACT of the link between deposition and grazing it is unlikely that it is involved in the observed changes in this class.

General conclusion

Nitrogen deposition is not likely to be involved in the observed changes which are primarily concerned with an increase in light score.

14.4 General evidence

As in the previous section the nitrogen deposition maps show higher levels in the south until the north of Scotland. The work by Thompson (19??) also suggested that particular vegetation types could be affected by an interaction between recreation, nitrogen deposition and grazing. However this evidence refers to a specific type of vegetation and is unlikely to relate to the whole of this aggregate class.

ECOFACT analysis

This was confirmed in the upland survey where *Rhacomitrium lanuginosum* was found in many other situations other than that specifically referred to in the study by Thompson, mentioned above. The upland analysis did however show the co-incidence between grazing pressure and nitrogen deposition and the observed increase in fertility shown in bog vegetation would tend to agree with this hypothesis being valid under a particular set of conditions. The acidification and decline in nitrogen level in the drier heathland could also be co-incident with these changes. There was also no change in the functional strategies in this aggregate class.

General conclusion

Nitrogen deposition is likely to be implicated in the observed changes but it is not possible to estimate the magnitude of the effect.

AFFORESTATION (BROADLEAVED)

15.1 General evidence

Planting of trees directly in crops will have a similar effect to set aside, in that the ruderal species will gradually give way to longer lived perennial grasses, and eventually to woody species such as Brambles. The general observation is that small areas of cropland have indeed been planted with trees, presumably related to the small woodland grants.

ECOFACT analysis

The only evidence directly from this source is from the initial analysis of land cover in the CS90 survey which showed evidence of new broad leafed plantations. However these cover very small areas and it is unlikely that sufficiently large numbers of plots have been effected by this change to have any effect on the overall mean of the changes observed.

General conclusion

Although broad leafed woodlands may be locally involved in change, this activity is unlikely to have caused the observed changes which are not in-coincident with this type of effect.

15.2 & 15.3 General evidence

As in 15.1 it is a widely observed observation that woodlands have been planted in grasslands and in general this would be expected to be more common than in crops because of the lower value of the land. The small woodland schemes would be involved in this change.

ECOFACT analysis

There is evidence of new broad leaved plantations on grasslands mapped during CS1990 and several were observed in the ECOFACT field survey in 1996 and 1997. There is some evidence from the matrix of change that there is a shift away from fertile and infertile grassland towards the tall grassland/herb aggregate class, but this may be masked by other changes along roadsides and streamsides with comparable vegetation. There is no evidence of dereliction from the analysis of functional strategies. Therefore any local changes are likely to be lost within the overall variation in the data.

General conclusion

Although woodland planting may be involved in changes at a local scale, this activity is unlikely to have contributed to the overall observed changes within either of these aggregate classes.

AFFORESTATION (CONIFEROUS)

Annex E - Section F, Interim Report, Dec 1997

16.1 General evidence

The forest statistics for CVS show that there has been an increase in forest area between 1978 and 1990 of round about 250,000 hectares. Previous studies by Hill and Jones (1978) and Wallace et al (1992) described the loss of plant species that occurrs as plantation conifer canopies close. The initial effect of afforestation is usually a loss of grazing, following exclusion of stock by fencing. Under these conditions potential dominants such as Pteridium aquilinum, Calluna and Molinia increase in cover. These species eventually die out as the field layer is subject to increasing light deprivation. Within the upland wooded class, the main shift is in the final stages of the succession, since the early stages of afforestation may well contain sufficiently undisturbed vegetation for them to be within aggregate Classes VII & VIII. Therefore it would be expected that the principle shift caused by afforestation is likely to be in this class.

ECOFACT analysis

The initial results showed the single largest loss of species in any of the aggregate classes between 1978 and 1990, and initially this observation was difficult to explain. Analysis during the ECOFACT studies of individual species, and their changes suggested that a particular group of plots which had lost the most species were in fact those that were effected by canopy closure. The ECOFACT analysis subsequently carried out, showed conclusively that the loss of biodiversity in those plots was due to the recorded change in conifer cover over the period 1978 to 1990. This did not show up in the analysis of Ellenberg scores because the few species that were left were still moorland species and the plantations were not acquiring actual woodland species, so that a shift to loss of light has not occurred.

General conclusion

Afforestation is probably involved in the observed changes in upland wooded vegetation.

16.2 General evidence

The evidence for the impact of afforestation has already been covered in section 16.1, but it shoud be emphasised that the direct effect of afforestation within vegetation in this class in 1990 is likely to be confined to dereliction of the current vegetation, since canopy closure could not be involved.

ECOFACT analysis

This general statement concerning the likely changes due to afforestation are directly in conflict with the evidence from the ECOFACT analysis of Ellenberg scores in this class which showed that there had been an increase in light. It should be emphasised that the indirect effects of afforestation due to change in grazing patterns are included under section 17.

General conclusion

Afforestation is not involved in the observed changes.

16.3 General evidence

Although it has been shown that afforestation has had a very wide influence on bog vegetation in the Flow country these categories of vegetation would almost certainly be so far removed from the original bog vegetation and heath in this class as to be within the upland wooded class. Therefore, it would be generally expected that afforestation would not be likely to have caused changes within vegetation that in 1990 came within this class. Although individual trees may have been planted within it.

ECOFACT evidence

The increase in fertility and decline in light is directly in conflict with the literature concerning the effect of afforestation.

General conclusion

Afforestation is not involved in the observed changes in these classes.

AFFORESTATION (INDIRECT)

Discussed in section 6, Interim Report, April 1997

17.1 to 17.3 General evidence

There has been much work at the Institute of Hydrology on loss of water from catchments following afforestation. Over 30% of water is lost during the process of afforestation, which also changes the composition of the river water beneath the catchment. There is therefore a wide body of evidence to show that there are very strong indirect effects of afforestation upon the flow of water in rivers. It has not been possible to find any literature referring to the transfer of this effect to bog, spring or flush vegetation outside the original forested catchment. Furthermore, afforestation generally occurs at middle altitudes within upland catchments. This is because the valley bottoms are too fertile and remain in agriculture, whereas the highest ground is climatically too severe for economic growth. There is therefore likely to be a major effect of faster run off from the upland areas above the forest, with a faster change in deposition rates in the lowland areas below the forest line.

ECOFACT analysis

The loss of moisture observed in the heath/bog classes could well be co-incident with the indirect effect of afforestation in upland areas. Observation during the field work for the upland study and for the farm study suggested that certain areas adjacent to forests had certainly dried out both from anecdotal evidence from farmers but also according to species composition of plots adjacent to forests as they changed between 1978 and 1990. There was no change in the functional strategies of the species within this category.

General conclusion

There is strong evidence that the indirect effect of afforestation could be involved in the changes in upland wooded vegetation, grass mosaic/moorland and heath/bog.

FELLING (BROADLEAVED & CONIFER)

18.1 General evidence

In this class it is mainly broad leaved felling.

Felling opens up the vegetation to light and increases the diversity in woodland vegetation. This is a well known ecological process that has been much studied (Whitbread, 19?? - great storm report) and is realised on the ground as a result of conservation management practice in many woodlands.

ECOFACT analysis

There is no evidence of light increase from the Ellenberg scores, or disturbance from the functional analysis carried out at Sheffield, but there was an increase in species observed in the lowland wooded category. No evidence of widespread felling was observed during the land cover survey in CS90, nor was any extensive felling observed during the field work for the farm survey, but the increase in species number would be due to this effect.

General conclusion

The felling of broadleaved trees is unlikely to be involved in the observed changes in lowland wooded vegetation.

18.2 General evidence

Felling of conifer plantations that are mature is more usual in this aggregate class. It results in opening up gound which has been completely bare of any vegetation cover. The vegetation takes some time to recover because of the large heaps of brash covering the land surface following the felling process. The effect of this process is well documented, particularly in the massive flows of nitrogen out of the system following deforestation.

ECOFACT analysis

Observation of several plots during the farm survey showed that ground vegetation regenerated rapidly following felling. This regeneration was very patchy, depending upon suppressive effects of brash heaps and largely consisted of species recruited from the seed bank. This vegetation is likely however to be of short duration because the majority of conifer plantations are replanted. The increase in species to be expected following felling is in oppostition to the observed decline in species numbers.

General conclusion

The felling of conifers is likely to be of local significance in CS plots but there is no evidence that it is involved with the observed overall changes in this aggregate class.

STREAMSIDES

Annex F - Summary of land use data from IFE waterside samples

19.1 General evidence

Cutting has a major effect on tall herb vegetation and will change its composition over time. It will shift the balance of species away from tall vigorous species to smaller species that are not able to compete so readily. It will be important however whether the vegetation which is cut is left lying on the surface because this will act as a mulch and will counteract the effect of the cutting.

ECOFACT analysis

The vegetation within this class has shown a decline in fertility and got more acidic over the period 1978 to 1990. There is no change in the functional strategy. In the matrix of change however aggregate Class II gained from both fertile grassland and infertile grassland suggesting that cutting was not taking place.

General conclusion

Positive bank management is unlikely to have caused the observed change in tall grassland/herb on streamsides.

19.2 General evidence

Positive bank management is more usual by fertile lowland rivers which are likely to be in this aggregate class.

ECOFACT analysis

No change was observed in mean species richness in this class. The increase in moisture levels observed are likely to be an artefact of the dry season. The increase in continentality is difficult to explain.

General conclusion

Positive bank management could be maintaining the status quo but is unlikely to have caused the observed change in fertile grassland on streamsides.

19.3 General evidence

Infertile grassland vegetation is likely to be beside smaller streams than the more fertile banks of the managed lowland rivers but may also be beside managed drains in East Anglia. A wide variety of different types of vegetation are involved in this class from those which are typical of completely unmanaged grasslands such as those by rushy margins or tall herb vegetation with a high proportion of grasses present within them.

ECOFACT analysis

Regular cutting could be involved in the increase in fertility change if dead material were left on the surface. This would be co-incident with the decrease in light.

General conclusion

Bank management could be involved in the observed changes in infertile grassland on streamsides.

20.1 General evidence

Neglect leads to a change in structure from managed grassland into tall herb vegetation dominated by coarse grasses and large vigorous competitive species (Dawson and Haslam, 1983; Krause, 1977; Raven, 1986). Eventually the shift would be to woodland or scrub vegetation.

ECOFACT analysis

There was an observed significant decline in fertility and acidification together with evidence of eutrophication from the UCPE analysis. Evidence from the ECOFACT field survey on farms showed that the majority of streamsides do not appear to be regularly managed although locally this may not be the case e.g. in East Anglia drainage dykes. Circumstantial evidence from the decline in farm labour between 1978 and 1990 from the FBS analysis, would support the probability of bankside vegetation now being neglected. There was also evidence of increase in woodland species on the streamsides from the species group analysis.

General conclusion

Neglect could be involved in the observed changes in tall grassland herb on streamsides.

20.2 General evidence

Fertile grassland when not managed moves into tall herb vegetation because of the influence of the competitive species.

ECOFACT EVIDENCE

This shift is consistent with evidence from the matrix of change which showed that there was a shift from aggregate class III into II. The evidence of increase in moisture could be an artefact because of the dry season and the evidence in continentality could not be interpreted, except that the species which are faster growing will generally expand at the expense of the less competitive species. This change may therefore, be linked to a general increase in more competitive generalists rather than an indication of a vegetation response to climate change. On balance therefore the stability of the mean species number per plot and lack of other changes in indicator scores suggests that neglect is could be indirectly involved due to interactions between species in this category of vegetation.

General conclusion

Neglect could be involved in the observed changes.

20.3 General evidence

Infertile grasslands are affected by neglect since the sensitive species are easily removed by competition of the larger competitive plants. This is the same process that has been observed in a wide range of experimental studies and is a well recognised ecological phenomenon.

ECOFACT analysis

This category shows a major loss of species with a corresponding increase in the fertility and density of the vegetation. The analysis of functional types shows eutrophication and confirms that such eutrophication is taking place throughout the landscape. The matrix of change showed that there was a relatively small shift in the total number of vegetation plots falling within this aggregate class involving gains from the less fertile aggregate classes and losses to the more fertile classes.

General conclusion

Neglect is likely to have been a major factor in the observed changes in this catergory.

21.1 General evidence

Eutrophication derived either from run-off or direct fertilizer effects by riverside vegetation is likely to have a significant effect in favouring faster growing more vigorous species at the expense of the smaller stress tolerant species (van Strein et al, 1989). The tall/grassland herb aggregate class is already relatively dense and eutrophic in its initial state.

ECOFACT analysis

The decline in fertility in acidification are not co-incident with the observed effect of this action.

General conclusion

Eutrophication is unlikely to be involved in the observed change.

21.2 General evidence

Since grassland in this category was itself characterised in 1978 by species adapted to eutrophic conditions, further increases in fertility would be unlikely to result in a marked vegetation response.

ECOFACT analysis

Moisture levels have increased but these could well be due to an artefact of the season 1990 in the south of Britain. The lack of increase in fertility and light scores suggest a vegetation type already typified by species suited to fertile conditions and therefore less responsive to further increases in trophic status.

General conclusion

There is no evidence that eutrophication is involved in the observed changes.

21.3 General evidence

Many of the vegetation classes within the infertile aggregate class already have low nutrient levels. Eutrophication is therefore likely to effect them significantly because they are adding nutrients to a low initial level. It is a widely observed effect that eutrophication has effected streamside vegetation (Betton et al, 1991) and reports elsewhere for example by the BSBI have shown that *Urtica dioica* has greatly increased along lowland watercourses (Oliver,1995) whilst the vigorous competitive ruderal *Galium aparine*, significantly increased in cover in CS steamside plots.

ECOFACT analysis

The increase in fertility scores and decline in light scores is consistent with an increase in fertility. This is also in agreement with the functional strategy analysis of eutrophication reported in this category. The general trend for expansion of generalists would fit in with the decline in continentality and with the likely influence on biogeographic elements.

General conclusion

Eutrophication is likely to have been a major factor in the observed changes in infertile vegetation by streamsides.

21.4General evidence

The vegetation by streamsides could be affected by increased nutrient loads in run-off and soil water favouring nitrophilous species at the expense of less competitive species. However this is likely to be quite localised along the immediate edge of the river water course.

ECOFACT analysis

The decrease in light and increase in moisture scores could be caused by further growth of the undergrowth species. There were no changes in species number nor evidence of functional analysis change.

General conclusion

Eutrophication could be involved in the changes observed but is unlikely to be the major factor.

21.5General evidence

The run off of fertilizer from forestry could be significant because of the very low initial levels by many streamsides in upland vegetation. However most unchanged bogs are either outside the forested area or above the forest influence, so the local patterns could well be influencing the riverside vegetation.

ECOFACT analysis

Fertility scores increased whilst acidity and moisture scores decreased ????, the latter due reported elsewhere and possibly due to forest drainage. This suggests a synergistic effect and that the increase of fertility beside streamsides could be caused by afforestation linked run off of nutrients. Eutrophication and disturbance were both recorded in upland vegetation from the functional analysis, confirming the above conclusion.

General conclusion

Afforestation could be involved in the increase of fertility by streamsides in the uplands.

22.1 & 22.2 General evidence

The evidence from critical loads analysis and acid deposition studies (refs) indicates that there are particularly high impacts on soils and vegetation in the uplands. However, this is likely to be modified by run off through the soil when it comes to impacting on vegetation by streams in the uplands, since many upland streamsides are to some degree enriched by any nutrients involved in run off.

ECOFACT EVIDENCE

The loss of species in upland streamsides could not be co-incident with acid deposition which would be expected to reduce nutrient levels besides streams and reduce the ???finishing effect. The contrast in moisture are difficult to explain, the uncertainty associated with the impact of deposition suggests that this factor cannot be directly linked to the observed changes.

General conclusion

Acid deposition is unlikely to be involved in the observed changes by upland streamsides.

23.1 & 23.3 General evidence

It is a widespread practice in upland vegetation to improve drainage to remove water and increase the efficiency of run off, both from the stream itself, and from the land. This effect removes marginal water vegetation and deposits the soil and vegetation on the bank temporarily destroying all the vegetation. It is therefore a major impact, but one that is likely to be reversible.

ECOFACT analysis

Stability of mean species numbers suggests that such a catastrophic change is not involved across the whole population. Also, field observation during the farm study showed that bank management was a rare occurrence in the landscape. The decline in farm labour reported in the FBS analysis, would be further, albeit circumstantial, evidence that this factor is not likely to be significant.

General conclusion

It is unlikely that ditching is involved in the overall observed changes, but is likely to cause reversible local disturbance.

23.4 &23.5 General evidence

Ditching and gripping were formally widespread practices in the uplands, but usually only applied to narrow watercourses and were not, in total, as destructive as the practices in the lowlands. General knowledge would suggest that this practice is no longer widespread.

ECOFACT analysis

During ECOFACT field work no obviously new drainage schemes were seen though many old drains are visible present in upland sample squares. The general decline in agricultural work in the uplands would be consistent with this observation. The figures available from the analysis of the FBS data also confirm that little money is now spent on upland drainage schemes.

General conclusion

Drainage is unlikely to be involved in the observed changes.

24.1 - 24.3 General evidence

Canalisation causes complete removal of natural river features and leads to a subsequent restriction of waterside vegetation owing to the removal of seed sources from the banks. Faster colonisation can take place if local sources of seed are available. However recruitment from the local species pool may preferentially involve competitive species capable of rapid vegetative spread (review in vegetatio). Even introduced seed mixes often contain a species poor, grass dominated mixture designed to achieve the primary goal of bank stabilisation and the rapid establishment of vegetation cover (Raven, 1986). Higher discharge rates can also result in a deleterious change in inundation patterns, subjecting bankside vegetation to less frequent flood events and less of the disturbance that may previously have deflected succession creating sufficient gaps for less competitive species to establish and reproduce. Observations suggest that canalisation may have been important historically but, is unlikely to be taking place over the period of time between 1978 to 1990 to any great degree.

ECOFACT analysis

Such drastic changes do not fit with the combination of stability and change observed during ECOFACT. Few examples of such change were observed during the field work carried out in 1996 and 1997.

General conclusion

Although locally catastrophic this practice is unlikely to be involved in the observed changes at the national level.

25.1 & 25.2 General evidence

Burning is a locally important practice effecting upland vegetation specifically on grouse moors but also occasionally for agricultural purposes. The practice does affect heather vegetation by streamsides although ground wetness is likely to reduce the surface temperature of the burn.

ECOFACT analysis

The observed changes of increase in fertility and decline in acidity are unlikely to be linked to this practice. Burning was observed by streamsides in the farm survey but only in a very limited number of plots on a managed grouse moor.

General conclusion

Burning is unlikely to be involved in the observed change but could be locally important.

26.1 General evidence

Most tall herb vegetation is not grazed and therefore an increase in grazing would have a major effect by reducing the larger dominants and encouraging a more fine grained, potentially more species rich sward (Wheeler, 1983).

ECOFACT analysis

The decline in fertility and increase in acidity observed would not be in agreement with this effect. In addition observations made during the farm survey would refute any notion of an increase in streamside grazing. Many streamsides are fenced already and would fall within this category of vegetation.

General conclusion

The stability of the species number in this vegetation together with the lack of agreement between the impact and the observed changes indicate that an increase in grazing is not likely to be involved in the observed change.

26.2 General evidence

Fertile grassland is likely to be grazed during part of the year consistent with the annual farming cycle on such high productivity swards.

ECOFACT analysis

The stable situation suggests that change is minimal with the exception of a minor increase in moisture score. The farm study suggested that fertile grassland by streamsides is generally in a relatively stable condition.

General conclusion

Grazing at the present level would be likely to maintain current status and not be involved in the observed change.

26.3 General evidence

Infertile grassland is likely to require grazing to maintain diversity since the management of old grassland systems have had this as an integral part of the management practice. Generally the riversides by infertile grassland are relatively small and are likely not to be fenced.

ECOFACT analysis

The observed decline in mean species number and increasing light scores are not consistent with the effects of an increase in grazing.

General conclusion

An increase in grazing is not likely to be involved in the observed changes in infertile grassland besides streams.

26.4 General evidence

Many streambanks that fall within the upland wooded vegetation category, are either tree lined and grazed, especially in winter, and the vegetation is thus susceptible to releases in grazing pressure. Grazing is rarely involved in coniferous plantations.

ECOFACT analysis

An increase in grazing is unlikely to be correlated with the detected reduction in mean species number and the decrease in light and increase in continentality score. General evidence from the farm study suggested that most situations where grazing was taking place were relatively stable.

General conclusion

An increase in grazing is unlikely to be involved in the observed changes.

26.5 General evidence

Grazing is widespread throughout the uplands and is likely to be particularly intensive beside streamsides within aggregate class VII vegetation since moderate increases in base status associated with flushing result in locally more nutritious forage. The class does however comprise a wide variety of vegetation types from moderately species rich *Agrostis/Fescue,* through to almost pure *Molinia*.

ECOFACT EVIDENCE

The observed decrease in mean species number and increase in moisture score is unlikely to be linked to any increase in grazing pressure. There is little other supporting evidence from either the functional analysis or from the farm study, except that, in one or two locations it was noted that streamsides were particularly heavily grazed. This would support the fact that grazing is a locally important factor but is unlikely to be involved accross the majority of plots.

General conclusion

An increase in grazing is unlikely to be involved in the observed change.

26.6 General evidence

The heath and bog vegetation beside streamsides have variable levels of grazing, depending upon their location in the landscape and their situation in Britain.

ECOFACT analysis

The stability of the species is likely to be associated with grazing in this class of vegetation and changes could therefore be associated with increased grazing pressure. Increase in grazing could be implicated in conjunction with eutrophication in causing the increase in fertility in this vegetation class. Conversely, during the farm study a decline in grazing was noticed on several streamsides but again as with other previous comments this may be limited to one or two areas and it must always be born in mind that the results reflect change across the whole countryside.

General conclusion

An increase in grazing could be involved in conjunction with eutrophication, in causing the observed changes in this class.

27.1 General evidence

A decrease in grazing in tall grassland/herb vegetation would cause a shift towards woodland species and eventually to woodland. However, the aggregate class is itself likely to be characterised by nil or very infrequent grazing, so that a reduction in grazing pressure would be unlikely. A shift to woodland species could be a continuance of the succession which has already been initiated.

ECOFACT analysis

This trend is not be consistent with the observed increase in fertility and relative stability of species.

General conclusion

There is no evidence that a decrease in grazing is involved in the observed change in this tall grassland/herb vegetation by streamsides.

27.2 General evidence

A decrease in grazing would affect fertile grassland, which is generally highly managed and often grazed. This factor is therefore likely to be a strong potential influence in any change in this vegetation.

ECOFACT analysis

The general stability of the species number and of the Ellenberg scores, with exception of moisture and continentality, would show that there is no evidence for a decrease in grazing in this vegetation class.

General conclusion

There is no evidence that decrease in grazing being is involved in the limited changes observed in this class.

27.3 General evidence

The botanical character of the infertile grasslands is such that they are, in most situations, likely to depend upon grazing for the maintenance of species richness and floristic character. Any change in this pattern of grazing is likely to cause an effect and shift in the vegetation.

ECOFACT analysis

Fencing was frequently observed by streams during ECOFACT fieldwork and could be implicated in the observed decline in mean species number because release of grazing favours the growth of competitive species at the expense of less competitive species. This would fit in well with the observed increase in light score ??? and could well be synergistic with the likely increase in eutrophication observed from the functional analysis and from the summary of impacts in section 2.1. This change would also accord with detected shifts from managed fertile and infertile grasslands into tall grassland/herb between 1978 and 1990.

General conclusion

A decline in grazing besides streams could have contributed to the observed changes, in conjunction with other factors such as eutrophication.

27.4 General evidence

Upland wooded vegetation by streams is often present in rocky species rich ghylls but also in a very different situation when considering watercourses within conifer plantations. The former might be locally grazed, whereas the latter would not.

ECOFACT analysis

The observed decrease in Ellenberg light and increase in moisture scores is not (REST IS CONFUSING) co-incident with the effect of an increase, grazing especially as it woodland species groups that have declined. However if there was a cumalative effect of exclusion of grazing theis could have caused the observed change.

General conclusion

A decrease in grazing could be involved in the observed changes in upland wooded vegetation by streamsides.

27.5 General evidence

A decrease in grazing in these categories would favour increased abundance of competitive species at the expense of less vigorous and more specialised plants.

ECOFACT analysis

The loss of species is not co-incident with the decrease in Ellenberg light score, so that it is not in agreement with the observed effect. ECOFACT field work showed that release from grazing may have happened locally but was unlikely to have characterised the site between 1978 and 1990 as the area concerned had only recently gone out of farming.

General conclusion

A decrease in grazing is unlikely to be involved overall, but could be locally important.

27.6General evidence

Relaxation in grazing is unlikely to have had a major impact in this category of vegetation, because the vegetation is itself typified by slow growing stress-tolerant species constraining the potential for a rapid response (Hodgson et al, 1994).

ECOFACT analysis

Gains in fertility could develop but are not co-incident with the observed change.

General conclusion

Relaxed grazing is unlikely to be involved in the observed changes in heath/bog vegetation on streamsides.

28.1General evidence

Within the upland wooded aggregate class, canopy closure is likely to have resulted in reduced mean species richness. In existing coniferous plantations however starting species richness was likely to be low limiting the potential effect within at least afforested plots. However it is a major impact and will effect many streamsides within the forest boundary. There is also the influence of the indirect effect of afforestation in that streamsides within large coniferous plantations will no longer be grazed so that there is strong evidence that this factor is likely to be important.

ECOFACT analysis

The observed increase in forest canopy in the land cover analysis, agrees with the evidence of afforestation from independent figures???. This would not however, be consistent with the detected increase in mean Ellenberg light score (DOES THIS MEAN MORE SHADE?). This could well be an example of a spurious effect because woodland species by upland river banks are likely to have disappeared with the increase in canopy forest cover. The change in Ellenberg score could therefore be due to an indirect effect of overall loss of species. This factor could therefore well have effected streamside vegetation.

General conclusion

Afforestation is likely to be a contributory factor to the observed changes in the upland wooded aggregate class by streamsides.

28.2 General evidence

New afforestation breaks down existing streamside patterns and disrupts the hydrology and drainage patterns of water flow within. This therefore is likely to have a massive impact on riverside, streamside and wetland vegetation.

ECOFACT analysis

New afforestation occurred but in relatively small numbers of CS plots. New afforestation was observed during ECOFACT field work and occurs very widely throughout Scotland.

General conclusion

Afforestation is likely to be locally important because of the extent of disturbance, but is not likely to have had yet an impact upon this vegetation which has not yet shifted in the upland wooded class.

28.3 General evidence

Afforestation of lower slopes causes faster run-off from the upper slopes which often contain bog vegetation. It could therefore be an indirect effect because of the changing in the hydrology of the overall catchments leading to loss of wetland species.

ECOFACT analysis

This is co-incident with the decline in moisture observed in ECOFACT, but is not likely to be associated with the other changes observed in acidification and fertility.

General conclusion

Afforestation could be indirectly involved in the loss of species associated with moisture in upland bogs.

29.1 General evidence

Removal of trees and shrubs by streams in the lowlands has similar effects to coppicing although can lead to a marked expansion in competitive species on stream banks and channels (Krause, 1977; Dawson and Haslam, 1981). Coppicing is well known to be beneficial in that more light reaches the ground encouraging the growth of woodland edge species, but also those species which are not favoured by high density canopies such as *Endymion non-scripta*. Broad-leaved felling is therefore likely to be beneficial to biodiversity provided that it does not lead to coniferisation or space pre-emption by competitive herbs.

ECOFACT analysis

The species number in the lowland wooded category is stable but, the increase in light could be evidence of the effect of this factor. However, is difficult to see how it could be involved in the changes in continentality.

General conclusion

The felling of broad-leaved trees has a local effect and could be involved in the observed changes.

29.2 General evidence

Felling of broad-leaved trees in upland woods is not likely to have such a major effect as in the lowlands because the woodlands are already much more open and often grazed. It would however be likely to increase the species number in the short term.

ECOFACT analysis

The loss of species is not co-incident with the likely impact of this action and also would not agree with the increase in species associated with high moisture levels.

General conclusion

Felling of broadleaved trees is not likely to be involved in the observed changes in species number in upland wooded vegetation by streamsides.

30.1 General evidence

Conifer felling has a major impact as the bare ground beneath the plantations are expanded and opened to light.

ECOFACT analysis

The predicted increase in species richness resulting from conifer felling is not consistent with detected changes but could be locally important. During the ECOFACT field survey such an effect was observed in several locations with regrowth of former vegetation. However recruitment was biased towards species that maintained persistent seedbanks, such as *Carices* and *Juncus* species, and bryophytes that are either efficiently dispersed by means of vegetative fragments or exhibit a degree of shade tolerance.

General conclusion

Conifer felling is locally important and could be involved in the observed changes to upland wooded vegetation by streamsides.

ROADSIDES

31.1 General evidence

Annex G - Section C Interim Report, December 1997

Disturbance is less likely to affect the tall grassland/herb category because the vegetation type itself reflects infrequent disturbance. However long term neglect would be likley to result in slow succession to scrub and eventually woodland: 'Pulse' disturbance ie. infrequent major disturbance rather than more frequent 'press' disturbance (Underwood, 1986) is likely to favour the development and maintenance of vegetation types within this aggregate class.

ECOFACT analysis

Increased mean species richness in the tall grassland/herb class could be caused by sporadic 'pulse' disturbance. This at first might seem inconsistent with functional analysis results which interpreted changes as resulting from dereliction. However detailed analysis of changes in Cumbrian road verges as well as tests for dependence between changes in potential dominants and less competitive species in CS data showed that road verge plots contain within them the potential for divergent trends in different parts of the plot. Thus dereliction can occurr farthest from the road edge reflecting infrequent mowing post-1975 (Way,1973,1977) whilst increased availability of open conditions next to the carriageway can result in increases in ruderal species such as *Matricaria matricoides* and *Polygonum aviculare* favoured by traffic diturbance which also results in efficient dispersal of seed (Schmidt, 1989; Hodkinson and Thompson, 1997). The change in Ellenberg moisture score could be an artefact of the dry year in 1990.

General conclusion

Disturbance could be involved in the increase of species in tall grassland/herb vegetation by roadsides.

31.2 General evidence

Disturbance takes place frequently on many verges from a variety of causes, such as cattle and horse trampling, but especially by vehicles. A case study carried out on Cumbrian road verges also gathered evidence of an increase in annual average daily traffic on A roads which was linked to increased abundance of small annuals and open conditions in the narrow strip adjacent to the road surface.

ECOFACT analysis

Functional analyses suggested an increase in dereliction on road verges. For reasons outlined in the previous section both disturbance and dereliction could be occurring together in the same plots. However in terms of vegetation response dereliction seems to exhibit the strongest signal.

General conclusion

Disturbance is likely to be involved as a contributory factor in the observed changes to fertile grasslands on roadsides.

31.3 General evidence

Disturbance in infertile grassland is also likely to have had a major effect depending upon the current condition of the grassland. Because the vegetation class is characterised by low fertility and a high mean species richness is likely to have a more significant effect than in 31.2.

ECOFACT analysis

Although this would be expected and the change in fertility agrees with that of the previous class there is not a similar decrease in acidity or increase in light. The increase in ruderals however observed in the ECOFACT analysis and field work on Cumbrian verges suggests that disturbance can operate but iits effects are likley to be concentrated only on the narrow strip of open ground adjacent to the carriageway.

General conclusion

Disturbance on roadside verges is likely to be have impacted infertile grasslands.

31.4 General evidence

Most upland verges support moorland vegetation which is less likely to affected by disturbance than those in other aggregate classes because of lower traffic volumes whilst a response is initself likely to be less well marked because of the stress-tolerant attributes of component species (Hodgson et al, 1994).

ECOFACT analysis

Disturbance is unlikely to be involved in the observed changes. The otherwise stable situation suggests that disturbance not involved to any great ex#### ######

General conclusion

Disturbance is unlikely to be involved in the observed change in grass mosaics moorland on roadside.

32.1 General evidence

Road verge management is primarily concerned with fulfilling a legal requirement to maintain

visibility. This entails frequent mowing of the 1 metre strip adjacent to the road whilst the remainder of the verge width recieved very infrequent mowing post-1975 with cuttings left on the verge (Way, 1973;1977). Some county councils now operate verge management schemes which explicitly aim to achieve road safety and environmental objectives. Some road verges, especially on major roads, may well have been affected by engineering works during the 70s (Bradshaw and Roberts, 1978): Such impacts will have included disturbance and reseeding with grass dominated seed mixes, fertilisers and often a legume based green manure. Experimental studies of the effects of roadside management have concentrated upon roadside flailing. For example Parr and Way (1988) and Melaman et.al.(1988) both showed how increased species diversity could be achieved by annual or biennial cutting. In summary management effects are likley to differ in detail and effect from place to place with mowing regime most likley to be linked to trends in CS data beause of its widespread occurrence on county adopted roads.

ECOFACT analysis

The observed increase in species and decline in moisture would be consistent with the above observed effect, but mulching would contain some evidence from the decline in woodland species groups.

General conclusion

Management could be involved in the observed change tall grassland/herb vegetation on roadsides.

32.2 General evidence

Management has an effect on fertile grassland by maintaining the balance of species which often required regular management. Continued management would therefore be expected to maintain the current species composition.

ECOFACT analysis

Although the above would be co-incident with the stability of the species composition it would not be in agreement with the widespread observed effect of increased fertility and decline in acidity. The widely observed mulching in the ECOFACT fieldwork could be a major effect even when the management was taking place. This therefore is likely to be co-incident with the increased observed fertility observed in the ECOFACT analysis and the field work.

General conclusion

Management is probably involved in the observed change in fertile grassland or roadsides but in an indirect way.

32.3 General evidence

The management of infertile grassland maintains the balance of species although they may be indirect effects from the cuttings.

ECOFACT analysis

The widespread observed mulching in the ECOFACT fieldwork would be co-incident with the observed increase in fertility and could mean that species are being replaced rather than lost by this action (but see section 37). The decline in moisture could not be explained by this effect nor could the increase in continentality. The ### could be a spurious result because of the dry weather in the south of England in 1990.

General conclusion

Cutting regimes and the indirect effect of mulching are likely to be involved in the observed changes in infertile grassland and roadsides.

32.4 General evidence

The management of upland verges is less widespread because the vegetation grows more slowly than in the lowlands and therefore needs less cutting for visibility purposes. The low productivity would also mean that cutting is likely to have less effect.

ECOFACT analysis

The stability of species numbers and all the Ellenberg's except continentality would confirm that management is unlikely to be effecting this class of vegetation.

General conclusion

Management is unlikely to be involved in the observed change but could be involved in the maintenance of the current state of grass mosaic/moorland vegetation on roadsides.

33.1 General evidence

Neglect could cause the loss of species owing to expansion of vigorus species. By the end of the 950s the traditional lengthsmen, who not only cut rural the verges regularly but also removed the material, had dissappeared from the countryside. A key difference between their practice and modern verge mowing is that cuttings are not removed from the sward. This is likley to result in a net gain in fertility since nutrients are returned rather than removed, whilst the mulching effect reduces the availability of germination sites (Parr and Way, 1988). There is therefore a sense in which the effects of modern road verge mowing may be similarly to some of effects of ecological effects of neglect.

ECOFACT analysis

The increase in species number and decline in moisture are unlikely to be co-incident with this process, although there is evidence of derelict and eutrophication from the functional analysis. On balance therefore this action could be involved in the observed change by increasing the dereliction process.

General conclusion

Neglect is possibly involved in the observed change. In tall grassland/#### vegetation on roadsides

33.2 General evidence

Neglect from the loss of the lengthsmem nd also from a general observation of the lack of management of roadside verges leading to a build up of dead material, could be linked to dereliction and eutrophication.

ECOFACT analysis

The increase fertility and decrease in light would be in direct agreement with the impact of this action, especially when taken in conjunction with the observed eutrophication and dereliction from the functional analysis. There is also likely to be a synergistic effect with the deposition in nitrogen beside roads.

General conclusion

This factor is probably the observed change in balance of species in fertile grassland vegetation by roadsides.

33.4 General evidence

Neglect is less likely to have influenced grass mosaics/moorland because many of them are open and would be grazed, therefore this factor is less likely to be important.

ECOFACT analysis

The stability suggests that this type of action has not taken place since in general the vegetation is relatively stable.

General conclusion

There is no evidence that neglect is involved in the observed change in grass mosaic/moorland vegetation on roadsides.

34.1 - 34.3 General evidence

Salt has an effect on the immediate road edge, but in such a narrow band that it is unlikely to cause a shift between aggregation classes. The observed evidence is that it does have a cumulative and widespread effect that has been linked to the spread of particular salt tolerant plant species along major roads throughout Britain (Watsonia paper).

ECOFACT analysis

The initial analysis in CS90 showed a small increase in salt tolerant species but these have not been identified in ECOFACT. However, during the EOFACT survey, several roadside verges were observed to have had salt tolerant species invading since 1990. These were in a narrow band along the edge of the road and only involved one or two species. There is no evidence that they are likely to have caused the major changes observed in the ECOFACT analysis.

General conclusion

Although local effect has been proven this there is no evidence salt is involved in the observed overall changes in roadside grasslands.

35.1 General evidence

Mowing would have a major effect on tall grassland herb vegetation and could cause an increase in species by removal of the fast growing competitive plants.

ECOFACT analysis

Although the observed evidence in ECOFACT was of increase in species number the other changes likely to be associated with this factor were not observed for example, an increase in light would have been expected. This provides strong circumstantial evidence that this factor is not involved in the changes.

General conclusion

This factor is unlikely to be involved in the observed change in tall grass herb vegetation by roadsides but could have a local effect.

35.2 General evidence

Mowing fertile grassland could maintain the current condition as this type of vegetation is usually managed.

ECOFACT analysis

This likely effect is in direct disagreement with the observed changes and therefore is unlikely to be involved.

General conclusion

There is no evidence that mowing is involved in the observed changes.

35.3 General evidence

Mowing infertile grasslands would be expected to maintain diversity especially if the cuttings were removed (Parr and Way, 1988; Melaman et al, 1988).

ECOFACT EVIDENCE

Although generally stable, the increase in fertility in nfertile grassland is not co-incident with mowing.

General conclusion

There is no evidence that mowing is involved in the observed change to infertile grassland on roadsides

36.1 - 36.3 General evidence

A proportion of roadside verges are in the shade and felling of roadside trees and hedgerow cutting will have an effect on the vegetation locally.

ECOFACT analysis

The field survey showed that felling is a localised impact and that the effects are comparable to coppicing, in opening up heavily shaded areas which have sparse vegetation to light. However this action is not consistent with the observed effects in any of the aggregate classes.

General conclusion

Although tree cutting may be important locally there is no evidence that it is involved in the observed changes on roadsides.

37.1 General evidence

Tall grass/herb vegetation is characterised by competitive herbaceous species of moderately fertile soils. Additional nitrogen deposition is therefore unlikely to have a major effect but could well be synergistic with the already high fertility.

ECOFACT analysis

This is not consistent with the lack of significant change in fertility or light and also would not be co-incident with the increase in species number since this synergistic effect would have a further influence of increasing the trophic level. There is however some evidence of eutrophication from the functional analysis which would support and effect by this factor.

General conclusion

Nitrogen deposition could be a synergistic with the observed in tall grassland/### vegetation on roadsides

37.2 General evidence

The addition of nitrogen to already fertile grassland will change the balance of species but is not likely to effect the overall species numbers.

ECOFACT analysis

The increased fertility and decrease in pH together with the strong evidence for eutrophication both from the Ellenberg analysis and the functional analysis are directly consistent with the effects of this factor. However, deposition rates are low in comparison with those elsewhere and are not therefore likely to have directly caused the change.

General conclusion

Nitrogen deposition could be a contributory factor in the observed changes to fertile grassland on roadsides.

37.3 General evidence

Compared with fertile grassland the lower fertility of this aggregate class means that lower levels of additional nitrogen are likely to have more effect. There is experimental evidence that high levels of nitrogen deposition next to roads results in increased productivity of the adjacent vegetation (Spencer et al,1988; Spencer and Port,1988).

ECOFACT analysis

This effect is in agreement with the observed increase in fertility but, not with the decline in moisture and continentality which are more difficult to explain. No evidence was found in the analysis of functional strategy showing that the correlation is likely to be weak.

General conclusion

This action could be involved to a minor degree in the observed changes to infertile grassland on roadsides.

37.4 General evidence

Grass mosaics/moorland are low in nutrients and, therefore the deposition is likely to have more effect. The expected deposition rates are therefore low in comparison with the lowlands because of lower traffic levels.

ECOFACT analysis

The stability of mean species number and the majority of the Ellenberg values suggest that no change is taking place and that therefore this factor is not having an effect.

General conclusion

There is no evidence that nitrogen deposition is affecting grass mosaics/moorland vegetation on roadsides.

38.1 General evidence

An increase in grazing on verges maybe important but there is no evidence of any major change in the extent to which upland verges are grazed other than a presumed increase in grazing in places where stock numbers have generally risen and verges are accessible.

ECOFACT analysis

The ECOFACT field survey suggested that many of the infertile grass verges in the uplands are associated with probably deeper and slightly more fertile soils compared to adajacent well grazed pasture. Such verges are often built on hardcore and spoil. Sheep occassionally congregate on these verges and may therefore have contributed locally to the detected increase in mean Ellenberg fertility score.

General conclusion

Increases in grazing could be contributing to the observed change in infertile grassland by upland roadsides.

38.2 General observation

Most verges in this category will be grazed and open to stock.

ECOFACT analysis

The stability of this vegetation class suggest that no major place has taken place and that therefore grazing has probably not been involved in any change, but rather has maintained the original condition.

General conclusion

An increase in grazing is unlikely to be involved in the observed changes.

39.1 & 39.2 General evidence

There is little circumstantial evidence that verges were grazing has taken place have had a decline in grazing pressure due to fencing or other factors.

ECOFACT analysis

Although this factor could have a major effect, there is no evidence that it is co-incident with the observed change.

General conclusion

There is no evidence that decrease in grazing has effected roadside verge vegetation.

40.1 General evidence

In the 1970s herbicide was used very widely on roadside verges but details of the full extent of the use are difficult to obtained (Way, 1973). However by 1990 the application of herbicide, except in urban areas had become uncommon

ECOFACT analysis

No evidence of the use of herbicides was observed during the field work on roadside verges although some application was observed on motorways. The recovery of vegetation from herbicide could be in agreement with the observed increase in species number but difficult to give a categoric statement that this factor has caused the observed increase in species.

General conclusion

Decline in herbicide use could be involved in the observed changes to tall grasaland/herb vegetation by roadsides.

40.2 & 40.3 General evidence

As quoted in 40.1 herbicide use has probably declined.

ECOFACT analysis

This change of herbicide is not consistent with the observed changes in these classes, but rather the opposite.

General conclusion

There is no evidence that herbicide use is involved in the observed changes in grassland on roadsides.

41.1 to 41.4 General evidence

Some roadsides have a ditch as an integral part of the linear feature. These are cleared out occasionally to encourage drainage. However, there is no evidence as to how often this takes place or what vegetation is involved. The effect would probably be to increase disturbance on the roadside vegetation as the ditch species would not be included.

ECOFACT analysis

Ditching by roads could be linked to the increased infertility in aggregate classes III and IV but its importance remains uncertain and it cannot be definitely linked to detected changes.

General conclusions

There is no evidence that ditching is involved in the observed change in roadside vegetation.

HEDGEROWS

42.1 General evidence

It is a widespread observation that there are indirect effects of crop management on hedgerows, not only from the shading effect of tall crops such as maize and oil-seed rape but also indirect effects as shown by Heggarty and McAdam (???). This is further confirmed by the analysis during CS90 of the relationship between the crop and the characteristic of the hedgerow, especially those with tall herb vegetation.

ECOFACT analysis

The species group analysis showed that grassland species had declined. This agreed with field observations in ECOFACT, where crops were observed falling against hedgerows and having a major effect upon the vegetation along the edge of the hedgerow canopy. This is consistent with the observed increase in Ellenberg fertility score and the decline in species number because of the strong shading effect. Therefore although this may be a minor influence it is probably involved in the observed change, both directly and indirectly.

General conclusion

Crop management could be involved in the observed changes to the tall grassland/herb vegetation beside hedges.

42.2 General evidence

Infertile grassland vegetation is likely to be heavily impacted by additional nutrients from decaying organic material or indirectly from nutrients spread from the adjacent crop.

ECOFACT analysis

The indirect effects of crop management are consistent with the observed increase in fertility and decline in light levels.

General conclusion

Crop management could be involved in observed changes to infertile grassland vegetation beside hedges.

42.3 General evidence

It would be expected that intact hedges associated with wooded conditions would be somewhat protected from the effect of crop management, since they are likely to be some way back from the crop edge.

ECOFACT analysis

Although the Ellenberg values showed no fertility increase the functional analysis indicated eutrophication. The increase in light score accords with the analysis of change in species groups which showed that woodland species had declined crop edge species had increased. This is a salutary example of how vegetation which remains unchanged in terms of mean species richness conceals ecologically significant turnover and replacement of species that differ in their habitat affinity.

General conclusion

This action could be involved in the observed change in the balance of species with linked wooded vegetation beside hedges.

43.1 General evidence

Grassland management is unlikely to directly effect tall grassland/herb vegetation because this is likely to be protected either by fencing or by being away from the edge of the managed grassland. Several studies have shown the indirect effect of field management on hedgerow vegetation (refs). Also see section 46.

ECOFACT analysis

Grass management is only likely to be weakly linked to the observed increase in Ellenberg fertility score, by encouraging growth of competitive species.

General conclusion

Grassland management could be linked to observed changes to tall grassland/herb vegetation beside hedgerows. There is however, likley to be a strong interaction with neglect and increased fencing.

43.2 General evidence

Grassland management is likely to have an effect as this class of vegetation is typified by relatively low fertility hence hedge bases are likley to be vulnerable to the effects of slurry, fertilizer or manuring.

ECOFACT analysis

There is evidence in the ECOFACT analysis that the characteristics of hedgerow base vegetation, is linked to that in the fields, particularly away from the edge of the canopy. The increase in fertility and decrease in light is therefore consistent with the influence of grassland management and eutrophication observed in the functional analysis.

General conclusion

Grassland management is likely to be involved in the observed changes to infertile grassland at the base of verge.

43.3 General evidence

Grassland management is likely to have a weak impact on wooded vegetation as there is some protection by the canopy from the effects of grazing and management of adjacent grassland.

ECOFACT analysis

It is difficult to link the observed increase in Ellenberg light scores to adjacent grassland management.

General conclusion

There is no evidence that grass management is involved in the observed changes in wooded vegetation by hedges.

44.1 General evidence

Changes due to felling, layering and management of hedges are well documented. Tall grassland vegetation by hedges however is probably in a relatively open condition already, therefore the impact is likely to be relatively small.

ECOFACT analysis

The observed effect of coppicing and layering is directly in opposition to the observed changes of a decrease in light level and a decrease in species number, since the practice of hedgerow management would have the effect of opening up the canopy which is generally regarded as being beneficial to the ground vegetation. It is also not consistent with the observed dereliction from the functional analysis.

General conclusion

The observed changes are opposite to the effects of positive management. The evidence therefore suggests that such management is unimportant.

44.2 General evidence

Fertile grassland has a requirement for a relatively high light level. Therefore opening the canopy would help to maintain the grassland flora and restrict the expansion of woodland species.

ECOFACT analysis

This impact is likely to have reduced the impact of dereliction, which was observed in the function of analysis but it is difficult to see how it could lead to the observed increase in fertility. This does not therefore agree with the observed change.

General conclusion

Canopy management is unlikely to be involved in the observed change.

44.3 General evidence

Removing the tree canopy has a major effect on this category of vegetation by increasing light demanding species and encouraging the growth of woodland edge species as opposed to other species that require dense shade.

ECOFACT analysis

The removal of the canopy cover would be co-incident with the observed increase in light level and would be confirmed by the wood and woodland edge plants which have been observed to be in decline. Disturbance observed in the ECOFACT field work would also be significant following removal because species would occupy areas that previously were in relatively dense shade. However the lack of the increase in species number suggest that this effect is relatively limited. The link between this action and the decrease in acidity and increase in continentality is difficult to explain.

General conclusion

Canopy management could be involved in the observed changes in lowland wooded vegetation beside hedges.

45.1 General evidence

Hedge management by flailing reduces the effect of shading by restricting the expansion of the hedge canopy. This effect would be beneficial but is counteracted by the effect of the fine chippings from the flail which fall on the base of the hedge and can act as a mulch. This practice therefore has complex interactions from negative on the one hand and positive on the other.

ECOFACT analysis

The effect of modern hedge management would be in agreement with the observed increase in fertility through the mulching effect. It would also be consistent with the observed eutrophication from the functional analysis. The most widely observed influence other than neglect in the farm study was flailing, so there is strong circumstantial evidence that this practice is widespread. Impacts are likely to be confounded with the effects of crop management and with indirect effects of grassland.

General conclusion

Flailing is probably involved in the observed changes in tall grassland/herb vegetation by hedges.

45.2 General evidence

Hedge management by flailing restricts the shading effect of the hedge and can therefore reduce the effect of shading on the grassland species which are indicative of this vegetation class.

ECOFACT analysis

The decrease in light observed would not be co-incident with this action unless the hedge became more bushy and dense and shaded out more species. The increase in fertility would be co-incident with the effect of chippings on the surface of the vegetation.

General conclusion

Flailing is likely to be involved in the observed changes to infertile grassland by hedges both by indirect and direct effects.

45.3 General evidence

The same comments apply as in 4.5.1 and 4.5.2 except that the woodland vegetation usually receives regular amounts of litter and could well be more adapted to the reception of organic matter.

ECOFACT analysis

The increase in light is likely to be caused by the loss of woodland species as shown by the analysis of the changes in species groups. This would be co-incident with eutrophication observed in the functional analysis. The mulching effect could also have influenced the loss of the smaller woodland plants.

General conclusion

Failing is probably involved in the observed change to lowland wooded vegetation beside hedges.

46.1 General evidence

The dereliction of hedgerow leads to an increase in shade and shade tolerant species. This has been shown in a wide range of studies and is recognised as a major factor effecting species composition in hedgerows. For example the largest change to have occurred in CS hedgerow plots between 1978 and 1990 was a 71% increase in overgrown relict hedges with a substantial increase in relict hedges with fences in the pastural landscape type (Barr et al,1991; 1993). Since woody hedgerow species are mostly potentially dominant species, lack of management would favour their expansion.

ECOFACT analysis

The observed changes in hedgerow length and character observed in the analysis of CS90 confirms that many hedgerows are now neglected. This is conistent with observations from ECOFACT field work since many hedgerows had claearly not been cut for many years having become non-stockproof lines of trees. Increased Ellenberg fertility scores and decreased light scores which agrees with the case study findings also.

General conclusion

Neglect is probably involved in the observed changes in tall grassland/herb vegetation beside hedgerows.

46.2 General evidence

The dereliction referred to in 46.1 is likely to lead to greater effects because the vegetation is less adapted to heavy shade and the grassland species previously out in the open would be gradually effected by the shade as the hedge extended.

ECOFACT analysis

The further decline in light observed in ECOFACT analysis together with the increase in fertility would support this effect. This further agrees with the case study finding of the influence of shade in the centre of the hedge compared with the grassland species on the edge and with the observed Ellenberg values in that study.

General conclusion

Neglect is probably involved in the observed changes in balance of species in infertile grassland beside hedges although it has not caused losses.

46.3 General evidence

The dereliction of hedges is not likely to have as large an effect in this aggregate class because it is already dominated by woodland species as it is within the wooded lowland aggregate class.

ECOFACT analysis

The likely effect of this action is not consistent with the observed changes.

General conclusion

There is no evidence that dereliction is involved in the observed change in lowland wooded vegetation beside hedges.

47.1 - 47.3 General evidence

Nitrogen deposition has been shown to be locally important in hedgerows in that the hedgerows are efficient in capturing nitrogen from the atmosphere. This was demonstrated by Kovar ( ) in his analysis in Wensleydale.

ECOFACT analysis

The measurement of nitrogen in *Crataegus* leaves in ECOFACT could not determine whether nitrogen levels were higher in different regions. Therefore although nitrogen deposition could be involved locally it is unlikely to have anything other than a synergistic effect with the observed changes.

General conclusion

There is no direct evidence that nitrogen deposition is involved in the changes observed in hedges across the landscape.

48.1 General evidence

Most tall grassland/herb is not grazed, therefore an increase in grazing would have a major effect by altering the balance of species.

ECOFACT analysis

This effect is not co-incident with the observed changes of increase in fertility and decline in species number, rather it would have the opposite effect.

General conclusion

There is no evidence in support of the fact that increased grazing is involved in the observed changes in tall grassland/herb vegetation by hedges.

48.2 General evidence

Grazing is an important factor in grassland plant communities alongside hedgerows and stopping the expansion of competitive species. However detected increases in Ellenberg fertility score and decrease in light score suggest that if grazing is operating its effects are outweighed by other impacts such as dereliction and eutrophication of adjacent garsslands.

General conclusion

There is no evidence that an increase in grazing is involved in the observed changes to infertile grassland by hedges.

48.3 General evidence

Grazing would not generally be high in hedgerows that have strongly related to woodlands and are dominated by woodland species.

ECOFACT analysis

An increase in grazing could be correlated with the observed increase in light and the increase in grassland and crop edge plants as well as those from disturbed conditions. It would not however be co-incident with the dereliction observed and eutrophication in the arable landscape.

General conclusion

Increase in grazing could be a contributory factor to the observed changes in wooded vegetation by hedges.

49.1 General evidence

A decrease in grazing although already low in this type of vegetation could lead to an increase in woodland species.

ECOFACT analysis

This would be consistent with the observed decrease in Ellenberg light score, the reduction in mean species number loss of species and the dereliction suggested by the functional analysis. This could be caused by fencing of hedges to maintain stock proofing. Biomass can then accumulate unchecked in the resulting ungrazed strip.

General conclusion

A decline in grazing could be involved in the changes observed in tall grassland/herb vegetation by hedges

49.2 General evidence

This aggregate class depends on grazing to maintain the balance of species, removal will enable the competitor species to expand.

ECOFACT analysis

A decline in grazing would be consistent with the detected increase in Ellenberg fertility score and eutrophication although the evidence from the maintenance of the species number would not necessarily be in agreement. Such a decline could be caused by fencing of hedges.

General conclusion

Decline in grazing could be involved in the observed change to infertile grassland by hedges.

49.3 General evidence

Hedgerow vegetation in this class is not usually grazed.

ECOFACT analysis

A decline in grazing would not be co-incident with the observed change, although it could be involved in the increase in light.

General conclusion

There is no evidence that a decline in grazing is involved in the observed analysis in lowland woodland vegetation beside hedges

50.1 - 50.3 General evidence

Climate change is likely to have less effects on closed vegetation as there is less space for species to move in. It is less likely therefore to have aof a short term impact.

ECOFACT analysis

Compared with the known effects of eutrophication and dereliction, through aggregate classes, the implications of climate change is #### ####.

General conclusion

It remains impossible to estimate the impact of climate change on the vegetation.

ANNEX A

PROJECT ECOFACT - ECOLOGICAL FACTORS CONTROLLING BIODIVERSITY IN THE BRITISH COUNTRYSIDE

REVIEW PAPER

GRASSLAND MANAGEMENT PRACTICES AND THEIR EFFECTS ON BOTANICAL COMPOSITION

A. HOPKINS

Institute of Grassland and Environmental Research
North Wyke, Okehampton, Devon, EX20 2SB

GRASSLAND AND AGRICULTURAL LAND USE IN BRITAIN

Grasslands occupy a higher proportion of agricultural land in the UK than in most other European countries. Of a total area of 12 million hectares of crops and grass, nearly 7 million hectares consists of 'permanent' or 'temporary' grasslands. In addition there are some 6 million hectares of unenclosed ‘rough grazing’. This heterogenous census category includes heather moor, bracken and *Molinia/Nardus/Festuca* grassland, and occurs mainly in the cool, wet uplands of the north and west: some of this is botanically and agronomically indistinguishable from permanent grassland (Hopkins and Hopkins, 1994; HMSO, 1995a).

In mainland Britain grassland is concentrated in northern and western areas, and arable land in the East. The extent of this difference has actually increased in recent decades with the adoption of stockless farming in eastern areas and grassland in northern and western areas. This trend has implications for many plant and animal species that are adapted to cultivation cycles, and for species adapted to stock-proof field boundaries and their margins. The basis for the regional distribution of grass and arable land can be attributed partly to increased on-farm specialization, and explained by differences in physical geography. Climate, soils and hydrology combine to give much of western Britain advantages for grass production in regions only marginally suitable for grain production. In areas such as Dyfed, south-west Scotland, Northern Ireland, and in parts of north-west and south-west England, grassland accounts for over 80% of agricultural land, compared with e.g. Lincolnshire where only 13 per cent of the agricultural area supports grassland. In the uplands of Wales and northern Britain, grazing by sheep and beef cattle extends the area for food production on to marginal land where crops could not be grown for human consumption. The highest levels of grassland production, and the livestock production it supports, are achieved where rainfall is well distributed, soils have a good water holding capacity, and where grass growth is not limited by extremes of environment such as low temperatures in spring or autumn. The maritime climate of western Britain meets these requirements well. The oceanic influence diminishes from west to east, giving lower rainfall with colder winters. Cereal production is suited to the more level land and relatively continental climate of eastern Britain; drier summers enable the grain to ripen and harvesting and cultivation operations can be completed in a timely manner. The topography of many northern and western parts also limits the area suitable for the safe working of machinery needed for arable cropping.

In addition to providing most of the dietary requirements of the ruminant livestock sector, grassland also has an important amenity role. It dominates the landscape, particularly in the north and west where most National Parks and other designated landscapes are situated. In some districts the regional income associated with the recreational and conservation value of the landscape, and its associated flora and fauna, exceeds the direct income from agricultural production, so extending employment opportunities for rural communities at a time when agricultural incomes are falling. Recognition of non-agricultural roles of grassland is not new; they found their expression in the creation of parkland estates in the eighteenth century, and sporting interests have often conflicted with pressures to bring land under the plough. The populist movements in the 1930s led to pressures for greater access to the countryside for recreation and for its protection from inappropriate development. Sir George Stapledon, although nowadays best remembered for his advocacy of ley farming, also argued passionately for 'a great return to nature for the nation as a whole; the urban population should have sufficient opportunity for simple enjoyment of the country,' (Stapledon, 1935).

RECENT HISTORICAL DEVELOPMENTS IN AGRICULTURAL MANAGEMENT

The areas of grassland and arable land, and their management and its consequences, have fluctuated in response to population growth, economics and international politics. Agricultural management during the period from the late 1930s (at the end of a 60-year agricultural depression) to the present has developed in response to technical and structural changes which have had huge implications for landscapes and nature conservation. Many polemicists (e.g. Shoard, 1980) have tended to regard the late nineteenth and early twentieth centuries as an Arcadian high point; a period when, despite grinding rural poverty, agricultural management was beneficial for wildlife, and the countryside was diverse biologically, with distinct regional differences. In a review of agricultural texts and journals, Davies and Davies (1996) also concluded that the grassland landscape was floristically rich until at least the end of the nineteenth century. However, it is beguilingly simplistic to assume that this period represented a natural or stable state. In reality enormous changes occurred in the nineteenth century: land enclosures, crop rotations, extensive land drainage, and the introduction of steam powered machinery to farms. Increased numbers of cattle and horses necessitated increased use of hay to overwinter them, and the widespread use of industrial by-products as fertilizers (e.g. basic slag), or as feed (e.g. cotton-seed cake and brewers grains) in turn contributed to increased soil fertility. By around 1870 the arable acreage had increased (at the expense of pasture) to an unprecedented level. This was followed in the late nineteenth century by an agricultural depression in Britain, and the availability of cheap food imports resulting in large areas of cropped land reverting to unsown pasture: in the twenty years from 1871 the area of permanent grass in England and Wales increased by 33%, largely at the expense the corn acreage (Ernle, 1961).

During and since the second world war, a combination of food shortages, government and EC policies, and technological innovations have led to greatly increased production from both grassland and arable land. Modern farming has been variously promoted as either having brought about a successful agricultural industry, or accused as being responsible for4 enormous losses of semi-natural habitats and farmland biodiversity. In the 40 years to the mid-1980s, output of beef and lamb doubled, and that of milk more than trebled, while the grassland area actually fell. Cereal yields per hectare doubled over the same period as a result of technological improvements in plant breeding, machinery and agronomy (Orson, 1987) which was to provide a further stimulus for many grasslands to be ploughed for cereal crops.

In the period from the 1940s to the early 1980s there was a degree of political consensus on countryside management. Successive governments encouraged the intensification of agriculture through guaranteed prices and capital grants, and farmers were provided with a free extension service in turn supported by a large production-oriented research service. Increased self-sufficiency in food production was justified on grounds of national security, and later because of its contribution to the balance of payments and rural prosperity. Although the post-war period had seen the creation of National Parks, National Nature Reserves and the Nature Conservancy, in the 1940s agriculture was not identified as a threat to the countryside (Sheail, 1976). For 40 years agricultural improvement was carried out with scant regard for conservation values.

The 1980s was a radical decade which saw most of the arguments for increasing agricultural production gradually fall away, and a progressive 'greening'of mainstream British politics. The 1981 Wildlife and Countryside Act heralded a change in emphasis in terms of encouraging conservation, and several contentious issues during the period, including debates over the future of the Somerset Levels and the Halvergate Marshes (O'Riordan, 1985), focused attention upon grassland loss. The introduction of milk quotas in 1984 removed a major incentive to further increases in production, and the 1986 Agriculture Act imposed a duty for agriculture ministers to balance the needs of farming with conservation and enjoyment of the countryside, and gave ministers powers to establish Environmentally Sensitive Areas.

Despite these changes of policy and outlook, the loss of grassland continued. Fuller (1987) reports an approximate 2% per annum loss of semi-natural grasslands between 1930 and 1984, but in some areas this may have risen to 10% in the 1980s due to a combination of agricultural intensification, inappropriate management and neglect (Devon Wildlife Trust, 1990; Porley and Ulf-Hansen, 1991). Ironically, the reasons for this increased rate of loss would appear to relate to government policy. Many dairy farmers responded to milk quotas by intensifying their grassland, to reduce expenditure on bought feed-stuff. Falling incomes from other livestock enterprises, and anticipation of a quota system on cattle and sheep numbers, was countered by increasing stocking rates and intensification of grassland management.

GRASSLAND MANAGEMENT TODAY

Information on grassland management, output, and sward composition is derived mainly from surveys and field trials (Forbes *et al.*, 1980; Hopkins and Wainwright, 1989; Hopkins *et al.*, 1985;1990). These studies, some aspects of which now need updating, add substantially to data from other sources, such as the Survey of Fertilizer Practice (ADAS/FMA, 1992), the annual MAFF Census and the ITE Countryside Surveys (Barr *et al.*, 1993).

A major effect of intensification in management has been the reduction in botanical diversity. The proportion of perennial ryegrass *(Lolium perenne)* in grassland provides one of the best indicators of botanical change: it is the most important sown species and an indicator of agricultural improvement in most lowland permanent pastures. Overall, *L. perenne* has increased at the expense of most other species due, primarily, to three developments acting together: reseeding, increased use of fertilizers, and increased silage making. Earlier cutting for silage favours ryegrass at the expense of late-flowering species, and has allowed the economic potential of improved ryegrass varieties and nitrogen fertilizers to be realized. To these can be added land drainage, increased stocking rates (and therefore more nutrient returns) and changes in grazing management, and the use of herbicides. Whilst the major impacts of these management changes have been on lowland grasslands (Fuller, 1987), some upland areas have been affected similarly (Hopkins and Wainwright, 1989). The effects of different aspects of management will be considered in turn.

ASPECTS OF MANAGEMENT

Ploughing and Reseeding

Before the development of cultivated grass varieties, cultivated land being returned to grass after cereals or root crops was either sown with hay loft sweepings or allowed to tumble down to a natural sward. During the earlier part of this century grass seeds mixtures were relatively complex and contained a range of minor grasses, legumes and forage herbs (Davies, 1960). Modern seeds mixtures are relatively simple, often pure *L. perenne*, and this, combined with better seed cleaning, better weed control during the crop phase of ley-arable rotation, and improved techniques for sward establishment, has resulted in greatly reduced botanical diversity and reduced seed banks in the resulting ley grassland.

The plough-up campaign of World War 2 was responsible for about 35% of the then permanent grassland area being converted to crops or sown leys. However, despite the impact of this campaign and subsequent agricultural improvement, nearly 60% of the old grass that existed in 1939 remained unploughed 20 years later (Baker, 1960). Since then there has undoubtedly been a slow attrition of remaining old species-rich grassland by ploughing and reseeding to sown ryegrass swards (often when such land changed ownership or passed to a younger generation) and by conversion of grass to arable land (including many chalk grasslands and the once highly prized fattening pastures of the East Midlands, Norfolk and Romney Marsh).

Reseeding of grassland has continued at a rate of about 200,000 hectares annually, though much of this consists of renewals of ageing grass leys. Despite the reduction of grasslands of high conservation value, at least 50% of swards are at least 20 years old (in some cases with no known history of being ploughed). In a few areas, e.g. parts of the Pennines where over 60% of the grassland area is more than 35 years old, management changes have had comparatively little effect on old grassland (Hopkins and Wainwright, 1989). But elsewhere, modern grassland management has had a considerable impact. A note of caution accompanies these statements: some limited information on areas sown can be derived from annual Census returns, but grassland surveys have provided the main source of information, and only limited information is available for recent years. The most recent national grassland surveys (field scale botanical records combined with farmer interviews on management history and output) were conducted in the 1970s (Forbes *et al.*, 1980; Green, 1982) with some sample areas resurveyed in the early/mid-1980s (Hopkins *et al.*, 1985; Hopkins and Wainwright, 1989).

Land Drainage

A high proportion of British grassland is on soils derived from shales, clays or glacial drift and is prone to seasonal waterlogging which imposes management constraints, particularly on cattle grazing in spring and autumn. In the 19th century about 5 million ha were under-drained and many wetland areas were converted to arable land at this time. There was an active period of drainage during the period 1940-1980 encouraged by grant aid. Resulting changes in soil hydrology affect species composition either directly through changing the environment of species dependent on wet conditions (e.g. *Carex* spp.) or indirectly, by enabling other changes such as earlier grazing, silage cutting, higher fertilizer inputs etc, and often accompanied by a complete reseeding.

Wet grassland (and associated low wetland habitats of open water, i.e. swamp, sedge-bed and fen) occur where hydrological conditions result in a sward composition strongly influenced by waterlogging or flooding. Such events may be short-lived and seasonal. Lowland wet grasslands comprise those plant communities (at below 200m) where vegetation consists mainly of native grasses and forbs, often with rushes and sedges and few woody plants (Mountford *et al.*, 1997). The total area of wet grassland in England is *c.* 220,000 ha (Dargie, 1993), most of which has been agriculturally improved to some extent. Agricultural development in the lowlands has resulted in wet grasslands having suffered extensive destruction, damage or modification (Mountford *et al.*, 1994). As a result, the area of *unimproved* semi-natural wet grassland surviving at present probably amounts to less than 20,000 ha (Jefferson and Grice, 1997), and represents as little as 3% of the resource that was present in the 1930s (Fuller, 1987). Those unimproved wet grasslands which remain commonly occupy small, isolated and often fragmented relict sites. Sites continue to be at risk from activities such as bore-hole abstraction, drainage or the eutrophication of water sources (HMSO, 1995b).

Numerous studies have shown that drainage improvements are detrimental to botanical diversity in extensively managed grasslands, but on more intensive grassland the effect is relatively small compared with that of N fertilization. A further influence is the increase of N mineralization associated with lowering of the water table. In mixed farming areas such as the East Anglian marshes drained grassland has usually been converted to arable land, whereas in western grassland areas, such. as the Devon Culm Measures mire communities (e.g. M24 Cirsio-Molinetum, *sensu* Rodwell, 1992) have been converted to *L. perenne*-dominated swards.

The type and composition of wet grassland is further influenced by the water-regime, soil pH, fertility and agricultural management. The recorded distribution of lowland wet grassland communities was summarized by Tallowin and Mountford (1997) as indicated by ADAS monitoring of five English ESAs: Norfolk Broads, North Kent Marshes, Avon Valley, Somerset Levels and Moors, and Test Valley.

Fertilizers

Some 85% of all grassland in England and Wales now receives fertilizer N, at a mean annual rate of 160 kg N/ha; but while leys receive, on average, *c.* 200 kg N/ha, 40% of over-20-year-old grassland receives either none or less than 50 kg N/ha, and the average on fields mown for hay, 100 kg N/ha, is less than half that on silage fields (ADAS/FMA, 1992). Dairy farms use, on average, more than twice the amount of fertilizer N used on beef/sheep farms. On sites with good grass-growing conditions, herbage yield responses (up to 300 kg N/ha) are *c.* 15-20 kg dry matter (DM) per kg of fertilizer N (Hopkins *et al.*, 1990). Losses in utilization prevent such responses from being fully reflected in additional livestock production, but fertilizer N is associated with higher output and profitability. Additional grass from fertilizer N is usually cheaper than purchased feeds.

Other fertilizer inputs include phosphorus (P) and potassium (K), applied on *c.* 60% of grassland at average rates of 15 kg P/ha and 45 kg K/ha. Each year about 3% of grassland receives lime.

The application of increased rates of inorganic fertilizers represents the single greatest cause of reduced botanical diversity in grasslands; either directly through encouraging the rapid growth and survival of a few productive and competitive species, or indirectly through enabling more intensive utilization (higher stocking rates and earlier cutting for silage) which breaks the growth and flowering cycles of many grassland species. The effects of different plant nutrients and forms of fertilizer on the yield, plant species richness and species composition were reviewed by Smith (1994). The importance of low or moderate fertility for the maintenance of the original botanical composition of a wide range of grassland communities has been shown in experiments on calcareous grassland (Jeffrey and Pigott, 1973; Bobbink, 1991), upland *Molinia/Nardus/Festuca* grassland (Jones, 1967), and productive mesotrophic grasslands (Garstang, 1981; Hopkins *et al.*, 1990; Tallowin, 1996). Long-term experiments, notably the Rothamsted Park Grass Plots (Thurston, 1969) have demonstrated how swards develop and maintain distinct changes under different fertilizer inputs.

The effect of fertilizers on grassland composition has also been shown clearly in surveys (Hopkins, 1986; Hopkins and Wainwright, 1989). Fertilizer N use on grassland is significantly correlated with the proportion of *L. perenne*. On mesotrophic swards of moderately diverse composition (MG6/MG7) increasing the rate of fertilizer N leads to a rapid increase in the proportion of *L. perenne*, primarily at the expense of *Agrostis* spp., *Trifolium* spp and most forbs (Hopkins *et al.*, 1990); e.g. the addition of high inputs of N (300-450 kgN/ha with supporting P and K) can increase the proportion of *L. perenne* from about 20% to about 60% in one season. In trials on hay meadows on the Somerset Moors, fertilizer N rates as low as 25 kg/ha increased *L. perenne* and *Holcus lanatus* and significantly reduced species diversity within six years (Mountford *et al.*, 1994). In the absence of *L. perenne*, the species that respond to increased N supply include *Dactylis glomerata, Elytrigia repens* and *Holcus lanatus*; *Poa* spp. and *Festuca pratensis* are also tolerant of high N. Botanical changes resulting from increased N supply are to some extent reversible. Nitrogen is very mobile and, in most cases, its release by mineralization from soil organic is slow. This partly explains the progressive reduction in sown species in the years after reseeding to a grass ley, as *L. perenne* loses its competitiveness with declining fertility.

However, the situation is different for potassium and phosphorus for which there can be large available reserves in the soil. Potassium is relatively mobile and can be depleted by repeated cutting, but phosphorus is less mobile and only small amounts are removed in herbage, and most of the phosphorus ingested in herbage is returned in the excreta. In a study of the relation between soil chemical analyses and sward diversity on a large range of grasslands, Jenssens *et al.* (1997) reported that P was the only element that showed a strong correlation with diversity and concluded that diverse grasslands can persist only when extractable P is below 5 mg/100mg acetate extraction. In a small plot experiment on Tadham Moor, Somerset, P was also found to be more important than N in determining botanical change (Kirkham *et al.*, 1996).

Lime, although not strictly a fertilizer, is applied to maintain soil pH at around 5.5-6.0, the range at which responses to other fertilizers are optimized and the main sown species are likely to persist (Cromack *et al.*, 1970). The liming sub-treatments of the Park Grass experiment indicate how major grasses are affected by lime: with NPK at low pH *Holcus lanatus* dominates, but at neutral pH *Alopecurus pratensis* increases, and *Arrhenatherum elatius*, *Dactylis glomerata* and *Cynosurus cristatus* at pH 6.0-7.5 (Warren and Johnson, 1964). Lime applications have undoubtedly reduced many acid grassland communities, but, interestingly, this is one case when inputs can increase species diversity. Milton's classic experiments on *Festuca-Agrostis* and *Molinia*-dominated swards at Llety Hill in Mid-Wales showed that lime resulted in the development of diverse swards with lowland grass and forb species (Jones, 1967).

Stocking Rates and Grazing Pressure

Almost all agricultural grassland in the British Isles is grazed for at least part of the year, a feature of British grassland management which is different from many other parts of Europe. In general terms there is a 'bell-shaped' relationship between plant species diversity and grazing pressure (Milne, 1997). Intensity and seasonality of grazing, as well as type of grazing livestock, affect the composition of grassland. The nature of excretal return and the extent of trampling damage also influence the relationship, particular in terms of creating heterogeneity and regeneration niches (Grubb, 1977).

During the past 50-60 years average stocking rates on British grassland have doubled. One consequence is the greatly increased supply of nutrients in animal excreta returned either *in situ* under grazing or as manures from housed stock. The decline in mixed arable and livestock farming has also meant that manures are returned to the grassland rather than to cereal or root crops. Intensive grazing also has implications for species diversity through defoliation pressure reducing the opportunity for flowering and seeding, thus favouring species that rely on vegetative growth (*L. perenne, Trifolium repens*) or species that are avoided because of unpalatability (*Cirsium arvense, Rumex* spp) or those that can adapt morphologically (rosette forming forbs such as *Plantago major*). Cattle, sheep and horses exert different grazing behaviour patterns, both in terms of how close to the sward surface they graze, their selectivity, and the distribution of dung and urine relative to grazed areas. Grazed-only fields often have a higher level of spatial variability than mown fields (particularly silage fields) and this can favour species diversity as different species have adjacent niches to exploit. Some aspects of grazing management which have contributed to botanical change in recent years include:

- The large increase in sheep numbers in upland areas, and a reduction in cattle, have been cited as a reason for the increase in bracken (Smith and Taylor, 1986). Whilst cattle, like sheep, would normally avoid ingesting bracken, the shearing action of their hooves is effective in reducing the croziers of young bracken.
- Better understanding of grazing management, including the relationship between the growth and utilization (through varying grazing intensity) of swards; management using sward height guidelines; and the adoption of buffer feeding strategies to sustain maximum utilization and animal performance throughout the grazing season (Frame *et al.*, 1995). These developments, if implemented, enable higher levels of pasture utilization and overall higher stocking rates.
- The large increase in horses particularly on rural-urban fringe areas. The grazing habits peculiar to horses favour development of weedy pastures, particularly when kept at a high stocking density and fed on hay and other feeds brought from outside (Gibson, 1996; 1997).

Mowing for Hay and Silage

The seasonal growth of grass with peak production in early summer and little growth in winter necessitates that considerable areas be mown for forage. Approximately 40% of the British enclosed grassland area is mown either every year or in most years. Traditionally this was cut for hay during July or even August, and although silage making became firmly established in Britain in the late nineteenth century there was almost a 100-year lag before its use overtook that of the hay crop (Brassley, 1996). Technical innovation and improvements in the scientific understanding of silage making and utilization are amongst the most significant of all developments to affect agricultural grassland management in the post WW2-period (Frame *et al.*, 1995). However, even as recently as the early 1970s the ratio of hay to silage (expressed on a dry weight basis) harvested on British farms was about 85 : 15 ; something which was to change markedly over the following decade. Farmers in the upland areas of Britain had largely stayed with hay until into the late 1980s, the economics of upland stock farming not justifying the investment in silos. The 1980s saw the advent of the big round baler (Forster, 1989) and wrapped bale silage, which now accounts for about 20% of UK silage, has provided a cheap alternative to hay in situations where permanent silos are uneconomic (Eyers, 1989), thus extending silage making on to areas where hay making had persisted.

The implications for reduced botanical diversity associated with the adoption of silage are due to the following reasons:

- Silage can be, and therefore generally is, mown earlier in the season (e.g. mid- late May) before most forbs and minor grasses have flowered. Early cutting, particularly when followed by subsequent cuts, effectively prevents seed rain (the same applies when hay is mown early, e.g. Smith *et al.* (1996).
- Silage making is relatively independent of the weather, unlike hay making which may be excessively delayed in some seasons to the benefit of the life cycles of late flowering species. In the past, before hay making was mechanized, mowing and harvesting were spread over a long season, particularly in years with inclement weather (Smith and Jones, 1991).
- The early harvesting of silage crops enables farmers to get maximum benefits from applications of high rates of fertilizers at the time of maximum herbage growth in early summer: this encourages higher fertilizer use, to the detriment of late flowering species.
- Sown grasses, particularly *L. perenne,* are better suited than many permanent pasture species for making high digestibility silage (Wilson and Collins, 1980) and this may often be used to justify reseeding.
- Hay usually contains seed of grasses and forbs, and when fed to overwintered stock (whether directly outdoors or on straw bedding which is eventually spread as manure) opportunities for seed dispersal are thereby created; such opportunities do not exist when silage is fed (Marshall and Hopkins, 1990).

Weeds and Pests and their Control

Weeds and pests have been tolerated more on grassland than on arable crops. Consequently, the use herbicides has been confined mainly to the establishment phase of leys, or for spot-treatment of perennial weeds (*Rumex* and *Cirsium* spp.) or bracken. This is in marked contrast to their use on arable crops, where many arable weeds have now become rare species (Wilson, 1992). Nevertheless, a vast array of approved herbicide agents and formulations has been introduced for use on grassland over the past 50 years, for selective and non-selective use; and for contact, translocation or pre-emergence action (Frame *et al.*, 1995). About 5-10% of the grassland area is treated with herbicides each year. On grassland in ley-arable rotations the impact of herbicides has often been greater during the arable phase.

Unless there are clearly visible attacks by pests and diseases their insidious damage to roots and herbage is usually undetected, although there is clear evidence of significant economic effects caused by pests such as leatherjackets, sitona weevil and slugs. Nevertheless, the use of pesticide-based control measures, particularly on established grass swards, has been negligible compared with their use on arable land.

Field Size and Field Boundaries and Margins

A detailed consideration of field margins is outside the remit of the present paper, but changes in agricultural land management - grassland and arable - have resulted in considerable associated changes in the extent and biological quality of and hedges and field margins. This has had a considerable impact on the flora, fauna and landscape in many grassland areas. Hedgerows, ditches and dry-stone walls, and their associated field margins, are characteristic features of the British rural landscape. Each of these also provide important habitats for a wide range of plant and animal species and may serve as corridors for the movement of species, thus linking other habitats such as woodland and ponds (Boatman, 1994). Changes in agricultural practices in the 20th century, particularly since 1940, have resulted in widespread removal of hedgerows. In the past, when farming was less mechanized, boundaries were maintained using seasonally surplus farm labour, which is now seldom available. Farmers converting grassland to long-term arable production have little or no need for hedges, but may require larger fields to accommodate modern machinery. This has resulted in widespread abandonment or removal of hedgerows. In many areas with little woodland cover, hedgerows provide a vital habitat for woodland flora and fauna. At a landscape level consideration also needs be given to effects of field size; smaller fields provide a larger amount of field margin in a given area. The importance of ancient and species-rich hedgerows to biodiversity has been recognized by the inclusion of a costed action plan for this 'key habitat' in the UK's Biodiversity Action Plan (HMSO, 1995b). An action plan for field margins has also been prepared by the UK Biodiversity Steering Group, aimed in particular at the protection of rare arable plants (and associated faunal species) using management options such as wildlife strips and conservation headlands. Field boundaries and margins also provide important habitats, corridors or feeding locations for several individual mammal and bird species targeted for protection by the UK Biodiversity Steering Group, and also important breeding and feeding areas for many 'emblematic' species such as song birds and butterflies.

Other Aspects

The above analysis has identified components of agricultural land management and described how they can affect botanical composition. Management changes may occur individually (e.g. increasing the fertilizer input on a permanent pasture), but the most profound and irreversible effects are the result of either progressive or multiple changes, the latter being a common occurrence when land ownership changes. It is essential to recognize that influences arise from combinations and interactions, as shown by models such as Grime's hump-back model (Grime, 1979) and Huston's model of growth rate / reduction interactions (Huston, 1979).

Socio-economic factors also determine aspects of grassland management and their influence on biodiversity and landscape, such as opportunities for alternative incomes on and off the farm, the effect of subsidy payments and quotas, the relationship between landlord and tenant and, in more recent years, the opportunities offered by management agreements through Countryside Stewardship and ESA schemes (Coates, 1997; Swash, 1997).

THE FUTURE

Ruminant production is likely to remain the main use for most UK grassland, subject to no major changes in human diet or world trade. Farmers and politicians will, however, face increasing pressure to ensure that agricultural practices meet environmental and conservation objectives, and higher standards of animal welfare, and improvements in food quality and safety. This could favour greater product differentiation, including farming systems based on organic methods or the adoption regional distinctiveness in produce, requiring less intensive methods. Further increases in fertilizers and other inputs, particularly pesticides, are unlikely, and their use may decline. As farmers strive to achieve greater efficiency in a static or declining market, the total agricultural grassland area may fall: reductions of 2-4 million hectares by 2015 have been suggested (North, 1990).

In the short term, changes in support prices for cereals will reduce the cost advantage of grass silage, relative to maize, cereals and concentrates. This will probably affect the amount and average quality of silage, with delayed and heavier first cuts, possibly with less fertilizer, and subsequent cuts replaced by grazing. Such changes would affect grassland production, sward structure and composition.

The lack of strategic data on how grassland has changed since the mid-1980s makes prediction about the future of grassland of conservation interest very uncertain. However, evidence suggests that despite a greening of agricultural policy in the 1980s, semi-natural grasslands have been lost as farmers tried to maintain falling incomes. Increased knowledge about grassland management will also have contributed to this trend.

Despite further policy mechanisms being introduced in the early 1990s to encourage nature conservation, delays in the uptake of conservation incentives occur as farmers face uncertainty and attempt to make unfamiliar business judgements, resulting in further loss of semi-natural grasslands and associated habitats. Of particular relevance in this context are questions of how the agronomic value of remaining areas of semi-natural grasslands can be realized while protecting their value for nature conservation and landscape. Aspects such as: defining acceptable limits of manuring on species-rich swards; upgrading the nutritional value of late-cut hays; appraising the attributes of regional and traditional livestock breeds for utilizing semi-natural grasslands; and evaluating the total socio-economic value of semi-natural grassland in the countryside have been identified as possible priorities (Tallowin, 1997).

In addition there is the problem of damage to sites due to neglect, and policies to reduce livestock numbers could well intensify this. Additional pressures could also come from converting grassland to other uses, such as coppiced woodland for biofuel production, and from further demands for recreational use and commercial development.

REFERENCES

ADAS/FMA (1992) *Fertilizer use on farm crops in England and Wales 1991.* London: MAFF.

BAKER, H.K. (1960) Permanent grassland in England. In: *Proceedings of the 8th International Grassland Congress, Reading*, pp. 394-399.

BARR C., BUNCE R.G.H., CLARKE R.T., FULLER R.M., FURSE M.T., GILLESPIE M.K., GROOM G.B., HALLAM C.J., HORNUNG M., HOWARD D.C. and NESS M.J. (1993) *Countryside Survey 1990, Main Report.* London: DOE.

BOATMAN N.(Ed) (1994) *Field Margins: Integrating Agriculture and Conservation. BCPC Monograph No. 58.* Farnham: BCPC.

BOBBINK R. (1991) Effects of nutrient enrichment in Dutch chalk grassland. *Journal of Applied Ecology,* **28**, 28-41.

BRASSLEY P. (1996) Silage in Britain 1880-1990: the delayed adoption of an innovation. *Agricultural History Review*, **44**, 61-82.

COATES D. (1997) UK policy for the ESAs. In: Sheldrick R.D. (Ed) *Grassland Management in Environmentally Sensitive Areas. British Grassland Society Occasional Symposium* No. 32, pp. 5-11.

CROMACK H.T.C., MUDD C.H. and STRICKLAND M.J. (1970) A comparison of types of lime and their frequency of application to grassland. *Experimental Husbandry*, **19**, 40-48.

DARGIE T.C. (1993). *The Distribution of Lowland Wet Grassland.* English Nature Research Report No. 49. English Nature, Peterborough.

DAVIES A. and DAVIES O. (1996) English agriculturalists' attitudes towards grassland vegetation, 1780-1914: an ecological perspective. *Landscape History*, **18**, 71-80.

DAVIES, W. (1960) *The Grass Crop: Its development use and maintenance*. Second edition. London: Spon.

DEVON WILDLIFE TRUST (1990) *Survey of Culm Grasslands in Torridge District.* Exeter: Devon Wildlife Trust.

ERNLE (1961) *English Farming Past and Present.* 6th edition. London: Heinmann/Cass.

EYERS B. (1989) Place for big bales in the current silage scene. *Big Bale Silage. Proceedings of British Grassland Society Conference,* February 1989, NAC Stoneleigh, pp. 1.1 - 1.7.

FORBES, T.J., DIBB, C., GREEN, J.O., HOPKINS, A. and PEEL, S. (1980) *Factors affecting the productivity of permanent grassland - a national farm study*. Hurley: GRI/ADAS Permanent Pasture Group.

FORSTER L. (1989) Handling and storing of big bales. *Big Bale Silage. Proceedings of British Grassland Society Conference,* February 1989, NAC Stoneleigh, pp. 8.1 - 8.4.

FRAME J., BAKER R.D. and HENDERSON A.R, (1995) Advances in grassland technology over the past fifty years. In: Pollott, G.E. (Ed) *Grassland into the 21st Century. British Grassland Society Symposium No. 29*, pp 31-63.

FULLER, R.M. (1987) The changing extent and conservation interest of lowland grasslands in England and Wales: a review of grassland surveys 1930-84. *Biological Conservation,* **40**, 281-300.

GARSTANG J.R. (1981) The long term effects of the application of different amounts of nitrogenous fertilizer on dry matter yield, sward composition and chemical composition of a permanent grass sward. *Experimental Husbandry*, **37,** 117-132.

GIBSON C.W.D. (1996a) The effects of horse grazing on species-rich grasslands. *English Nature Research Report* No. 164.

GIBSON C.W.D. (1996b) The effects of horse and cattle grazing on English species-rich grasslands. *English Nature Research Report* No. 210.

GREEN, J.O. (1982) *A sample survey of grassland in England and Wales, 1970-72*. GRI, Hurley.

GRIME J.P. (1979) *Plant Strategies and Vegetation Processes.* London: Wiley.

GRUBB P.J. (1977) The maintenance of species-richness in plant communities: the importance of the regeneration niche. *Biological Reviews*, **52**, 107-145.

HOPKINS, A. (1986) Botanical composition of permanent grassland in England and Wales in relation to soil, environment and management factors. *Grass and Forage Science,* **41**, 237-246.

HOPKINS A. and HOPKINS J.J. (1994) UK grasslands now: agricultural production and nature conservation. In: Haggar R.J. and Peel S. (Eds.) *Grassland Management and Nature Conservation. British Grassland Society Occasional Symposium* No. 28, pp. 10-19.

HOPKINS, A. and WAINWRIGHT, J. (1989) Changes in botanical composition and agricultural management of enclosed grassland in upland areas of England and Wales, 1970-86, and some conservation implications. *Biological Conservation,* **47**, 219-235.

HOPKINS, A, MATKIN, E A, ELLIS, J A and PEEL, S.(1985). South-west England grassland survey 1983: 1. Age structure and sward composition of permanent and arable grassland and their relation to manageability, fertilizer nitrogen and other management features. *Grass and Forage Science,* **40**, 349-59.

HOPKINS, A., GILBEY, J., DIBB, C., BOWLING, P.J. and MURRAY, P.J. (1990) Response of permanent and reseeded grassland to fertilizer nitrogen. 1. Herbage production and herbage quality. *Grass and Forage Science,* **45,** 43-55.

HMSO (1995a) *The Digest of Agricultural Census Statistics 1994* (MAFF, SOAFD, DANI, WOAD).

HMSO (1995b) *Biodiversity: The UK Steering Group Report. Volume 2: Action Plans.* London: HMSO.

HUSTON M. (1979) A general hypothesis of species diversity. *American Naturalist*, **13**, 81-101.

JANSSENS F., PEETERS A., TALLOWIN J.R.B., SMITH R.E.N., BAKKER J.P., BEKKER R.M., VERWEIJ G.L., FILLAT F., CHOCARRO C. and OOMES, M.J.M. (1997) Relationship between soil nutrients and plant diversity in grasslands: definition of limits for the maintenance and the reconstruction of species-rich communities. In: *Management for Grassland Biodiversity, Proceedings of International Occasional Symposium of the European Grassland Federation*, Warsaw and Lomza, Poland, May 1997, pp.315-322..

JEFFERSON R.G. and GRICE P.V. (1997) The conservation of lowland wet grassland. In: C.B. Joyce and P.M. Wade (Eds). *European wet grassland: biodiversity, management and restoration.* John Wiley, Chichester.

JEFFREY D.W. and PIGOTT C.D. (1973) The response of grasslands on sugar-limestone in Teesdale to application of phosphorus and nitrogen. *Journal of Ecology*, **61,** 85-92.

JONES LL.I. (1967) Studies on Hill Land in Wales. *Technical Bulletin of Welsh Plant Breeding Station* No 2. Aberystwyth: WPBS.

KIRKHAM F.W., MOUNTFORD J.O. and WILKINS R.J. (1996). The effects of nitrogen, potassium and phosphorus addition on the vegetation of a Somerset peat moor under cutting management. *Journal of Applied Ecology*, **33**, 1013-1029.

MARSHALL, E J P and HOPKINS, A. (1990). Plant species composition and dispersal in agricultural land. In: R G H Bunce and D C Howard (Eds.) *Species Dispersal in Agricultural Habitats*. pp. 98-116. Belhaven Press.

MILNE J. (1997) Grassland management and biodiversity. In: Sheldrick R.D. (Ed) *Grassland Management in Environmentally Sensitive Areas. British Grassland Society Occasional Symposium* No. 32, pp.25-32.

MOUNTFORD J.O., TALLOWIN J.R.B., KIRKHAM F.W., and LAKHANI K.H. (1994) Effects of inorganic fertilizers in flower-rich hay meadows on the Somerset Levels. In: Haggar, R.J. and Peel, S. (eds) *Grassland Management and Nature Conservation. British Grassland Society Occasional Symposium* No. 28. pp. 74-85.

MOUNTFORD J.O., TALLOWIN, J.R.B., SPARKS, T.H., GOWING, D.J.G., MANCHESTER, S.J., ROSE, S.C., TREWEEK, J.R., GILBERT, J.C. and ARMSTRONG, A.C. (1997). Experimental and monitoring studies of the use of raised water-levels for grassland rehabilitation in lowland ESAs. In: Sheldrick R.D. (Ed) *Grassland Management in Environmentally Sensitive Areas. British Grassland Society Occasional Symposium* No. 32, pp. 67-72.

NORTH, J. (1990) Future agricultural land use patterns. In: D. Britton (ed) *Agriculture in Britain: changing pressures and policies.* pp. 69-93, Wallingford: CAB.

O'RIORDAN T. (1985) Halvergate: the politics of policy change. In: Countryside Planning Yearbook, 6, 101-106. Norwich: Geobooks.

ORSON J.H. (1987) Growing practices: an aid or hindrance to weed control in cereals. Proceedings British Crop Protection Conference - Weeds, pp. 87-97.

PARK, J.R.(Ed.)(1988) *Environmental Management in Agriculture.* London: Belhaven.

PORLEY, R.D. and ULF-HANSEN, P.F. (1991) Unimproved neutral grassland in Dorset: survey and conservation. *Proceedings of the Dorset Natural History and Archaeological Society,* **113**, 161-165.

RODWELL, J.S. (Ed.) (1991) *British Plant Communities, Vol 2, Mires and heaths.* Cambridge: CUP.

RODWELL, J.S. (Ed.) (1992) *British Plant Communities, Vol 3, Grasslands and montane communities.* Cambridge: CUP.

SHEAIL, J. (1976) *Nature in Trust.* London: Blackie.

SHOARD M. (1980) *The Theft of the Countryside*. London: Temple Smith.

SMITH, R.S. (1994) Effects of fertilizers on plant species composition and conservation interest of UK grassland. In: Haggar R.J. and Peel S. (Eds.) *Grassland Management and Nature Conservation. British Grassland Society Occasional Symposium* No. 28, pp. 64-73.

SMITH R.S. and JONES L. (1991) The phenology of mesotrophic grassland in the Pennine Dales, northern England: historic hay cutting dates, vegetation variation and plant species phenologies. *Journal of Applied Ecology*, **28**, 42-59.

SMITH R.S., PULLAN S. and SHEIL R.S. (1996) Seed shed in the making of hay from mesotrphic grassland in a field in northern England: effects of hay cut date, grazing and fertolizer in a spli-split-plot experiment. *Journal of Applied Ecology*, **33**, 833-841.

SMITH R.T. and TAYLOR J.A. (1986) *Bracken Ecology, Land Use and Control Technology.* Carnforth: Parthenenon.

STAPLEDON, R.G. (1935) *The Land - Now and Tomorrow.* London: Faber and Faber.

SWASH A. (1997) Environmentally Sensitive Areas in the UK and their grassland resource. In: Sheldrick R.D. (Ed) *Grassland Management in Environmentally Sensitive Areas. British Grassland Society Occasional Symposium* No. 32, pp. 34-43.

TALLOWIN J.R.B. (1996) Effects of inorganic fertilizers on flower-rich hay meadows: a review using a case study on the Somerset Levels. *Grassland and Forage Abstracts*, **66**, 147-152.

TALLOWIN J.R.B. (1997) The agricultural productivity of lowland semi-natural grassland: a review. *English Nature Research Report* No. 233.

TALLOWIN J.R.B. and MOUNTFORD J.O (1997) Lowland wet grasslands in ESAs. In: Sheldrick R.D. (Ed) *Grassland Management in Environmentally Sensitive Areas. British Grassland Society Occasional Symposium* No. 32, pp.100-111.

THURSTON J.M. (1969) The effect of liming and fertilizers on the botanical composition of permanent grassland and on the yield of hay. In: Rorison, I.G. (Ed) *Ecological aspects of the Mineral Nutrition of Plants. British Ecological Society Symposium* No 9. Oxford: Blackwell.

WARREN R.G. and JOHNSON A.E (1964) The Park Grass experiment. *Report of Rothamsted Experimental Station for 1963, part 2,* 240-262.

WILSON P.J. (1992) Britain's arable weeds. *British Wildlife*, **3**, 149-161.

WILSON R.K. and COLLINS D.P. (1980) Silage making with old permanent pasture grasses. *Food and Farm Research*, 124-125

Landscape-scale relationships between changes in abundance of potentially dominant and less competitive plant species in the British countryside

Simon M. Smart, Robert G.H. Bunce
ITE Merlewood, Grange-over-Sands, Cumbria LA11 6JU
(015395-32264, e-mail S.Smart@ite.ac.uk)

Abstract

Botanical data recorded from a national network of fixed surveillance plots recorded in 1978 and 1990 in Britain were reduced to two measures for each plot; total cover of potentially dominant species and total cover of less competitive species. Contingency table analysis was used to detect landscape-scale relationships between changes in the two measures over time. Out of 20 significant associations, 18 were negative supporting the hypothesis that increases in cover of potential dominants are implicated in reduced richness of less competitive species in the British countryside. Negative associations were characteristic of linear landscape features including hedgerows, roadside verges and streamsides. Negative associations were also detected in infertile grasslands and moorland grasslands and in vegetation types associated with linear features. Dependent relationships are likely to be linked to external impacts operating before and during the twelve year interval. These include eutrophication of lowland streamsides, neglect of hedgerows and increased fencing of field boundaries, changes in road verge management, grassland improvement and increases in sheep grazing and local encroachment of *Pteridium aquilinum* in upland grasslands.

Analysis of the overall pattern of independent and dependent variation showed that significant differences in changing cover of potential dominants but not less competitive species occurred between plot types and vegetation types in landscape scale data. Irrespective of location in the landscape there was an overall significant negative association between changing cover of both functional groups.

Keywords

species richness change, landscape scale, functional groups, CSR, competitors, stress-tolerators, ruderals, dominance.

Nomenclature

Clapham, Tutin & Moore (1987) for vascular plants

Introduction

Since at least the middle of the 20th century the British landscape has seen a loss of vegetation diversity. The areas of many semi-natural vegetation types have been reduced along with the native plant species that characterise them (Ratcliffe, 1984; Rich and Woodruff, 1996). Some evidence for the continuation of this trend has come from the GB wide landscape-scale surveillance program comprising the Countryside Surveys (CS) of 1978 and 1990. Initial results were published by Barr et al (1993) in which statistical tests of changes in plant species richness were presented for different vegetation types accross Britain (GB). Species richness however, conveys nothing about the ecological preferences of the taxa that changed or to what extent decreases in some species are dependent on increases in others. More informative would be an analysis of vegetation change using response variables that; a) are meaningful in terms of the fate of plant species and vegetation known to have declined and considered of high conservation value; b) are designed to indicate shifts in conditions which can be related to the effects of external impacts; c) can be used to test for dependence between shifts in the abundance of different groups of plant species.

We present a new analysis of changes in CS plant species abundance data based on the CSR model of Grime (1979). This model assumes that constraints on the accumulation of plant biomass can be classified into two categories. Firstly stress, which refers to resource shortages that limit photosynthetic production such as drought, shade, low temperature and nutrient limitation. The second constraint is disturbance associated with partial or total destruction of biomass resulting from phenomena such as fire, trampling, cultivation, flooding and herbivore activity (Grime, 1979). Thus three primary strategies are suggested to have evolved in response to stress (stress-tolerators) or disturbance (ruderals) or an absence of both (competitors). The three extremes define a theoretical space within which plant species can be located depending upon the importance of each constraint as it has impinged upon their evolutionary history.

Application of the CSR model can provide an objective means of conveying changes in abundance of species that differ in conservation value. This follows from the fact that many of the species that have historically declined in Britain are more likely to occupy the stress-tolerant and ruderal parts of the CSR triangle often typical of infertile and moderately to frequently disturbed conditions (Mountford, 1994; Ratcliffe, 1984; Hodgson, 1991; Rich and Woodruff, 1996; Chatters, 1996; Tubbs, 1997). Moreover descriptive and experimental studies carried out at smaller scales and in particular vegetation types in Britain have shown how increases in strongly competitive species are associated with reductions in abundance of more stress-tolerant and ruderal species (Davy and Bishop, 1984; Hopkins and Wainwright, 1989; Smith and Rushton, 1994; Pakeman and Marrs, 1992; Dolman and Sutherland, 1992; Mountford et al., 1993). However the extent to which such relationships are involved in changes in vegetation diversity in the wider countryside remains uncertain. In this study we apply Grimes' (1985) classification of the CSR model into two mutually exclusive groups (potential dominants and less-competitive species) which define these extremes (Figure 1, Table 1). By analysing changing plant species abundance within CS surveillance plots in terms of the joint behaviour of these two groups we test the hypothesis that on average, decreases in total abundance of less-competitive species are associated with increases in cover of potential dominants in the British countryside.

Table 2 shows the range of expected relationships between changes in abundance of potential dominants and less-competitive species. A positive relationship between changing cover of both groups might conceivably occurr if surveillance data captured the consequences of wholesale destruction and replacement of the vegetation, for example ploughing up and re-sowing of grasslands or closure of plantation conifer canopies. In vegetation unaffected by such drastic changes but impacted by changes in trophic status and cutting or grazing regime, it is more likely that if both potential dominants and less-competitive species are present then a negative association is expected ie. one group increases and the other decreases. For example potential dominants are likely to capitalise on heightened fertility and reduced disturbance, increasing in abundance as a result. Less-competitive species may then be reduced as a direct consequence of the increasingly asymmetric competitive effect of potential dominants in the sward (Keddy et al, 1997; Silvertown et al, 1994; Grime, 1985) although this analysis does not attempt to identify the actual mechanisms that might be involved. Negative associations are less likely to involve rapid increases in less competitive species in response to decreased cover of potential dominants (table 2) if constrained by lack of dispersal back into the patch from the seedbank or adjacent habitats (Gibson and Brown, 1991; Jefferson and Usher, 1989; Bekker et al., 1997; Hodgson and Grime, 1988).

Dependent relationships maybe set against a background of independent changes in abundance of potential dominants and less-competitive species since differences in the extent to which cover changes occurrd may be a function of other factors such as vegetation type or location in the landscape. We therefore examine overall relationships in CS surveillance data to provide a context for the search for dependence between changes in cover of functional groups. In summary we address the following questions:

a) Do changes in total cover of potentially dominant plant species exhibit a negative dependent relationship with changes in cover of those species least capable of tolerating their competitive effect ?

b) Are differences in response of the two functional groups most clearly expressed between broad vegetation types or between landscape features such as hedgerows, streamsides and fields ?

c) What do the changes mean in terms of land-use change in the British countryside between 1978 and 1990 ?

Methods

Vegetation recording

The Countryside Survey of Great Britain began in 1978 and was repeated in 1990 (Barr et al. 1993). This is a long term vegetation and land use monitoring programme designed to measure stock and change of vegetation types and land cover at the national level. The CS dataset is unique in that it comprises a repeated random sample of plant species records from fixed plots throughout the wider British countryside.

Recording was carried out in a random sample of 256 1 km^2 which were selected and stratified by the Institute of Terrestrial Ecology Land Classification which stratifies Britain into 32 land classes on the basis of environmental data (Bunce et al. 1996).

During the CS within each 1 km square the vegetation was recorded in a series of quadrats located on a stratified random basis in order to sample different landscape elements such as open field and unenclosed upland, hedgrows, streamsides and road verges (Table 3). The element sampled thus differentiates each plot type.

Vegetation recording in each plot followed standard CS field practice as follows: Each quadrat was relocated from a 1:5000 site map and compass bearings. Each field (X) plot was sudivided into 5 further concentric squares making up 5 nests within which the presence of all rooted vascular plants and bryophytes was recorded. The central 2x2 m nest was censused first and only additional species were recorded in outer nests. For linear (H, R and S) plots no nesting was carried out. Percentage cover estimates to the nearest 5% were then made for each species contributing at least 5% cover to the total area of each plot.

Plot data recorded in 1978 and again in 1990 were stratified three ways (Table 3). Firstly by four major landscape types: arable, pastural, marginal uplands and uplands, which were created by a statistical aggregation of attribute data for the 32 ITE land classes (Barr et al, 1993). Data was also stratified by eight vegetation types defined by cluster analysis of the entire CS quadrat dataset (Bunce et al, 1997) and lastly by the four different plot types located in each 1 km square (Table 3).

Generation of response variables

The classification of species into two functional groups roughly corresponds to that in Grime (1985) and Stockey & Hunt (1994), and is based upon a division of the CSR triangle into 1) potential dominants, 2) subordinates and 3) "plants highly adapted to extremely disturbed and/or unproductive conditions" here referred to as less competitive species. The classification was designed to reflect the differing ability of species to dominate plant communities: Less competitive species are likely to be most vulnerable to the intensifying competitive effect of potential dominants as resource availability increases.

In his original paper Grime (1985) did not expicitly attribute every part of the CSR triangle to each of the three groups. In the analyses presented here we follow the published division of the triangle (Figure 1) but had to allocate each CSR category to each group after inspection of species lists for each category in Grime et al (1995) (see Table 1). CSR codes for individual species were extracted from Electronic Comparative Plant Ecology (Grime et al, 1995).

In each CS plot that was recorded in both 1978 and 1990, total plant cover data in each year was apportioned between potential dominants and less-competitive species; subordinate species were omitted. Only records for plant taxa consistently and reliably identified to species level in the Countryside Survey were included in the analysis. Data were arranged as sets of 2-way tables with entries indicating the number of plots in which cover of potential dominants and less competitive species increased or decreased. Changes in presence and absence were also included in the data with a minimum change of 5% cover necessary for the inclusion of a potential dominant. A disadvantage of reducing cover change data to two categorical variables is that subsequent analyses cannot distinguish between the magnitude of each response; whether for example increases in less competitive species cover have resulted from small increases in few species whilst decreases reflect greater reductions of abundance in more species. Thus net changes in the absolute abundance of species within each group will be masked to some extent. The approach is designed to search for dependence between functional group changes rather than to estimate net change in abundance over time (see Wilson, in prep).

Analysis

Associations between changes in cover of both groups were tested by sequences of two-tailed Fisher's exact tests (PROC FREQ; SAS Institute, 1990) for 2 way tables. The direction and strength of the association between changing cover of potential dominants and less-competitive species is conveyed by the odds ratio (Fleiss, 1981). For 2 way tables this ranges from 0 to infinity with a value of 1 indicating complete independence between changes in cover. Values below 1 indicate a positive association and greater than 1 a negative association. For example an odds ratio of 2.5 indicates that cover of less competitive species is 2.5 times more likely to go down when potential dominant cover goes up than when it goes down. The reciprocal of the odds ratio for values less than 1 then indicates how many more times cover of less competitive species is likely to increase when potential dominant cover increases than when potential dominant cover decreases.

Log-linear analysis (StatSoft Inc, 1997) was used as an overall test of the importance of either vegetation type or plot type in separating changes in cover of potential dominants and less competitive species.

A liberal approach to the problem of multiple testing was adopted: No formal statistical dependence is assumed between analyses. As a result results are presented without adjustment of alpha but the number of significant results expected purely by chance is noted.

Results

An overall negative relationship was detected between changing cover of potential dominants and less competitive species (Tables 4a and 4b, Figure 2). On average, accross the British countryside, cover of less competitive species was1.6 times more likely to decrease where potential dominant cover increased than when it decreased. Analysis of the independent behaviour of changes in cover of the two functional groups showed that it was only changes in potential dominants that differed significantly between both vegetation types (Table 4a, Figure 3a) and plot types (Table 4b, Figure 4a): Figure 3a shows that potential dominant cover increased in more plots than it decreased in all vegetation types except heath/bog with the largest number of increases in crops/weed communities and lowland wooded vegetation. Differences in the direction of potential dominant cover change between plot types are shown in figure 4a; again increases outweighed decreases with the largest increase in hedgerow plots.

Conversely differences between changing cover of less competitive species between vegetation types and plot types did not significantly contribute to the overall pattern of relationships analysed in tables 4a and b. Indeed figures 3b and 4b show few major differences in the number of increases and decreases in cover of less competitive species between strata with substantially more increases only observed in the heath/bog vegetation type. Although marked differences in cover change in both groups were apparent within heath/bog communities the lack of any significant association involving this vegetation type indicates that changes in cover of potential dominants and less competitive species were independent of each other (table 5).

Contingency table analyses within individual combinations of vegetation type, plot type and landscape type revealed a range of significant dependent relationships between changing cover of potential dominants and less competitive species (table 5). In all but two instances, both in crops/weed communities, associations were negative in sign indicating that as expected increases in cover of potential dominants accompany decreases in cover of less-competitive species and *vice versa*. Significant associations were not confined to any one type of stratification of the data: Three associations were detected within three separate vegetation types; crops/weed communities (positive), tall grassland/herb (negative) and moorland grass/mosaics (negative) whilst accross all hedgerow, streamside and road verge plots negative associations were detected. Notably a negative association also characterised the relationship between changing cover of both functional groups accross all plots in the marginal upland landscape irrespective of vegetation and plot type (table 5). Other significant associations were located within subsets of CS data stratified by different combinations of plot type, vegetation type and landscape. The two negative associations involving infertile grasslands in the marginal uplands and on roadside plots are important since this vegetation type encompasses a variety of unimproved herbaceous communities which saw a significant decline in species richness *per se* between 1978 and 1990 (Barr et al, 1993) and a reduction in representation of species considered typical of species rich neutral grasslands (Bunce et al, 1997).

Discussion

Links with external impacts

Whilst vegetation responses can be measured with some precision, much more uncertainty attaches to the identification of external impacts driving change. This is a consequence of the nature of the surveillance program where responses cannot be attributed to predetermined treatments. As a result links between impact and response are coined as hypotheses, only testable by an inductive application to the large scale of the results from experiments and observations carried out at smaller scales, and by marshalling evidence for different types of land-use change before and during the surveillance period. On this basis a judgement regarding the strength of links can be made in the light of evidence that the impact has occurred in the relevant parts of the British landscape and that the impact can cause the observed response.

Examination of species data included in the analysis of crops/weed communities showed that in 44% of the plots analysed *Triticum aestivum* or *Hordeum vulgare* were present in 1978 giving way to fallow open grassland or more often a sown *Lolium perenne* or *L.multiflorum* dominated ley. Thus an arable crop largely devoid of either potential dominants or less competitive species was replaced by recently established swards in which potential dominants such as *Elymus repens, Cirsium arvense, Agrostis stolonifera* and *Urtica dioica* coexisted in 1990 with low covers of less competitive species such as *Festuca rubra, Polygonum aviculare* and *Stellaria media*. The positive association is therefore related to fact that the establishment of short-term vegetation in which low numbers of both functional groups are present represented a joint net increase in cover for both groups compared to the pre-existing crop.

All other dependent relationships between changing cover of potential dominants and less competitive species were negative.

The importance of changes in cover of potentially dominant species on linear features is highlighted by the preponderance of negative associations for hedgerows, streamsides and road verges in the results (table 5). This conclusion is also supported by the two negative associations involving tall grassland/herb since in this vegetation type all but 3% of plots were located on linear features comprising 21% streamside, (23% field boundary not recorded in 1978), 10% hedgerow and 30% road verge.

Taking streamsides first there is evidence that species diversity on river and ditch banks is lowered following establishment and expansion of competitive species (Raven, 1986; Krause, 1977; Dawson and Haslam, 1983) although information on the extent to which these effects have impacted upon British drainage watersides exists for very few sites. However many British catchments have seen dramatically increased nutrient loads since the 1950s (Betton et al, 1991) and this trend has certainly been linked to the documented spread of coarse nitrophiles such as *Urtica dioica* along river, stream and ditch banks particularly in the lowlands (Pearce, 1994; Oliver, 1995). Moreover significant increases in this species and the potential dominant *Galium aparine* were detected on British streamsides accross Britain between 1978 and 1990 based on CS data (Bunce et al, 1997). In additon ongoing agricultural improvement and land drainage affected grasslands in many CS sample squares (Potter and Lobley, 1996) whilst the impact of increased fertility of grasslands in the Netherlands was linked to reduced species diversity and conservation value of the vegetation on adjacent ditch banks by van Strein et al (1989). Heightened fertility of drainage waters and land beside watercourses may therefore be linked to a marked increase in abundance of potential dominants in streamside plots in Britain.

Recent management trends affecting hedgerows are also likely to have favoured a shift toward conditions favourable to potential dominants and inimical to less competitive species. For example the largest change to have occurred in CS hedgerow plots between 1978 and 1990 was a 71% increase in overgrown relict hedges with a substantial increase in relict hedges with fences in the pastural landscape type (Barr et al,1991; 1993). Hedgerows used to function as stockproof boundaries and required constant maintenance for this purpose. With a decline in this practice hedge bottoms have become increasingly open so that fencing is undertaken to maintain stockproofing (eg. Webb, 1988). Since woody hedgerow species are mostly potential dominants, lack of management would favour their expansion. Increases in the abundance and vigour of potential dominants in and around many linear features is also likely to have resulted from ongoing improvement of adjacent grasslands between 1978 and 1990 (Potter and Lobley, 1996 and see below). Thus plant biomass accumulating in the undisturbed strip between hedge base and fence is more likely to comprise potentially dominant species than less competitive species.

For road verges, national historical management information is also scarce. However Way (1978) reported that during the 1950s and 60s many roadsides were sprayed with herbicide or cut more frequently than necessary with at least an estimated 50% of all verges in England and Wales receiving an annual full-width cut (Way, 1973, 1977). This gave way to a situation post -1975 and ongoing where 1m safety swathes next to the road are mown once a year or more to maintain visibility, whilst the remainder of the verge width may be cut very infrequently if at all. High levels of nitrogen deposition on road verges from passing traffic have also been linked to heightened productivity of competitive grasses such as *Lolium perenne* at the road edge (Spencer et al, 1988; Spencer and Port,1988). Although more precise management information is lacking it can be postulated that the net effect of these changes has been to increase fertility accross the verge whilst creating a steeper disturbance gradient with more disturbance at the road edge and accross the first metre and an abrupt switch to increasing neglect through the remainder of the verge width. Under such conditions increases in potential dominant cover might be expected further from the road edge whilst nearer to the carriageway more open conditions may be associated with the appearance of less competitive ruderals. In fact increases in cover of less competitive species on road verge plots outweighed decreases by a small margin (figure 4b) whilst increases in cover of potential dominants were also more common than decreases (figure 4a). Given that all associations on road verges were negative in sign some decreases in cover of potential dominants must have been accompanied by increases in cover of less competitive species, a response expected on many verges subject to more frequent safety swathe mowing at the road edge especially since propagules of ruderal species are efficiently dispersed by passing traffic (Schmidt, 1989; Hodkinson and Thompson, 1997).

Two negative associations were located within the moorland grass/mosaic vegetation type which includes a diverse range of upland pasture, flushes and streamside vegetation. It is possible that these results partly reflect increased sheep densities in much of upland Britain which have resulted in losses of heather moorland (Anderson and Yalden, 1981; Hudson, 1984). This trend is supported by other analyses of CS data which showed net shifts from the heath/bog vegetation type to moorland grass/mosaic between 1978 and 1990 (Bunce et al, 1997). Additional support for the impact of heightened grazing pressure in the British uplands rests on the detection of significant increases in cover of the less competitive species *Agrostis capillaris*, *Anthoxanthum odoratum* and *Galium saxatile* all of which have been shown to increase following reductions in heather by sheep (Welch and Scott, 1995; Welch,1984). However these species specific changes only occurred in heath/bog vegetation. In moorland grass/mosaic vegetation these species increased in some plots but declined in others in which potential dominants such as *Molinia caerulea, Calluna vulgaris, Juncus effusus, Eriophorum vaginatum* and *Pteridium aquilinum* increased. In moorland grass/mosaic plots in which vegetation change did not result in a shift to upland woodland or heath/bog between 1978 and 1990, the grazing indicators *Anthoxanthum odoratum, Holcus lanatus* and *Potentilla erecta* all increased significantly in cover (Bunce et al, 1997). Increased cover of *Pteridium aquilinum* was certainly implicated in reductions of less competitive species in 13% of moorland grass/mosaic plots analysed however the relative importance of different impacts on detected associations in moorland grass/mosaic vegetation remains uncertain.

Unimproved grasslands apart from extensively grazed upland pastures are grouped within the infertile grassland vegetation type in CS data. Reductions in the extent of unimproved grasslands since the middle of the century have been well documented (Green, 1990; Ratcliffe, 1984; Fuller, 1987; Hopkins and Hopkins, 1994) whilst between 1978 and 1990 the infertile grasslands saw overall species richness significantly reduced (Barr et al, 1993; Bunce et al, 1997). The negative associations between changing cover of potential dominants and less competitive species in the infertile grasslands of the marginal upland landscape type highlight the fact that species losses are correlated with from increases in potentially dominant species. In fact in all infertile grassland plots throughout Britain a negative association was detected at just above the 5% level (Fisher's exact 2-tailed $p = 0.057$, n = 327, Odds ratio = 1.5). These changes must partly reflect the effects of widespread grassland improvement prior to 1978 and ongoing to 1990. For example Hopkins (1988) indicated that the quantities of mineral nitrogen being applied to British grasslands had doubled between 1968 and 1988 whilst Potter and Lobley (1996) showed that application of fertilisers, stocking density and land drainage had all increased between 1978 and 1990 based upon a sample survey of land owners in CS 1km squares. All such impacts will have favoured potentially dominant species at the expense of less competitive species.

Factors influencing associations between species cover and species richness change

Detection of dependent responses between potential dominants and less competitive species maybe heavily influenced by the time elapsed between cover change and sampling in 1990. For example we have no way of knowing whether a disturbance impact occurred days or many months before sampling in 1990. If this interval was short then even subsequent recruitment of species from a persistent seed bank following disturbance might not replace richer pre-existing assemblages of less competitive species. To some extent our analysis was insensitive to this phenomenon since small or very large changes in abundance are reduced to a categorical variable, either change up or down.

The innate capacity of the vegetation to respond to changes in fertility and disturbance is also likely to differ between vegetation types. For example a lowland road verge in which competitive ruderals (potential dominant) and small annuals (less competitive species) are present is likely to respond more rapidly to changes in fertility and disturbance than an upland sward in which coexisting potential dominants and less competitive species may share stress-tolerant attributes such as slow relative growth rate limiting the capacity of the vegetation to respond rapidly to changing conditions (Hodgson et al, 1994). Clearly major perturbations such as ploughing and afforestation will have a common and large impact on both functional groups over time since rather than working through pre-existing assemblages they are more likely to obliterate field layer species irrespective of established strategy.

The likelihood of a joint response in cover of potential dominants and less competitive species is of course dependent on the presence of both groups in the vegetation in either 1978 or 1990. Crops/weed communities provide an extreme example where only 16% of the total number of plots in the vegetation type took part in the analysis. Most plots were excluded simply because of the absence of members of both groups in both years. In all other vegetation types around 80% of plots in each were analysed.

In conclusion it is apparent that changes in plant species diversity in the British countryside can be partly understood in terms of mutually antagonistic shifts in the abundance of the least and most competitive members of the flora.

The CSR typology offers a useful framework for summarising landscape scale responses accross vegetation that differs widely in species composition. That the model classifies established strategies of plants in relation to disturbance and fertility gradients means that responses can be linked through to land use changes whose likely effects can also be simply summarised in terms of changes in these conditions. The challenge for future repetition of CS and post-survey analysis is to more precisely partition vegetation change among the range of potential causes operating in different parts of the landscape.

Acknowledgements

This work was funded by the Department of the Environment, Transport and the Regions and the Ministry of Agriculture, Fisheries and Food. Our thanks go to

Andrew Scott for statistical advice and to Les Firbank, David Howard, Jennifer Duckworth and Mike Hornung for comments on earlier versions of the manuscript.

Figure 1. The distribution of three divisions in the CSR triangle after Grime (1985). PD = Potentially dominant species comprise competitive dominants, ruderal dominants and stress-tolerant dominants. LC = Less competitive species theoretically least able to coexist with PD species and adapted to disturbed or unproductive conditions.

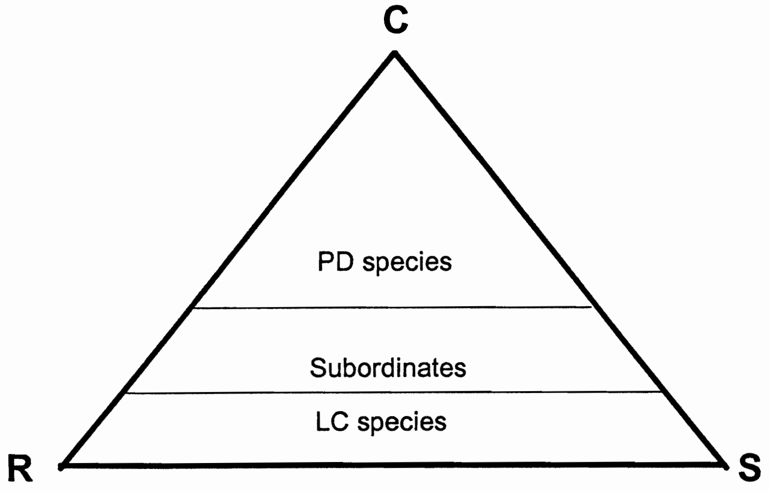


Table 1. Strategic composition of the functional groups used to define the response variables for the analysis.

Established strategy	Potential dominants	Less competitive species
R		✓
R/SR		✓
SR		✓
S/SR		✓
S		✓
R/CR		
R/CSR		✓
SR/CSR		✓
S/SC	✓	
S/CSR		✓
CR	✓	
CR/CSR		
SC	✓	
SC/CSR		
CSR		✓
C/CR	✓	
C/SC	✓	
C/CSR	✓	

C ✓

Table 2. Expected dependent relationships between changing abundance of two groups of plant species classified as extremes in the CSR model of Grime (1985).

		Cover of less-competitive species	
		UP	DOWN
Cover of potential dominants	UP	Possible where post-disturbance colonisation of bare ground occurrs	Expected as a result of increasing asymmetry of competitive effect
	DOWN	Expected but limited by availability of propagules from seedbank or local habitats	Possible response to impacts capable of removing all species eg. afforestation and cultivation

Table 3. Stratification of Countryside Survey botanical data.

a)

Plot type	Details
X	fields and unenclosed land (14 x 14m)
H	hedgerow (1m x 10m)
R	roadside verge (1m x 10m)
S	streamside (1m x 10m)

b)

Landscape type	Details
Arable (Ar)	Largely S and SE England; intensive agriculture, high proportion of arable.
Pastural (Pa)	Western British lowlands; less arable, mainly grassland management for sheep, dairy and beef production.
Marginal upland (Mu)	Much of Wales, the Pennines, Lake District and Scotland; extensive sheep grazing, grouse moor and forestry.
Upland (Up)	High montane, blanket bog and Scottish islands; Scotland and northern England.

c)

Vegetation type	Description
1	Crops and weeds; communities of cultivated and disturbed ground.
2	Tall grasslands; typical of road verges and infrequently disturbed patches of herbaceous vegetation.
3	Fertile grasslands; improved often intensively managed agricultural swards.
4	Infertile grasslands; unimproved wet or dry and basic to acidic graminaceous vegetation.
5	Lowland wooded; hedges, woodland and scrub in lowland Britain.
6	Upland wooded; upland semi-natural broadleaved woodland and scrub plus forestry plantation.
7	Moorland grass/mosaics; extensive graminaceous upland vegetation, usually grazed.
8	Heath/bog; ericaceous vegetation of wet or dry ground largely in uplands.

Table 4. Log-linear analysis of association between a) vegetation type, change in cover of potential dominants (PD) and less competitive species (LC), b) plot type, change in cover of PD and LC species. Percentage of the total partial association chi-square is shown. This conveys the unique contribution of the effect combination in the presence of all other effects. See table 3 for key to vegetation and plot types.

a)

Effect (n =)	**df**	**partial χ^2 (% of total)**	***p***
Vegetation type (1 to 8)	7	77	***
PD cover (up or down)	1	6	***
LC cover (up or down)	1	0.7	ns
Vegetation x PD cover	7	10	***
Vegetation x LC cover	7	2	ns
PD cover x LC cover	1	4	***

b)

Effect (n =)	**df**	**partial χ^2 (% of total)**	***p***
Plot type (H, R, S, X)	3	84	***
PD cover (up or down)	1	5	***
LC cover (up or down)	1	0.6	ns
Plot x PD cover	3	5	***
Plot x LC cover	3	0.8	ns
PD cover x LC cover	1	4	***

Table 5. Change in cover of potential dominants versus change in cover of less competitive species stratified by combinations of landscape type, vegetation type and plot type. Total number of tests = 57 therefore three times as many significant results at $0.01<p<0.05$ were detected than would be expected by chance. No significant results at $0.001<p<0.01$ would be expected by chance. See table 3 for key to stratification of CS data.

n	**Landscape**	**Vegetation type**	**Plot type**	***p***	**Direction**	**Odds ratio**
48		1		0.003	+	0.1
203		2		0.003	-	2.5
188		7		0.02	-	2.1
40		1	X	0.004	+	0.1
73		2	H	0.048	-	2.9
107		3	R	0.006	-	3.2
24		3	S	0.038	-	8.9
64		4	R	0.019	-	4.1
104		7	X	0.005	-	3.2
86	Mu	4		0.0008	-	5.3
90	Pa	2		0.0009	-	3.5
194			H	0.01	-	2.4
283			R	0.0001	-	2.6
296			S	0.034	-	1.7
118	Ar		R	0.033	-	2.2
75	Ar		S	0.031	-	3.1
37	Mu		R	0.017	-	6.7
126	Mu		X	0.004	-	3.1
90	Pa		H	0.03	-	3.2
231	Mu			0.0002	-	3.4

Figure 2. The relationship between changing cover of potential dominants and less-competitive species over all CS plots, Fisher's two-tailed $p<0.0001$, n = 1485, Odds ratio = 1.6.

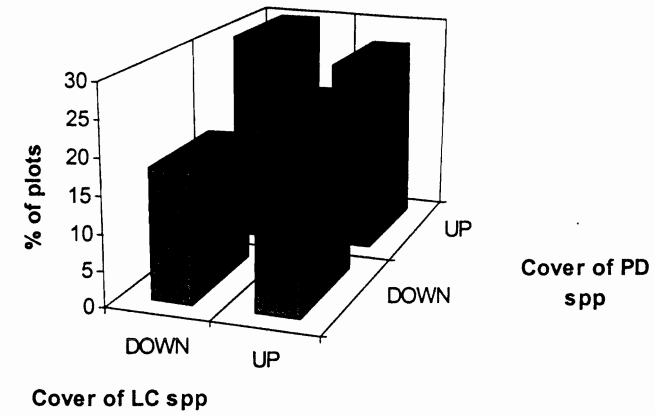


Figure 3 a. Change in PD cover by vegetation type.

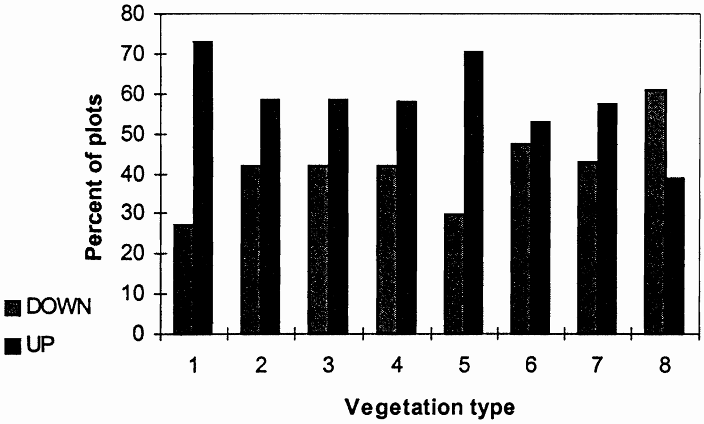


Figure 3 b. Change in LC cover by vegetation type.

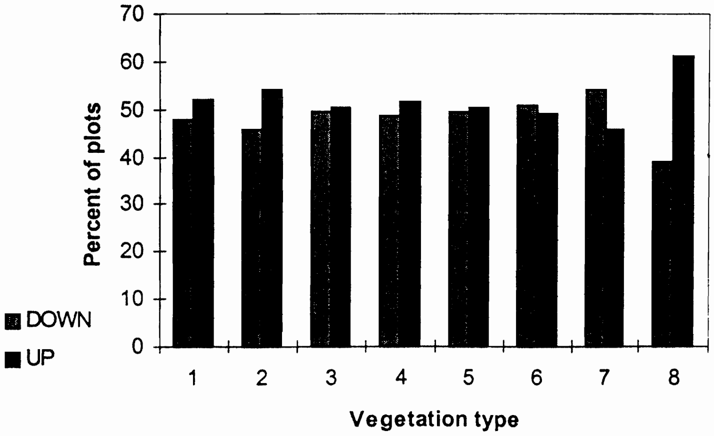


Figure 4 a. Change in PD cover by plot type.

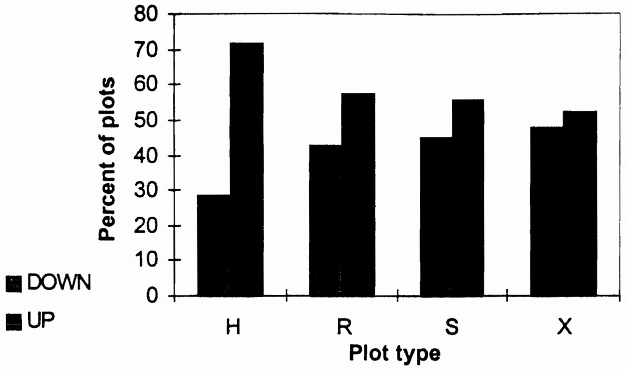
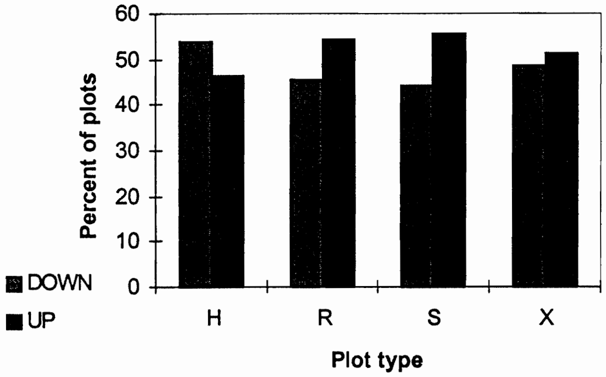


Figure 4 b. Change in LC cover by plot type.



References

Anderson, P., Yalden, D.W. 1981. Increased sheep numbers and the loss of heather moorland in the Peak District, England. Biol. Cons. 20, 195-213.

Barr, C.J., Bunce, R.G.H., Clarke, R.T., Fuller, R.M., Furse, M.T., Gillespie, M.K., Groom, G.B.,Hallam, C.J., Hornung, M., Howard, D.C. & Ness, M.J. 1993. *Countryside survey 1990. Main report.* Department of Environment: London.

Barr, C.J.B., Howard, D.C.H., Bunce, R.G.H., Gillespie, M.K.G., Hallam, C.J. 1991. Changes in hedgerows in Britain between 1984 and 1990. NERC contract report to the Department of the Environment: Institute of Terrestrial Ecology, Grange-over-Sands.

Bekker, R.M, Verweij, G.L., Smith, R.E.N., Reine, R., Bakker, J.P., Schneider, S. 1997. Soil seed banks in European grasslands: does land use affect regeneration perspectives ? J. Appl. Ecol. 34, 1293-1310.

Betton, C. 1991. Recent trends in NO_3-N concentration and loads in British rivers. In: Water quality in a changing environment; trends and an explanation. IAHS Publications no. 203 pp.169-180.

Bunce, R.G.H, Barr, C.J., Clarke, R.T., Howard, D.C.H. & Lane, A.M.J. 1996. Land classification for strategic ecological survey. *J. Env. Manage.* 47: 37-60.

Bunce, R.G.H., Smart, S.M., Van de Poll, H.M., Watkins, J.W., Scott, W.A. 1997. The botanical character of the British Countryside. A reoprt to the Department of the Environment, Transport and the Regions: ITE Merlewood, Grange-over-Sands.

Chatters, C. 1996. Conserving rare plants in muddy places. British Wildlife 7, 281 - 286.

Clapham, A.R., Tutin, T.G. & Moore, D.M. (1987). *Flora of the British Isles.* 3rd edn. Cambridge University Press, Cambridge.

Davy, A.J., Bishop, G.F. 1984. Response of *Hieracium pilosella* in Breckland grassheath to inorganic nutrients. J. Ecol. 72, 319-330.

Dawson, F.H., Haslam, S.M. 1981. The management of river vegetation with particular reference to shading effects of marginal vegetation. Landscape Planning 10, 147-169.

Dolman, P.M., Sutherland, W.J. 1992. The ecological changes of Breckland grass heaths and the consequences of management. J. Appl. Ecol. 29, 402-413.

Fleiss, J.L. 1981. Statistical Methods for Rates and Proportions. 2nd edn. John Wiley & Sons. New York pp. 61-63.

Fuller, R.M. 1987. The changing extent and conservation interest of lowland grasslands in England and Wales: a review of grassland surveys1930 - 1984. *Biol. Conserv.* 40: 281-300.

Gibson, C.W.D. & Brown, V.K. 1991. The effects of grazing on local colonosation and extinction during early succession. *J. Veg. Sci.* 2:291-302.

Green, B.H. 1990. Agricultural intensification and the loss of habitat, species and amenity in British grasslands: a review of historical change and assessment of future prospects. Grass and Forage Science 45, 365-372.

Grime, J.P. 1979. *Plant Strategies and Vegetation Processes*. Wiley and Sons: Chicester.

Grime, J.P., Hodgson, J.G., Hunt, R. & Thompson, K. 1995. *The Electronic Comparative Plant Ecology*. London. Chapman & Hall.

Grime, J.P. 1985. Dominant and subordinate components of plant communities: Implications for succession, stability and diversity. In: Gray, A., Edwards, P., Crawley, A. eds. Colonisation, succession and stability pp. 413-428. Blackwell: Oxford.

Hodgson, J.G. 1991. Mnagement for the conservation of plants with particular reference to the British flora. In: The Scientific Management of Temperate Communities for Conservation. eds. Spellerberg, I.F., Goldsmith, F.B., Morris, M.G. 31st Symposium of the British Ecological Society. Blackwell. Oxford pp 81-102.

Hodgson, J.G., Grime, J.P. 1988. The role of dispersal mechanisms, regenerative strategies and seedbanks in the vegetation dynamics of the British landscape. In: Bunce, R.G.H., Howard, D.C.H. eds. Species Dispersal in Agricultural Habitats. Belhaven Press pp. 65-81.

Hodgson, J.G., Colasanti, R., Phillipson, P., Leach, S., Montgomery, S., Hunt, R. 1994. A simple method for monitoring grassland vegetation. In: Haggar, R.J., Peel, S. (eds). Grassland Management and Nature Conservation. Occasional Symposium no. 28, British Grassland Society.

Hopkins, A. 1988. Distribution and management of grassland in the United Kingdom. In: Park, J.R. ed. Environmental Management in Agriculture: European Perspectives. Belhaven Press pp. 178-1185.

Hopkins, A. & Hopkins, J.J. 1994. UK Grasslands Now: Agricultural Production and Nature Conservation. In: Haggar, R.J & Peel, S. (eds). *Grassland Management and Nature Conservation,* pp. 10-19. Occasional Symposium No. 28, British Grassland Society.

Hopkins, A., Wainwright, J. 1989. Changes in botanical composition and agricultural management of enclosed grassland in upland areas of England and Wales, 1970-1986, some conservation implications. Biol. Cons. 47, 219-235.

Hudson, P.J. 1984. Some effects of sheep management on heather moorlands in northern England. In: Agriculture and the Environment. Ed. Jenkins, D. Institute of Terrestrial Ecology, Monkswood pp. 143-149.

Jefferson, R.G., Usher, M.B. 1989. Seed rain dynamics in disused chalk quarries in the Yorkshire Wolds, England, with special reference to nature conservation. Biol. Cons. 47, 123-36.

Keddy, P.A., Twolan-Strutt, L., Shipley, B. 1997. Experimental evidence that interspecific competitive asymmetry increases with soil productivity. Oikos 80, 253-256.

Krause, A. 1977. On the effect of marginal tree rows with respect to management of small lowland streams. Aquatic Botany 3, 185-192.

Mountford, J.O, Lakahni, K.H., Kirkham, F.W. 1993. Experimental assessment of the effects of nitrogen addition under hay-cutting and aftermath grazing on the vegetation of neadows on a Somerset peat moor. J. Appl. Ecol. 30, 321-332.

Mountford, J.O. (1994). Floristic change in English grazing marshes: the impact of 150 years of drainage and land-use change. Watsonia, 20, 3-24.

Oliver, J. 1995. Nettles IV. 28 miles (46 km) of stinging nettles. Botanical Society of the British Isles News. 68, 17.

Pakeman, R.J., Marrs, R.H. 1992. The conservation value of bracken *Pteridium aquilinum* (L.) Kuhn- dominated communities in the uk, and an assessment of the ecological impact of bracken expansion or its removal. Biol. Cons. 62, 101-114.

Pearce, F. 1994. "Giant nettles stalk polluted Britain". New Scientist, 29th October pg. 9.

Potter, C., Lobley, M. 1996. Processes of Countryside Change in Britain. Countryside Survey 1990 series, volume 7. HMSO: London.

Ratcliffe, D.A. 1984. Post-medieval and recent changes in British vegetation: the culmination of human influence. New Phytologist 98, 73-100.

Raven, P.J. 1986. Vegetation changes within the flood relief stage of two-stage channels excavated along a small rural clay river. J. Appl. Ecol. 23, 1001-1011.

Rich, T.C.G., Woodruff, E.R. 1996. Changes in the floras of England and Scotland between 1930-1960 and 1987-1988: The BSBI Monitoring Scheme. Biol. Cons. 75, 217-229.

SAS Institute Inc. 1990. SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 1, Cary, NC: SAS Institute Inc, pp. 851-889.

Silvertown, J., Dodd, M.E., McConway, K., Potts, J., Crawley, M. 1994. Rainfall, biomass variation and community composition in the Park Grass experiment. Ecology 75, 2430-2437.

Smith, R.S., Rushton, S.P. 1994. The effects of grazing management on the vegetation of meotrophic (meadow) grassland in Northern England. J. Appl. Ecol. 31, 13-24.

Spencer, H.J., Scott, N.E., Port, G.R., Davison, N.W. 1988. Effects of roadside conditions on plants and insects. I. Atmospheric conditions. J. Appl. Ecol. 25, 699-708.

Spencer, H.J., Port, G.R. 1988. Effects of roadside conditions on plants and insects. II. Soil conditions. J. Appl. Ecol. 25, 709-714.

StatSoft, Inc. (1997). STATISTICA for Windows. Computer program manual III pp. 3447-3478. Tulsa, OK.

Stockey, A., Hunt, R. 1994. Predicting secondary succession in wetland mesocosms on the basis of autecological information on seeds and seedlings. J. Appl. Ecol. 31, 543-559.

Tubbs, C.R. 1997. The ecology of pastoralism in the New Forest. British Wildlife 9, 7 - 16.

Van Strien, A.J., van der Linden, J., Melman, C.P., Noordervliet, M.A.W. 1989. Factors affecting the vegetation of ditch banks in peat areas in the Western Nertherlands. J. Appl. Ecol. 26, 989-1004.

Ward, L.K., Jennings, R.D. 1990. Succession at disturbed and undisturbed chalk grassland at Aston Rowant National Nature Reserve: dynamics of species changes. J. Appl. Ecol. 27, 897-912.

Way, J.M. 1973. Road verges on rural roads: management and other factors. Monkswood Experimental Station. Occasional Reports No. 1.

Way, J.M. 1977. Roadside verges and conservation in Britain: A review. Biol. Cons. 12, 65-74.

Way, J.M. 1978. Roadside verges and their management. In: Colwill, D.M., Thompson, J.R., Rutter, A.J. eds. The impact of road traffic on plants. Proceedings of a symposium organised by the British Ecological Society and the Transport and Road Research Laboratory. Supplementary report 513. Department of the Environment pp.41-44.

Webb, R. 1988. The status of hedgerow field margins in Ireland. In: Park, J.R. ed. Environmental Management in Agriculture: European Perspectives. Belhaven Press pp. 125-131.

Welch, D. 1984. Studies in the grazing of heather moorland in north-east Scotland. III. Floristics. J. Appl. Ecol. 21, 209-225.

Welch, D., Scott, D. 1995. Studies in the grazing of heather moorland in north-east Scotland. VI. 20-year trends in botanical composition. J. Appl. Ecol. 32, 596-611.

Willems, J.H., Peet, R.K., Bik, L. 1993. Changes in chalk grassland structure and species richness resulting from selective nutrient additions. J. Veg. Sci. 4, 203-212.

Functional Analysis of Countryside Survey Vegetation Data.

Tables 1 to 3 show the results of functional analyses carried out on Countryside Survey vegetation plot data split by ecotope group, landscape type and plot type, the data being split differently in each table. As well as results at the level of single plot types in single landscape types in each ecotope group, data for groupings of plots at higher levels are also included. This overcomes problems associated with the small samples of plots in certain groupings. It also validates some of the observed functional shifts seen at fine divisions by showing the same processes in higher aggregations of plots. This may strengthen evidence of a consistent functional shift in species characteristics.

Definition of the 3 Analyses.

Detecting changes in plots with similar vegetation and management.

Table 1 contains the results from an analysis using 1978 data from plots that were classified as belonging to the particular ecotope group in 1978 compared to 1990 data from plots that were classified as belonging to the same particular ecotope group in 1990. Thus, the exact plots in 1978 and 1990 may not be the same. This analysis will be referred to as 'simple' analysis.

Detecting subtle changes in plots whose vegetation remained superficially the same.

Table 2 contains the results from an analysis of data from only those individual plots that were classified as belonging to the same ecotope group in 1990 as in 1978. This analysis will be referred to as 'stay the same' analysis.

Following the divergent fate of plots from a common starting point.

Table 3 contains the results from an analysis of data, the plot data from both 1978 and 1990 grouped according to the ecotope group into which the plot was classified in 1978, irrespective of which ecotope group they belonged to in 1990. This analysis will be referred to as '1978-based' analysis.

Results

The figures in tables 1 to 3 are the numbers of significant correlations (significant at P=0.05 or less) between the proportional change in species abundance (based on the number of plots in which it occurred) and the values of various traits for the species. The numbers in bold indicate those situations where the set of correlations suggests a consistent process of change affecting the group of plots between the 2 dates. Other values represent sets of correlations of uncertain ecological significance.

The magnitude of the number of correlations cannot be taken as an indicator of processes of change within the plots. The traits include those derived from plant species distributions (based on surveys of vegetation in Central England), through traits of plant morphology derived from floras (e.g. plant height) to reliable, traits predictive of species' ecology (e.g. leaf mineral nutrient contents relate to the nutrient status of the species' preferred habitats). Thus, a large number of correlations with the less reliable distribution data may be less indicative of change than a smaller number of correlations with hard, predictive traits. Furthermore, in situations where processes of change have affected the plots in more than one direction, a confused set of significant correlations may give an apparently self-contradictory picture. The bold figures are thus based on interpretation of the raw correlation data. brief commentary is also provided.

Discussion and Interpretation of Results.

'Simple' Analysis.

Crops ecotope group. Viable groups of plots occur in only 2 landscapes and significant changes are seen only in the arable landscape. The changes indicate increases in disturbance in linear as well as main plots. The consistent increases in species' seed weight and plant canopy height are associated with large-seeded ruderals that germinate in the autumn. The change is thought to be linked to a change from spring to autumn sown crops. No such changes occurred in the pastural landscape.

Tall grassland again only shows change in the arable landscape. When all landscape types are analysed together, these changes are masked by the lack of change or contradictory changes in other landscape types. Changes in both road verges and hedges in the arable landscape are quite strongly indicative of dereliction as both plot types become less ruderal and more dominated by competitive species or species with extensive canopies that undergo an extended period of growth before flowering. This pattern is not seen in streamside plots.

Eutrophic grassland shows very little in the way of consistent change. The ecotope group name suggests that this vegetation is already at the intensively managed end of the productivity gradient within vegetation and therefore unlikely to be further changed. The only change is seen in the marginal uplands where intensification may be less advanced, however the correlations are not strongly indicative of any particular process.

Lowland grassland shows many significant changes, particularly in streamside and main plots. The data also provide a good example of the efficacy of using a wide variety of plant traits. In several cases subsets of the data indicate the same changes as higher groupings but via significant changes in different variables; the 'belt and braces' philosophy of using a variety of 'soft' predictive traits. The changes observed also differ between landscape types.

Results from arable landscape streamside, main plots and all plots indicate increases in disturbance as they all show increases in species richness and in species of disturbed habitats at the expense of species of more closed habitats. Smaller seeded species also seem to be increasing.

In the marginal upland landscape the changes to streamside and main plots seem to be in the direction of eutrophication. Both groupings show correlations that may indicate this process but via different sets of traits. The process is masked at the whole landscape level by many hedgerow and road verge plots that do not show the same changes.

The pastural landscape shows different processes of change, both streamside and road verge plots having correlations that suggest processes of dereliction or eutrophication. The results for the whole landscape type strongly suggest the process of eutrophication. This is a very abundant and widespread ecotope group in the pastural landscape and changes may be going on in more than one direction within the groups, particularly the main plots. However, eutrophication throughout the landscape type is strongly indicated.

Not surprisingly, no indication of processes of change is obvious at the all landscape types level due to the variety of processes identified in individual landscapes.

Lowland woods and hedges. Here again change is suggested in the arable landscape and not in the pastural landscape. The correlations for the arable landscape suggest that eutrophication may be occurring, a process indicated for the whole ecotope group throughout all landscape types.

Acid woods is a relatively limited type but still shows processes of change affecting vegetation between 1978 and 1990. Change is seen in the upland landscape where two reliable correlations indicate increases in species of nutrient rich habitats. When all upland plots are analysed the suggestion of eutrophication is much greater. Large, competitive species of nutrient rich habitats are increasing at the expense of stress tolerant species of species rich habitats. There is also an indication of dereliction, a process indicated for all the streamside plots of this ecotope group.

Upland grassland shows little evidence of change between 1978 and 1990.

Bogs and heaths again showed no overwhelming indications of change in the functional make-up of the vegetation. The large number of correlations in the marginal upland landscape are largely distribution related traits of little indicative value in this case.

Summary.

'Simple' analysis. *Detecting changes in plots with similar vegetation and management.*

Changed disturbance in **crops** group in arable landscape.

Dereliction of road verges and hedgerows in **tall grassland** in arable landscape.

Increased disturbance in **lowland grassland** in arable landscape.

Eutrophication of streamside and main plots in **lowland grassland** in marginal uplands.

Eutrophication of **lowland grassland** in pastural landscape.

Eutrophication of **lowland woods and hedges** especially in arable landscape.

Eutrophication of **acid woods** in the upland landscape.

'Stay the same' analysis

This analysis includes fewer plots than either of the other 2 analyses and so some of the plot groupings have been excluded, as they contain too few plots to give a meaningful indication of change. Such groupings are indicated with a '-' in table 2.

This analysis is able to detect the most subtle shifts in functional composition over the time period.

Crops ecotope group again shows changes in the arable landscape but not in the pastural landscape. Changes suggest an increased disturbance regime, favouring large seeded, tall species adapted to frequent disturbance. The same change is indicated when all crop plots are looked at together, demonstrating the overwhelming effect of the large number of arable landscape plots over the pastural landscape plots.

Tall grassland shows very little evidence of change in this analysis. The 4 correlations for arable landscape hedge plots did not provide any evidence of a consistent process of change. The results for all arable plots suggested that eutrophication may be occurring, with very reliable traits positively correlated. It could be that the changes detected in the 'simple' analysis were largely the result of shifts in the plots that altered enough to change ecotope group between 1978 and 1990. In the 'simple' analysis over 40% of the 1978 plots were classified differently in 1990 and 55% of the 1990 plots came from different ecotope groups in 1978. This could be an example of the change detected in the first analysis being largely due to change in a limited part of the landscape.

Eutrophic grassland again shows very little change other than in the arable landscape main plots. Here the correlations give quite strong evidence of eutrophication occurring. This may have been masked in the previous analysis by plots that changed between ecotope groups between 1978 ans 1990. The 1990 group contained over 40% of plots from several other 1978 ecotope groups making consistent shifts difficult to detect given the variety of starting points.

Lowland grassland shows changes occurring in road verges in the pastural and marginal upland landscapes, to streamsides in the pastural landscape, and also when all of these plot types are analysed for all landscape types.

All of the groupings show consistent increases in large, long-lived species able to dominate the vegetation indicating eutrophication or dereliction or both. The characteristics of decreasing species do not help to decide between these possibilities, giving evidence of both. It is likely that both are occurring. These changes are in accordance with findings of the 'simple' analysis. Here the results from smaller plot groupings all indicate the same processes, a conclusion strengthened by detection of the same process at higher level groupings of the plots.

Lowland woods and hedges. Relatively few plots were available for analysis in the individual landscape types, however both arable and pastural landscapes showed increases of large, competitive species. The results for all plot types in both landscapes tend further to indicate eutrophication. Stress tolerant species from species rich habitats are shown to be decreasing at the expense of the previously mentioned species. This result is further backed up by the results of analysis of all ecotope group 5 plots. These correlations strongly suggest eutrophication in these plots.

Acid woods showed no evidence of functional shifts between 1978 and 1990. Comparing this with the results of the 'simple' analysis, it may be that the very distinct shifts seen there were due to changes in those plots that changed enough to shift to another ecotope groups by 1990, other plots staying quite constant.

Upland grassland shows very little functional changes. Large numbers of correlations in the marginal uplands and higher level groups are collections of distribution related traits not indicative of any consistent process of change.

Bogs and heaths. No change.

Summary.

'Stay the same' analysis. *Detecting subtle changes in plots whose vegetation remained superficially the same.*

Increased disturbance to **crops** group especially in the arable landscape.

Possible eutrophication of **tall grassland** in arable landscape.

Eutrophication of **eutrophic grassland** main plots in arable landscape.

Eutrophication and/or dereliction in **lowland grassland** road verges and streamsides.

Eutrophication of **lowland woods and hedges** in the pastural landscape.

'78-Based' Analysis

This analysis follows the fate of plots, many of which may have changed ecotope groups between 1978 and 1990 i.e. plots that have been subject to fairly extreme changes in management. The matrices of change for plots in different landscape types can therefore act as a verification for some of the conclusions reached in the functional analyses.

Crops show quite distinct patterns of change across landscape types. Changes in many groups all point to the same conclusion. In arable and pastural landscapes species of arable habitats with long-lived seed banks are decreasing at the expense of longer-lived, larger species characteristic of various grassland and derelict habitats. This suggests dereliction and is in accordance with the change of 30% of crop plots to various grassland types.

Tall grassland shows more changes. Hedgerow plots show fairly consistent indications of change across landscape types and when taken as a whole. Ruderal species of arable and regularly managed habitats are giving way to large-seeded, large competitive species characteristic of shady and wooded habitats. This indicates dereliction of these plots. Many plots accordingly moved into the lowland woods and hedges ecotope group over the survey period. As matrices of change are not available for individual plot types, this cannot be reliably verified. In other plot types, no changes were detected.

Eutrophic grassland shows hints of the same processes occurring in road verges in both the arable and pastural landscapes and in arable streamside plots, and also in all pastural plot types together. All these groups show an increase in large, long-lived, competitive species at the expense of ruderal species i.e. dereliction. The lack of more definitive indications of processes of change may be due to the variety of directions in which plots moved between 1978 and 1990. In both arable and pastural landscapes huge numbers of plots moved from eutrophic grassland to other grassland ecotope groups and also to the crops group. These changes are very different functionally, and would give a very confused picture.

The dereliction may be due to the 21% shift of plots from eutrophic grassland to tall grassland.

Lowland grassland shows fairly consistent indications of dereliction and in some cases eutrophication across the pastural landscape and throughout road verge plots, these trends also show up in higher summary groups of plots.

Throughout road verges the trend is towards large, long-lived competitive species at the expense of smaller, short-lived species i.e. dereliction. There is also a hint in the less intensive marginal upland landscape of eutrophication accompanying dereliction, as stress tolerant species of species rich habitats are also decreasing.

Dereliction is suggested in pastural streamsides and all streamsides together giving a suggestion of dereliction of lowland grassland throughout the pastural landscape.

As a whole, the ecotope group shows signs of eutrophication and dereliction which could be linked to the large shifts of lowland grassland plots to tall grassland and eutrophic grasslands (more derelict and eutrophic types) as well as to woodland types.

Lowland woods and hedges show changes in both arable and pastural landscapes and in the ecotope group throughout all landscape types. For the 2 landscape groups, the sets of correlations are fairly consistent and show changes occurring as woodland species and species of shady habitats are lost to be replaced by species of more managed habitats. Several correlations with the 'hard' nutrient concentrations traits suggest increases in species of more nutrient rich habitats i.e. eutrophication. This is in agreement with observed shifts of over 25% of plots from group 5 to the more intensively managed tall grassland group between 1978 and 1990.

Acid woods show little change. Numbers of plots in individual landscapes are quite low and as a whole, plots moved from group 6 to the less intensive group 7 and to the more intensively managed lowland grassland and woodland groups, giving little net consistent shift.

The only evidence for a consistent process of change is in streamside plots where loss of stress tolerant species of woodland and shady places is at the expense of short-lived species of more managed habitats suggesting at least increases in disturbance of these plots.

Upland grassland shows no overwhelming evidence of change. The correlations are rather a mixture, possibly in accordance with the mixture of shifts in plots between 1978 and 1990. Plots moved to bogs/heaths, woodland and grassland groups.

Bogs / heaths show a mixture of correlations within each grouping of plots that as a group would be rather inconclusive. However, the pattern of correlations is very consistent across all groupings so some interpretation is possible. All show losses of large-seeded stress tolerant species at the expense of ruderal species of arable and regularly cut habitats with high SLAs. This very consistent shift would be consistent with eutrophication and increased disturbance (more intense management) and may coincide with shifts to upland grassland.

Summary.

'78-based' analysis. *Following the divergent fate of plots from a common starting point.*

Dereliction of **crops** group in arable and pastural landscapes.

Dereliction of **tall grassland** hedgerows in lowland landscape types.

Dereliction of **eutrophic grassland** in the pastural landscape and in road verges.

Dereliction of **eutrophic grassland** streamside plots in the arable landscape.

Dereliction of **lowland grassland** in the pastural landscape and in hedgerows and streamsides.

Eutrophication and increased disturbance in **lowland woods and hedges**.

Increased disturbance in **acid woodland** streamside plots.

Eutrophication and increased disturbance in **bogs and heaths**.

Table 1. Simple analysis.
Functional changes in ecotope groups between 1978 and 1990. Data for each year grouped according to the ecotope group in which the plot was classified in that year. Eu - correlations between species proportional changes and values of species traits consistently indicate eutrophication in those vegetation plots. De - the correlations consistently indicate dereliction of the vegetation in the plots. Di - correlations consistently indicate increased disturbance to the vegetation in those plots. np - correlations indicate no consistent process of change occurring in the vegetation detectable in the species traits used. Asterisks indicate plot groupings that do not occur or contain too few plots.

		Plot type				
Landscape type	Ecotope group	Hedges	Road verges	Streamsides	Main plots	All plots
Arable	Crops (1)	*	*	*	**Di**	**Di**
	Tall grassland (2)	**De**	**De**	np	*	np
	Eutrophic g'land (3)	*	np	np	np	np
	Lowland g'land (4)	*	*	**Di**	**Di**	**Di**
	Lowland wds/hdgs (5)	**Eu**	*	**Eu**	*	**Eu**
	Acid woods (6)	*	*	*	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Marginal upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	np	*	*	*	*
	Eutrophic g'land (3)	*	np	*	np	np
	Lowland g'land (4)	np	np	**Eu**	**Eu**	np
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	np	*	np
	Upland g'land (7)	*	*	np	np	np
	Bogs/heaths (8)	*	*	np	np	np
Pastural	Crops (1)	*	*	*	np	np
	Tall grassland (2)	np	np	np	*	np
	Eutrophic g'land (3)	*	np	np	np	np
	Lowland g'land (4)	np	**De/Eu**	**De/Eu**	np	**Eu**
	Lowland wds/hdgs (5)	np	*	np	*	np
	Acid woods (6)	*	*	np	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	*	*	*	*	*
	Eutrophic g'land (3)	*	*	*	*	*
	Lowland g'land (4)	*	*	*	*	*
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	*	**Eu**	**De/Eu**
	Upland g'land (7)	*	*	np	np	np
	Bogs/heaths (8)	*	*	np	np	np

All landscape types	Plot Type				
Ecotope Group	Hedges	Road verges	Streamsides	Main plots	All plots
Crops (1)	*	*	*	np	np
Tall grassland (2)	np	np	np	*	np
Eutrophic g'land (3)	*	np	*	np	np
Lowland g'land (4)	np	np	np	np	np
Lowland wds/hdgs (5)	**Eu**	*	*	*	**Eu**
Acid woods (6)	*	*	np	*	**De**
Upland g'land (7)	*	*	np	np	np
Bogs/heaths (8)	*	*	*	np	np

Table 2. Staysame analysis.
Functional changes in ecotope groups between 1978 and 1990. Data from plots that were classified as belonging to the same ecotope group in 1978 and 1990. Eu - correlations between species proportional changes and values of species traits consistently indicate eutrophication in those vegetation plots. De - the correlations consistently indicate dereliction of the vegetation in the plots. Di - correlations consistently indicate increased disturbance to the vegetation in those plots. np - correlations indicate no consistent process of change occurring in the vegetation detectable in the species traits used. Asterisks indicate plot groupings that do not occur or contain too few plots. Hyphens are plot groupings that contain too few plots for this particular analysis.

		Plot type				
Landscape type	Ecotope group	Hedges	Road verges	Streamsides	Main plots	All plots
Arable	Crops (1)	*	*	*	**Di**	**Di**
	Tall grassland (2)	np	np	np	*	**Eu**
	Eutrophic g'land (3)	*	np	-	**Eu**	**Eu**
	Lowland g'land (4)	*	*	np	np	np
	Lowland wds/hdgs (5)	**Eu**	*	-	*	**Eu/De**
	Acid woods (6)	*	*	*	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Marginal upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	-	*	*	*	*
	Eutrophic g'land (3)	*	-	*	-	np
	Lowland g'land (4)	-	**De/Eu**	-	np	np
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	np	*	np
	Upland g'land (7)	*	*	np	np	np
	Bogs/heaths (8)	*	*	-	np	np
Pastural	Crops (1)	*	*	*	np	np
	Tall grassland (2)	np	np	-	*	np
	Eutrophic g'land (3)	*	np	-	np	-
	Lowland g'land (4)	-	**De/Eu**	**De/Eu**	np	np
	Lowland wds/hdgs (5)	np	*	-	*	**Eu**
	Acid woods (6)	*	*	np	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	*	*	*	*	*
	Eutrophic g'land (3)	*	*	*	*	*
	Lowland g'land (4)	*	*	*	*	*
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	*	np	np
	Upland g'land (7)	*	*	np	np	np
	Bogs/heaths (8)	*	*	np	np	np

All landscape types	Plot Type				
Ecotope Group	Hedges	Road verges	Streamsides	Main plots	All plots
Crops (1)	*	*	*	np	**Di**
Tall grassland (2)	np	np	np	*	np
Eutrophic g'land (3)	*	np	*	np	np
Lowland g'land (4)	np	**De/Eu**	**De/Eu**	np	np
Lowland wds/hdgs (5)	np	*	*	*	**Eu**
Acid woods (6)	*	*	np	*	np
Upland g'land (7)	*	*	np	np	np
Bogs/heaths (8)	*	*	*	np	np

Table 3. 78 based analysis.
Functional changes in ecotope groups between 1978 and 1990. Data for each year grouped according to the ecotope group in which the plot was classified in 1978. Eu - correlations between species proportional changes and values of species traits consistently indicate eutrophication in those vegetation plots. De - the correlations consistently indicate dereliction of the vegetation in the plots. Di - correlations consistently indicate increased disturbance to the vegetation in those plots. np - correlations indicate no consistent process of change occurring in the vegetation detectable in the species traits used. Asterisks indicate plot groupings that do not occur or contain too few plots.

		Plot type				
Landscape type	Ecotope group	Hedges	Road verges	Streamsides	Main plots	All plots
Arable	Crops (1)	*	*	*	np	**De**
	Tall grassland (2)	**De**	np	np	*	np
	Eutrophic g'land (3)	*	**De**	**De**	np	np
	Lowland g'land (4)	*	*	np	**De**	np
	Lowland wds/hdgs (5)	**Eu**	*	np	*	**Eu**
	Acid woods (6)	*	*	*	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Marginal upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	np	*	*	*	*
	Eutrophic g'land (3)	*	np	*	np	np
	Lowland g'land (4)	np	**De/Eu**	np	np	np
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	np	*	np
	Upland g'land (7)	*	*	np	np	np
	Bogs/heaths (8)	*	*	np	np	np
Pastural	Crops (1)	*	*	*	**De**	**De**
	Tall grassland (2)	**De**	np	np	*	np
	Eutrophic g'land (3)	*	**De**	np	np	**De**
	Lowland g'land (4)	np	**De**	**De**	np	**De**
	Lowland wds/hdgs (5)	np	*	np	*	**Eu**
	Acid woods (6)	*	*	np	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	*	*	*	*	*
	Eutrophic g'land (3)	*	*	*	*	*
	Lowland g'land (4)	*	*	*	*	*
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	*	np	np
	Upland g'land (7)	*	*	np	np	np
	Bogs/heaths (8)	*	*	**Eu/Di**	np	**Eu/Di**

All landscape types	Plot Type				
Ecotope Group	Hedges	Road verges	Streamsides	Main plots	All plots
Crops (1)	*	*	*	**De**	**De**
Tall grassland (2)	**De**	np	np	*	np
Eutrophic g'land (3)	*	np	*	np	np
Lowland g'land (4)	np	**De**	**De**	np	**De**
Lowland wds/hdgs (5)	np	*	*	*	**Eu**
Acid woods (6)	*	*	**Di**	*	np
Upland g'land (7)	*	*	np	np	np
Bogs/heaths (8)	*	*	*	**Eu/Di**	**Eu/Di**
Grand Total					

Table 1. Simple analysis.
Functional changes in ecotope groups between 1978 and 1990.
Data for each year grouped according to the ecotope group in which the plot was classified in that year.
Figures are number of significant correlations (P=0.05) between species proportional change and values of species traits. Figures in bold are correlations that indicate consistent functional changes to the vegetation.
Figures in parentheses indicate correlations of uncertain ecological meaning. Asterisks indicate plot groupings that do not occur or contain too few plots.

		Plot type				
Landscape type	Ecotope group	Hedges	Road verges	Streamsides	Main plots	All plots
Arable	Crops (1)	*	*	*	**2**	**4**
	Tall grassland (2)	**8**	**5**	(2)	*	(4)
	Eutrophic g'land (3)	*	(0)	(1)	(0)	(0)
	Lowland g'land (4)	*	*	**4**	**8**	**6**
	Lowland wds/hdgs (5)	**2**	*	**4**	*	**4**
	Acid woods (6)	*	*	*	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Marginal upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	(1)	*	*	*	*
	Eutrophic g'land (3)	*	(4)	*	(4)	(5)
	Lowland g'land (4)	(4)	(2)	**5**	**4**	(5)
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	(2)	*	(0)
	Upland g'land (7)	*	*	(2)	(3)	(1)
	Bogs/heaths (8)	*	*	(6)	(1)	(0)
Pastural	Crops (1)	*	*	*	(1)	(1)
	Tall grassland (2)	(1)	(2)	(2)	*	(0)
	Eutrophic g'land (3)	*	(1)	(1)	(1)	(3)
	Lowland g'land (4)	(2)	**6**	**3**	(3)	**7**
	Lowland wds/hdgs (5)	(1)	*	(4)	*	(1)
	Acid woods (6)	*	*	(4)	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	*	*	*	*	*
	Eutrophic g'land (3)	*	*	*	*	*
	Lowland g'land (4)	*	*	*	*	*
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	*	**3**	**10**
	Upland g'land (7)	*	*	(1)	(4)	(4)
	Bogs/heaths (8)	*	*	(1)	(3)	(3)

All landscape types	Plot Type				
Ecotope Group	Hedges	Road verges	Streamsides	Main plots	All plots
Crops (1)	*	*	*	(2)	(2)
Tall grassland (2)	(7)	(3)	(4)	*	(2)
Eutrophic g'land (3)	*	(0)	*	(3)	(1)
Lowland g'land (4)	(3)	(6)	(4)	(6)	**8**
Lowland wds/hdgs (5)	**2**	*	*	*	**4**
Acid woods (6)	*	*	(7)	*	**11**
Upland g'land (7)	*	*	(0)	(4)	(6)
Bogs/heaths (8)	*	*	*	(5)	(3)

Table 2. Staysame analysis.
Functional changes in ecotope groups between 1978 and 1990.
Data from plots that were classified as belonging to the same ecotope group in 1978 and 1990.
Figures are number of significant correlations (P=0.05) between species proportional change and values of species traits. Figures in bold are correlations that indicate consistent functional changes to the vegetation. Figures in parentheses indicate correlations of uncertain ecological meaning. Asterisks indicate plot groupings that do not occur or contain too few plots. Hyphens are plot groupings that contain too few plots for this particular analysis.

		Plot type				
Landscape type	Ecotope group	Hedges	Road verges	Streamsides	Main plots	All plots
Arable	Crops (1)	*	*	*	**8**	**8**
	Tall grassland (2)	(4)	(0)	(0)	*	**4**
	Eutrophic g'land (3)	*	(1)	-	**8**	**4**
	Lowland g'land (4)	*	*	(1)	(0)	(1)
	Lowland wds/hdgs (5)	**3**	*	-	*	**3**
	Acid woods (6)	*	*	*	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Marginal upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	-	*	*	*	*
	Eutrophic g'land (3)	*	-	*	-	(2)
	Lowland g'land (4)	-	**4**	-	(4)	(0)
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	(1)	*	(3)
	Upland g'land (7)	*	*	(1)	(5)	(5)
	Bogs/heaths (8)	*	*	-	(0)	(1)
Pastural	Crops (1)	*	*	*	(0)	(0)
	Tall grassland (2)	(2)	(2)	-	*	(2)
	Eutrophic g'land (3)	*	(0)	-	(0)	-
	Lowland g'land (4)	-	**7**	**7**	(0)	(2)
	Lowland wds/hdgs (5)	(1)	*	-	*	**4**
	Acid woods (6)	*	*	(1)	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	*	*	*	*	*
	Eutrophic g'land (3)	*	*	*	*	*
	Lowland g'land (4)	*	*	*	*	*
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	*	(0)	(0)
	Upland g'land (7)	*	*	(2)	(0)	(1)
	Bogs/heaths (8)	*	*	(6)	(2)	(2)

All landscape types	Plot Type				
Ecotope Group	Hedges	Road verges	Streamsides	Main plots	All plots
Crops (1)	*	*	*	(2)	**5**
Tall grassland (2)	(2)	(2)	(1)	*	(1)
Eutrophic g'land (3)	*	(4)	*	(2)	(2)
Lowland g'land (4)	(3)	**5**	**4**	(0)	(2)
Lowland wds/hdgs (5)	(4)	*	*	*	**6**
Acid woods (6)	*	*	(1)	*	(2)
Upland g'land (7)	*	*	(1)	(5)	(6)
Bogs/heaths (8)	*	*	*	(2)	(2)

Table 3. 78 based analysis.

Functional changes in ecotope groups between 1978 and 1990.
Data for each year grouped according to the ecotope group in which the plot was classified in 1978.
Figures are number of significant correlations (P=0.05) between species proportional change and values of species traits. Figures in bold are correlations that indicate consistent functional changes to the vegetation.
Figures in parentheses indicate correlations of uncertain ecological meaning. Asterisks indicate plot groupings that do not occur or contain too few plots.

		Plot type				
Landscape type	Ecotope group	Hedges	Road verges	Streamsides	Main plots	All plots
Arable	Crops (1)	*	*	*	(3)	**8**
	Tall grassland (2)	**8**	(4)	(4)	*	(4)
	Eutrophic g'land (3)	*	**7**	**2**	(3)	(4)
	Lowland g'land (4)	*	*	(0)	**5**	(6)
	Lowland wds/hdgs (5)	**2**	*	(0)	*	**6**
	Acid woods (6)	*	*	*	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Marginal upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	(0)	*	*	*	*
	Eutrophic g'land (3)	*	(3)	*	(0)	(4)
	Lowland g'land (4)	(1)	**12**	(4)	(1)	(5)
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	(0)	*	(5)
	Upland g'land (7)	*	*	(2)	(1)	(2)
	Bogs/heaths (8)	*	*	(2)	(1)	(0)
Pastural	Crops (1)	*	*	*	**8**	**9**
	Tall grassland (2)	**7**	(2)	(0)	*	(0)
	Eutrophic g'land (3)	*	**4**	(2)	(1)	**6**
	Lowland g'land (4)	(3)	**6**	**10**	(3)	**12**
	Lowland wds/hdgs (5)	(1)	*	(4)	*	**10**
	Acid woods (6)	*	*	(5)	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	*	*	*	*	*
	Eutrophic g'land (3)	*	*	*	*	*
	Lowland g'land (4)	*	*	*	*	*
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	*	(3)	(6)
	Upland g'land (7)	*	*	(6)	(3)	(2)
	Bogs/heaths (8)	*	*	**5**	(3)	**8**

All landscape types	Plot Type				
Ecotope Group	Hedges	Road verges	Streamsides	Main plots	All plots
Crops (1)	*	*	*	**10**	**12**
Tall grassland (2)	**9**	(6)	(4)	*	(3)
Eutrophic g'land (3)	*	(5)	*	(1)	(4)
Lowland g'land (4)	(4)	**12**	**10**	(2)	**11**
Lowland wds/hdgs (5)	(1)	*	*	*	**11**
Acid woods (6)	*	*	**9**	*	(5)
Upland g'land (7)	*	*	(3)	(2)	(5)
Bogs/heaths (8)	*	*	*	**6**	**8**
Grand Total					