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ECOLOGICAL FACTORS CONTROLLING BIODIVERSITY IN THE BRITISH COUNTRYSIDE (ECOFACT)

MODULE 6A - Understanding the Cause of Changes in Biodiversity in Linear Features and Upland Vegetation

Interim Report

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1. INTRODUCTION

1. INTRODUCTION

1.1 Although the majority of the studies in progress have not been completed the project is on schedule. Further field work is involved in several of the studies and will be discussed at the Technical Sub-Group Meeting 16 April 1997. Accordingly, the present document is a presentation of the current state of the various studies involved.

1.2 The principle change in emphasis from the initial project design has been that the Ecological Indicator Values for species (Ellenberg scores) have superceded the suggested approach of extracting information from individual previous studies, such as the Park Grass experiment. The results presented here demonstrate that these values, originally produced by Professor Ellenberg in central Europe, but now modified for British vegetation in this project, define the major determining factors which control British vegetation. The strength of the correlations are such that the understanding of vegetation change is greatly facilitated. There is inevitably a considerable degree of overlap between the results of Modules 1 and 2 and those reported in this document. The separation has been made according to the discussions held during the Technical Sub-Group Meetings for Modules 1 and 2. Nevertheless, to make the necessary point that the Indicator Values were derived under Module 6, their derivation is included in the present document.

2. ECOLOGICAL INDICATOR VALUES OF BRITISH SPECIES: AN APPLICATION OF GAUSSIAN LOGISTIC REGRESSION

This paper describes the derivation of the Indicator Values.

Ecological indicator values of British species: an application of Gaussian logistic regression

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Abstract. In a large ecological survey of Britain, 13841 quadrats were sampled in 508 1-km squares. The quadrats included 1132 species of vascular plants, of which 643 occurred in 10 or more quadrats. Applying the method of Ter Braak & Gremmen (1987) to data from this survey, ecological optima and tolerances of species were estimated for Ellenberg's seven ecological indicator variables. Although a few species lacked optima for some variables, most optima were within the range of the original scales. Optima showed a strong positive relation to original values, but the resulting scale was compressed. Tolerances showed very little relation to the original scales. Because the scale of the optima is compressed relative to the original scale, the method is not directly suitable for repredicting indicator values for a new geographical region.

Keywords: Ecological survey; Ellenberg value; Environmental calibration; Optimum; Reprediction; Response function; Tolerance; Weighted average; Zeigerwerte

Introduction

Ellenberg's indicator values have been widely used to summarize the habitat preferences of vascular plants in Central Europe (Ellenberg 1988; Roo-Zielinska & Solon 1988; Thimonier *et al.* 1994; Wittig & Durwen 1982). These indicator values, sometimes known by their German name 'Zeigerwerte', allow each species to be placed on a scale according to its response to certain climatic and edaphic factors in the field. Ellenberg values define the realized niche of plants, not their fundamental niche (Thompson *et al.* 1993). They have been widely used in Germany (Ellenberg *et al.* 1991) and the Netherlands (Melman *et al.* 1988; Van der Maarel *et al.* 1985).

In Britain, indicator values have been less widely used, but can undoubtedly be useful in some contexts (Hill & Carey 1997; Sparks *et al.* 1996). A major attraction of them is that they can be used to monitor change in the countryside, particular when data from large repeated surveys are available (Thimonier *et al.* 1994). Doubts about the value of Ellenberg values outside Central Europe may have prevented them from being used more. They must inevitably become less reliable as one moves away from the region for which they were developed (Van der Maarel 1993). Not only will new species be represented (rather a small number of such in Britain), but species' preferences will change.

Thompson *et al.* (1993) have suggested that the ecological optima of species are dependent on the presence or absence of potential competitors, which change with geographic location. The ecological amplitude of species may also be narrower at the edge of their range; for example, *Hedera helix*, widespread and often growing as a liane in Britain, becomes restricted to the ground in parts of Europe with colder winters (Iversen 1944).

Ellenberg *et al.* (1991) recommended testing or calibrating indicator values in other regions. For countries where this has been attempted, there is good agreement with original values (Diekmann 1995; Van der Maarel 1993). For the purposes of monitoring changes in the British countryside, a standardized set of British values would be useful. Ter Braak & Gremmen (1987) have suggested that a technique based on Gaussian logistic regression could be used to extend the original values to a new area. We have tested their method on British data.

Data and methods

The Countryside Survey 1990

Countryside Survey 1990 (hereafter referred to as CS90) was a comprehensive survey of the British countryside, conducted in 1990 (Barr *et al.* 1993). A stratified random sample of 508 1-km squares was drawn from 32 relatively homogeneous strata called 'Land Classes'. In each 1-km square, records were made of land cover, landscape features, habitats and vegetation. The vegetation data are used here. Three plot types were used to record vegetation: (1) main plots placed at random throughout the 1-km squares; (2) linear plots placed along hedgerows, streams and verges; and (3) habitat plots targeted to provide additional information on areas of semi-natural vegetation (Table 1).

Indicator values

Indicator values were taken from the standard published source (Ellenberg *et al.* 1991), which provides scores for the large majority of species found in Britain. Ecological indicator values are available for seven scales, here given their German initials: L light, T temperature, K continentality, F moisture, R reaction (pH), N nitrogen, S salinity. Using data from the Park Grass Experiment, Hill & Carey (1997) have already shown that the indicator values for N are as much an indication of overall productivity as of nitrogen.

Gaussian logistic regression

Ter Braak and Looman (1986) proposed Gaussian logistic regression as a means of estimating ecological indicator values and amplitudes of species, given a series of samples with measured values of an ecological variable and data on species' presence or absence. Simulations have shown this method to be generally more reliable than simple weighted average of presence-absence data alone. The response of a species describes the probability, $p(x)$, that the species occurs as a function of an environmental variable x. The Gaussian-logit curve models the presence-absence response of a species:

$$\mathrm{og}\left[\frac{p(x)}{1-p(x)}\right]=b_0+b_1x+b_2x^2=a-\frac{1}{2}(x-u)^2/$$

where u is the species optimum or indicator value (the value of x with highest probability of occurrence) and t is its tolerance (a measure of ecological amplitude). The parameters b_0, b_1 and b_2 can be estimated by logistic regression to obtain the following:-

optimum $u = -b_1/2b_2$;

tolerance $t = 1 / \sqrt{(-2b_2)}$;

maximum probability $p_{\max} = p(u) = 1/[1+\exp(-b_0-b_1u-b_2u^2)]$.

The Gaussian-logit response curve is bell-shaped and symmetrical, and therefore its optimum is identical to its mean. Gaussian logistic regression was performed by the statistical package Genstat (Genstat 5 Committee 1993).

Reprediction of indicator values from an existing set

An iterative procedure using the Gaussian-logit model has been used to determine the amplitude of plant species responses and to test the internal consistency of Ellenberg's indicator values for moisture in the Netherlands (Ter Braak & Gremmen 1987). For any ecological indicator variable, the procedure consists of two steps.

(1) For each sample quadrat, calculate the mean indicator score for those species which have an initial ecological indicator value.

(2) For each species, use Gaussian logistic regression to calculate an optimum and tolerance, based on the quadrat means defined at stage 1.

The essential feature of this method is that it treats the mean values of species indicator values as if they were the value of a measured variable. The method was applied to CS90 data as a means of extending Ellenberg's ecological indicator values to Britain.

If the optimum lies outside or near the edge of the sampled range, the optimum is poorly estimated. When testing the Gaussian-logit response of species to Ellenberg indicator scales, the sampled range was restricted to the original range of the indicator values. In cases where the optimum lies outside the range of the indicator variable, the response curve is said to be truncated and a sigmoid curve (linear logit curve) is fitted.

Results

Distribution of quadrat indicator values

The distribution of quadrat indicator values (stage 1 of the reprediction procedure described above) differed widely between the indicator variables (Fig. 1). The variables L, T, K and F showed a simple unimodal pattern. Light values, L, had a negative skew, corresponding to the fact that low-light conditions are relatively rare in the British countryside, which is poorly wooded.

Both R and, especially, N showed a bimodal pattern of variation. This reflects the two types of countryside present in Britain, namely the intensively-used land of the lowland zone and the extensive, mostly acid countryside of the uplands.

High S values are rarely found in the British countryside except on the coast. It is perhaps surprising that there was an apparently unimodal distribution of S values. It should be noted that the mode falls at 0.2, which does not indicate salty conditions, but merely that at least one species of plant present has some salt tolerance, at least in coastal ecotypes.

Categories of response

In total, 1132 vascular plant species were recorded in the vegetation data, of which 643 occurred in 10 or more quadrats (Table 2). The most common species, *Holcus lanatus*, occurred in 5855 quadrats, 43% of the total.

Species responses can be listed in six categories (Table 2). The significance of an optimum can be judged by whether the quadratic coefficient b_2 is significantly less than 0. The majority of species optima were significant at the 5% level (Good optima) or non-significant but with negative b_2 and estimated optimum falling within the range of Ellenberg values (Weak optima). For many species, such as *Cirsium vulgare* (Fig. 2) a significant optimum was estimated for each Ellenberg scale.

For a few species, the fitted optimum was beyond the maximum or minimum of the original scale. These are indicated as Truncated good optima (b_2 significantly less than 0) or Truncated weak optima (b_2 negative but not significantly so). The truncation consisted of reassigning their optimum to the maximum or minimum of the original scale.

A small number of species did not have optima; i.e. the logit quadratic coefficient was positive. Where these species had significant linear logistic regression coefficients (b_1 significantly positive or negative), they were assigned to the category Linear logit (Table 2). An example of such a response is shown in Fig. 3. Species showing a linear logit response were given a repredicted value which was the maximum or minimum value for the scale in question.

Finally, those species where the logit quadratic coefficient was positive and the linear logit curve was not significant were assigned to the category Trough (Table 2). A striking example is provided by heather *Calluna vulgaris*, which has a wide tolerance for moisture (Fig. 4). Even this wide tolerance has its limits. Heather is common bogs, but only on hummocks; it does not occur in situations where there is prolonged submergence (F>8). This is a small but not completely negligible class of samples (Fig. 1).

Optima and tolerances in relation to original values

There was some general agreement between the Gaussian logistic regression point estimates and the original values. Of 488 species for which both an original Ellenberg and Gaussian logistic regression estimate of N is available, 11 species had the same value, 294 had a difference of one or less, 482 of two or less. However, the relation between the optima and original values was not linear (Fig. 5), nor did Gaussian regression prevent the shrinkage which is often regarded as a fault of the weighted-averaging method of calibration (Hill & Gauch 1980; Ter Braak & Gremmen 1987).

When only the species with good or weak optima are considered, the relation between optima and original values appears to be even weaker (Table 3). For the variable K, the mean optimum rose from 2.9 to 3.7 when the value of the original variable rose form 2 to 5. Although this is perhaps an extreme case, reflecting the unsuitability of a Central European K value in Britain (Preston & Hill 1997), it shows that the optima are not necessarily a good reprediction.

Tolerance values varied little along the gradient (Fig. 6). There was only a very slight tendency for supposedly wide-tolerance species, which were accorded the rating x by Ellenberg, to have broader observed tolerances in Britain. Species signified by * in Fig. 6, which were not included at all in Ellenberg's enumeration showed tolerances almost identical to those which were rated x.

Discussion and conclusions

Although field naturalists commonly use the associates of a given species to infer its ecological attributes, this method has several limitations if quadrat data are all that are available. Loss of information on both context and plant architecture makes light values particularly difficult to infer from quadrat lists. In principle, plant size and life form could be used to find out whether a species was small and growing in the shade of larger ones, but this would necessitate a methodology that was quite specific to light. Even then, the Ellenberg light values for trees are defined to be the values in which young trees can develop. They cannot be inferred by examining mature stands.

For all variables, the optima were compressed to a smaller range than that of the original variables. This compression means that the optima cannot be used directly to reconstruct values where these are not known. An intermediate step such as regression of original values on predicted optima would be required.

The large number of apparently good optima, compared with the small number of troughs and linear regressions, shows that these are a weak reflection of the quality of the original variables.

Progress in extrapolating ecological indicator values to new geographical areas will be greatest when the variables can be defined by external criteria. Some of the original variables may prove to be poorly defined. It is clear, also, that a more detailed study of the patterns of species occurrence in environmental space is required. A univariate approach such as that used here takes no account of the correlation between different variables. The method also takes no account of variations in species richness between differing parts of a given gradient. We have had greater success in extrapolation using a variant of the method of weighted averages that explicitly corrects for compression of rescaled variables. That work will be presented elsewhere. In the mean time, we conclude that the method of Ter Braak and Gremmen should not be used uncritically. Estimation of optima by logistic regression may well be a useful adjunct to other methods, but it is not reliable in itself.

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Table 1. Types and numbers of vegetation plots

Plot type	Max per 1km square	Total
X - Main plots (200 m²)	5	3 805
Y - Habitat plots (4 m²)	5	2 531
H - Hedge plots (1 m x 1 m)	2	847
B - Boundary plots (10 m x 1 m)	5	1 805
R - Verge plots (10 m x 1 m) - random	2	1 145
V - Additional verge plots (10 m x 1 m)	3	1 165
S - Streamside plots (10 m x 1 m) - random	2	1 258
W - Additional streamside plots (10 m x 1 m)	3	1 285
Total		13 841

Table 2. Numbers of species in classes of logistic regression fit

Class of fit	L	T	K	F	R	N	S
Good optima	436	497	474	444	455	513	351
Weak optima	176	139	146	152	134	102	185
Truncated good optima	1	0	0	3	3	8	0
Truncated weak optima	14	0	3	15	39	12	16
Linear logit	11	3	13	20	11	6	73
Trough	5	4	7	9	1	2	18
Total	643	643	643	643	643	643	643

Table 3. Optima and numbers of species for those species whose estimated optimum falls within the range of original values (good and weak optima); species lacking an original value are indicated by the symbol *, those originally signified as wide-ranging by x.

	0	1	2	3	4	5	6	7	8	9	10	11	12	*	x	All
L		4.9 (1)	4.6 (7)	4.9 (15)	5.2 (33)	5.6 (36)	6.4 (76)	6.7 (184)	7.5 (135)	7.9 (22)				6.3 (92)	6.1 (10)	6.6 (612)
T			3.1 (5)	3.9 (9)	4.7 (23)	5.2 (139)	5.7 (181)	6.1 (23)	6.3 (3)					5.3 (100)	5.0 (153)	5.3 (636)
K		2.5 (15)	2.9 (92)	3.2 (214)	3.5 (37)	3.7 (61)	5.2 (4)	4.2 (14)						3.6 (97)	3.7 (86)	3.4 (620)
F				3.8 (30)	4.1 (67)	4.5 (128)	5.3 (61)	6.2 (47)	6.7 (56)	7.5 (62)	8.4 (15)	9.8 (4)	8.5 (2)	5.0 (87)	3.5 (35)	5.3 (594)
R		2.0 (6)	3.1 (27)	3.7 (40)	4.2 (40)	4.9 (32)	5.7 (46)	6.3 (123)	6.4 (44)	5.9 (4)				5.4 (96)	5.6 (130)	5.4 (589)
N		2.5 (15)	3.1 (75)	4.0 (57)	4.7 (54)	5.3 (74)	5.7 (74)	6.3 (67)	7.1 (43)	7.9 (11)				5.3 (101)	5.1 (44)	5.1 (615)
S	0.4 (383)	0.7 (40)	1.7 (4)	1.2 (3)	2.0 (5)	2.8 (3)	3.1 (4)	4.5 (3)	6.8 (7)	6.4 (2)				0.7 (82)		0.7 (536)

Figure legends

Figure 1. Mean ecological indicator values for 13841 quadrats sampled in Britain during the Countryside 1990 survey.

Figure 2. Observed and fitted response frequencies for *Cirsium vulgare* for the ecological indicator variables L, T, K, F, R, N, S.

Figure 3. Observed and fitted response frequencies for N (Nitrogen) for *Phragmites australis*.

Figure 4. Observed and fitted response frequencies for F (Moisture) for *Calluna vulgaris*.

Figure 5. Optima for N (Nitrogen) in relation to original Ellenberg values; the value * signifies species lacking an original N value.

Figure 6. Tolerance for N (Nitrogen) in relation to original Ellenberg values; the value x denotes a species designated as wide-ranging for N, the value * denotes a species not scored for N.

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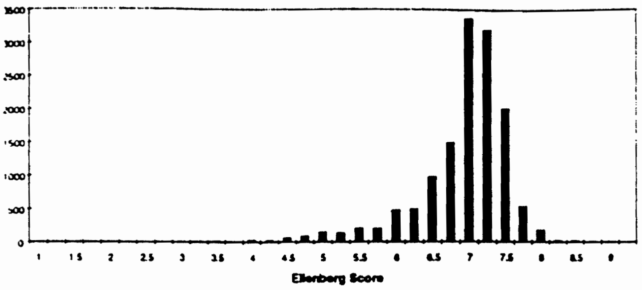
L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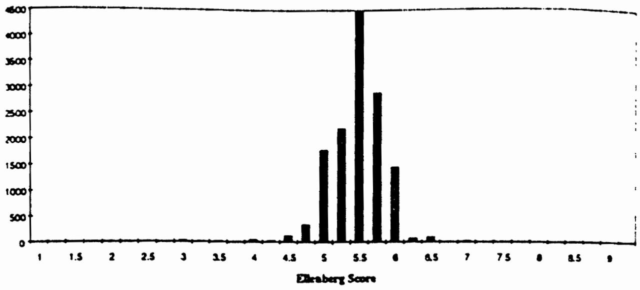
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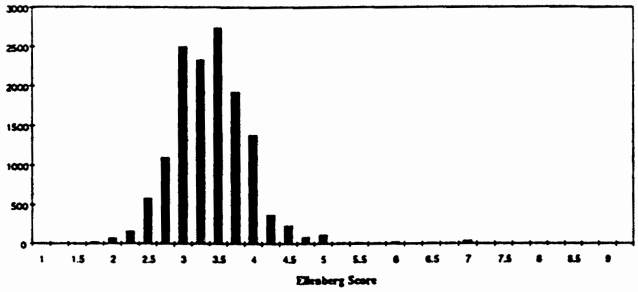
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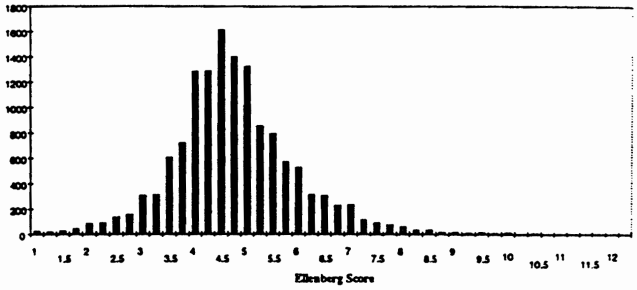
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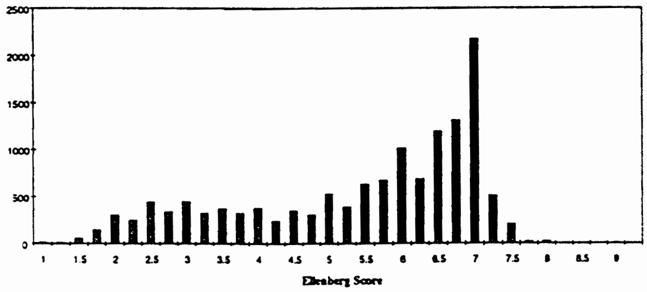
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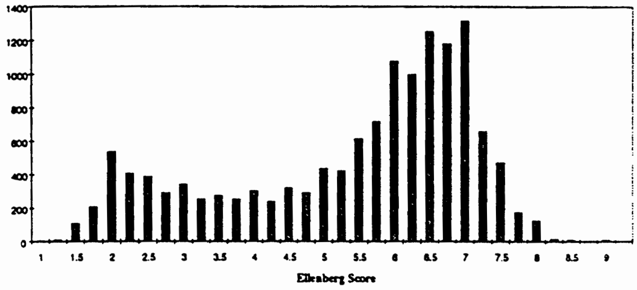
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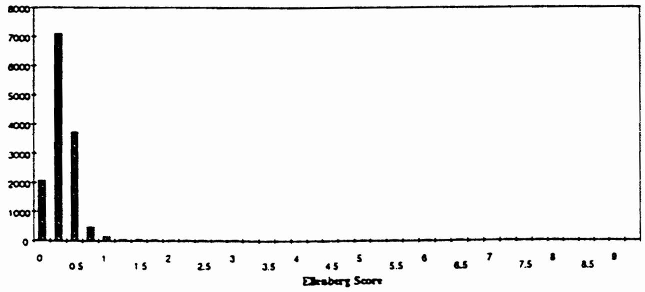
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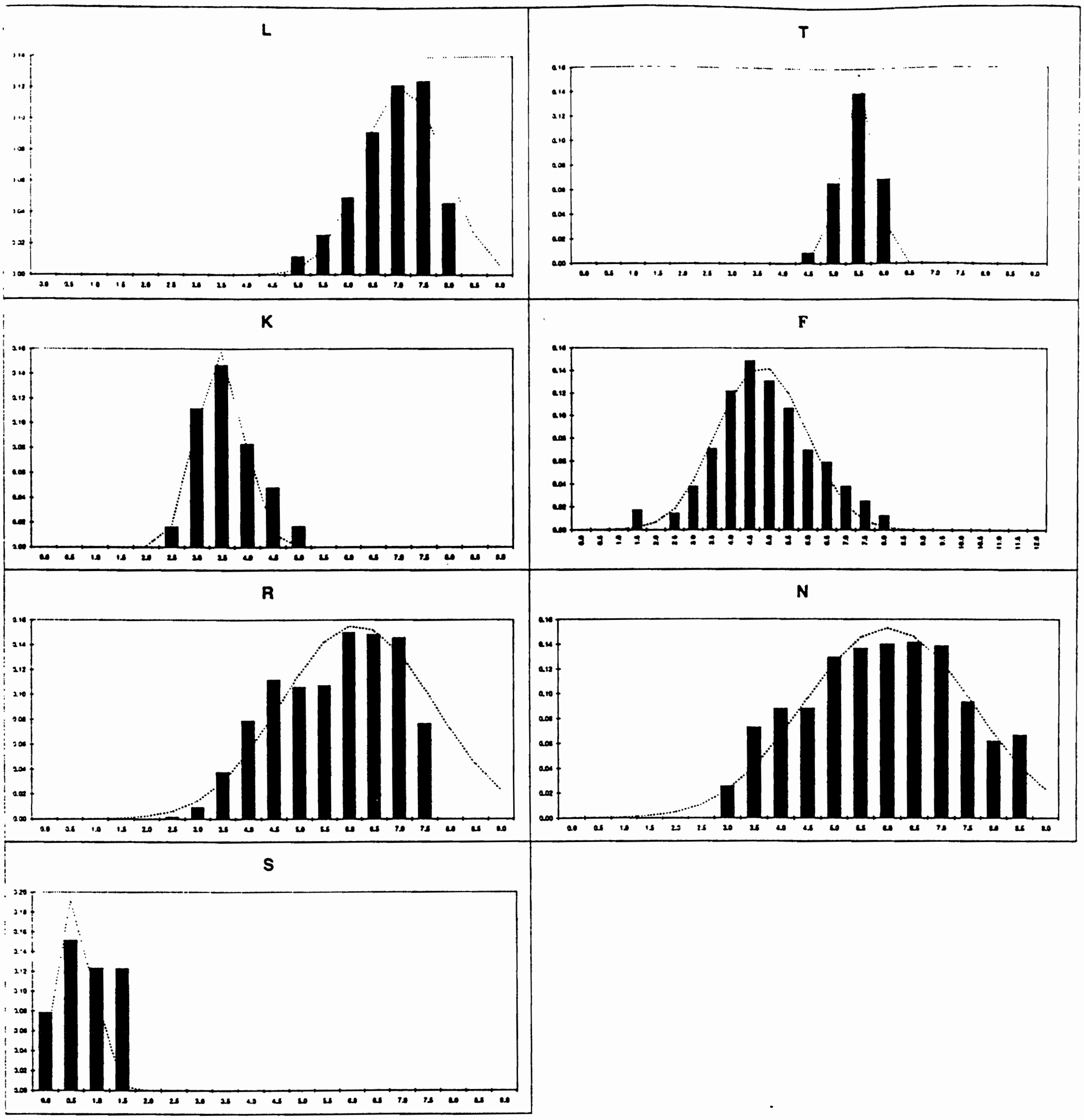
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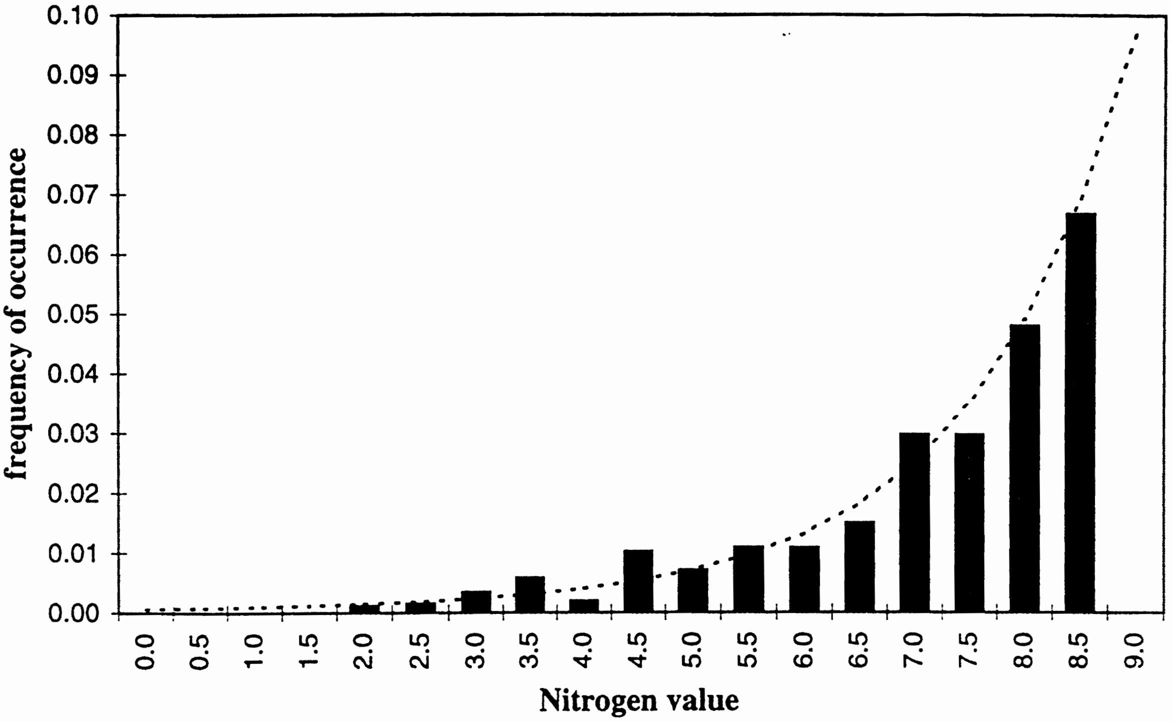
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9.0
Nitrogen value

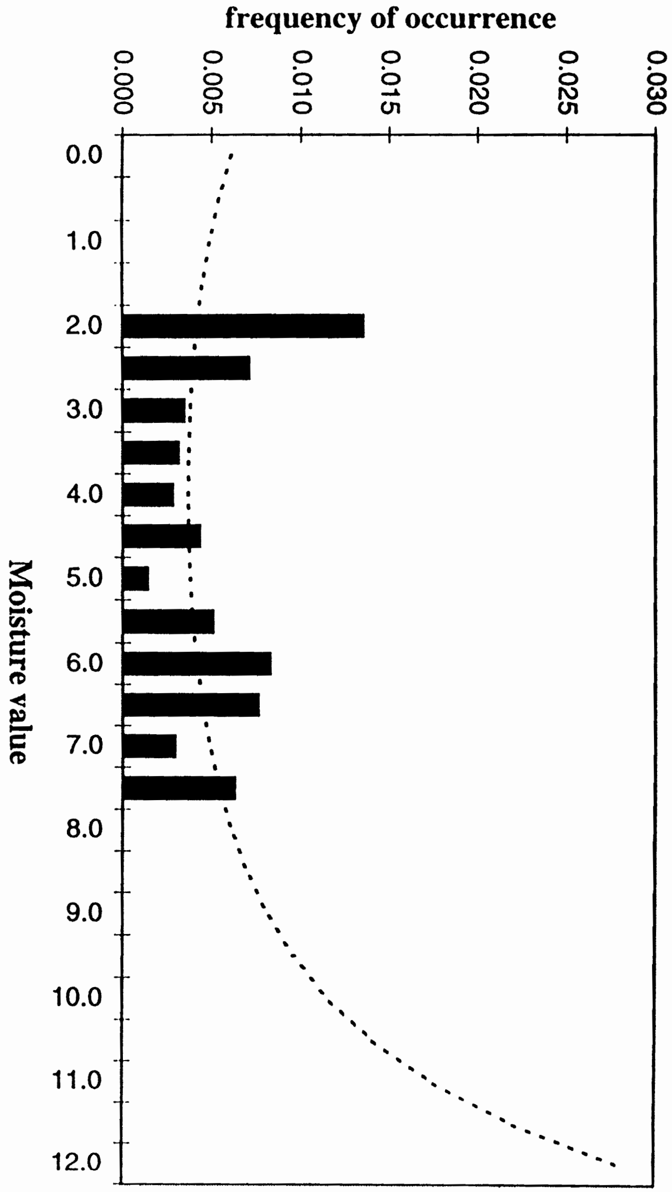

frequency of occurrence
0.000
0.005
0.010
0.015
0.020
0.025
0.030
Moisture value
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

Fig. 5.

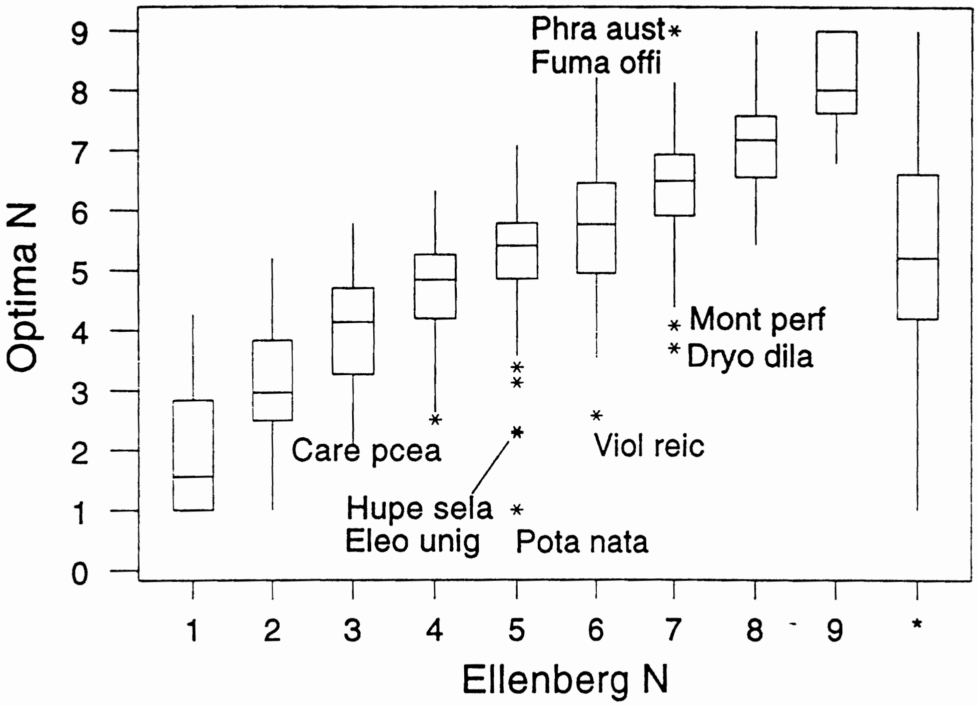
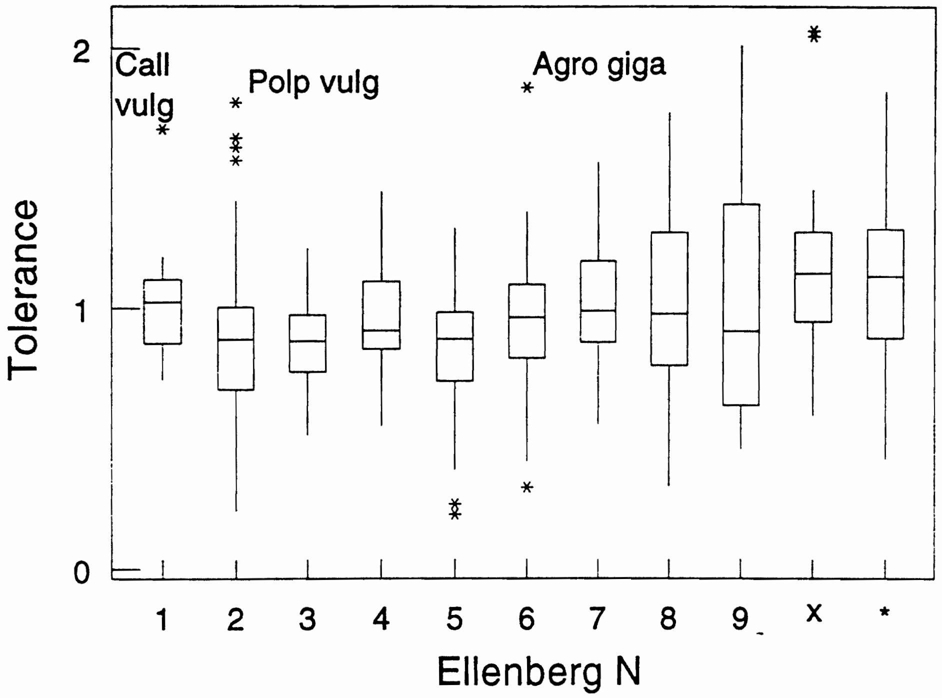

Optima N
0
1
2
3
4
5
6
7
8
9
Ellenberg N
1
2
3
4
5
6
7
8
9
*
Phra aust
Fuma offi
Mont perf
Dryo dila
Care pcea
Viol reic
Hupe sela
Eleo unig
Pota nata

Fig 6.


Tolerance
0
1
2
Ellenberg N
1
2
3
4
5
6
7
8
9
x
*
Call vulg
Polp vulg
Agro giga

3. RELATIONSHIP BETWEEN INDICATOR VALUES AND VEGETATION ANALYSIS

3. RELATIONSHIP BETWEEN INDICATOR VALUES AND VEGETATION ANALYSIS

3.1 The aggregate classes are so important in subsequent reporting, that it is useful to provide further background to their interpretation, as shown in Figure 1 where the Ellenberg scores for fertility and light are presented. The plot types were also included to show differences in the dispersion of variation between landscape elements. Aggregate class 1 and 2 show similar overall values, with little difference between the landscape elements. Classes 3 and 4 both contain grassland assemblages, and show lower levels. Hedges on the other hand, have a higher value than the other elements in class 4. Surprisingly, the other landscape elements are similar, suggesting that, although they may be under different management, their overriding association with the nutrient gradient is consistent. Aggregate classes 5 and 6, those associated with woodlands, not only do not fit easily into the series, but show most differences between plot types, with the hedgerows having high values, probably because they are adjacent to fields. Classes 7 and 8 both show a declining series between plot types, since the former receive nutrients from traffic, the streams from dissolved nutrients whereas the random plots are in open vegetation. The highest values appear in the two wooded aggregate classes 5 and 6. The moisture values are in a gradual sequence with, as would be expected, the stream side plots standing out, but in contrast to the light scores there is a true continuum.

The values have also been correlated with the average DECORANA scores of the species groups and because these were determined by the Ward's Minimal Variance technique, they show a strong correlation with the Ellenberg values as shown in Figure 2.

Recalibrated Ellenberg fertility v. Decorana axis 1

Labels are plot classes; r2 = 0.97.

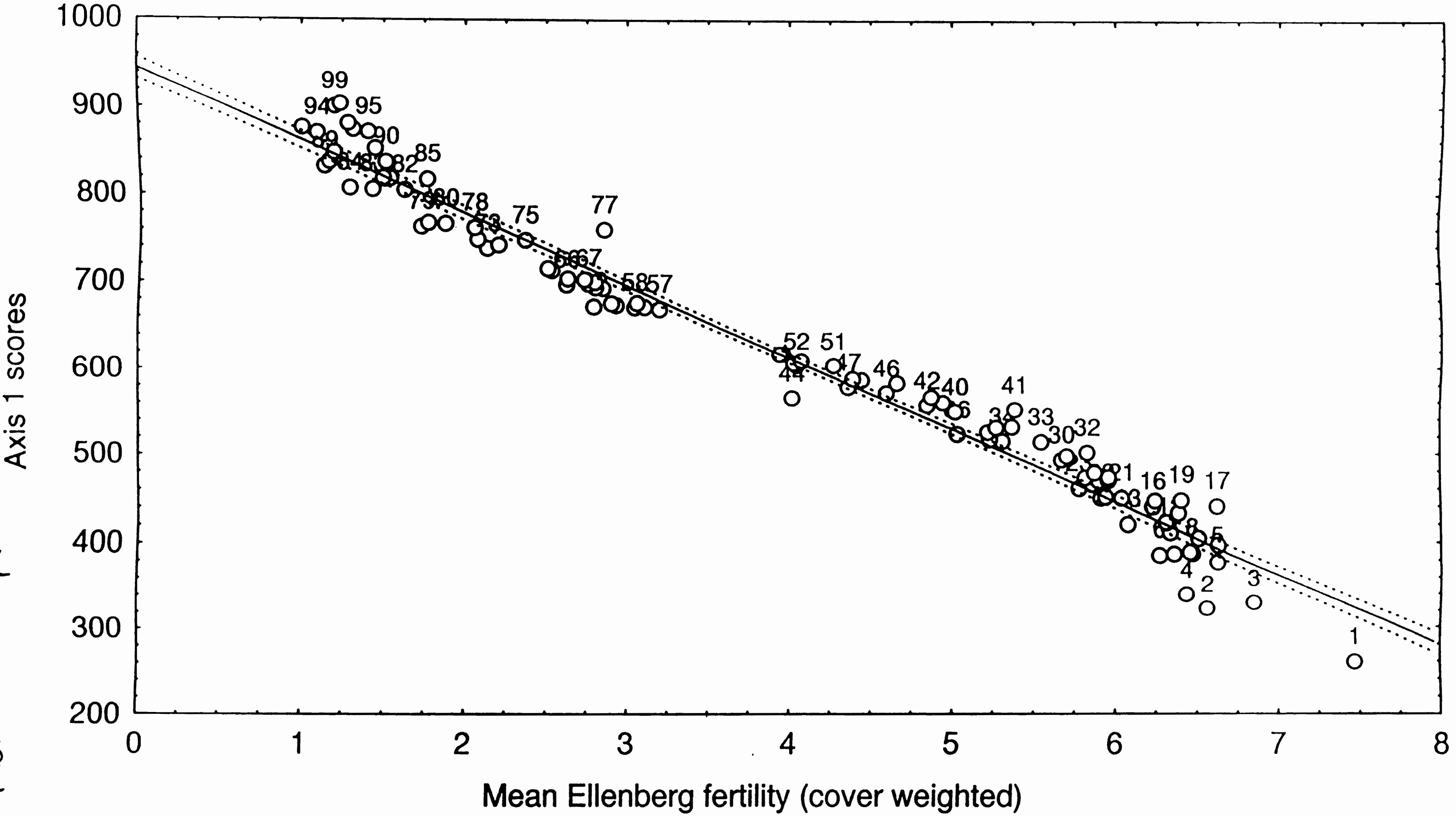
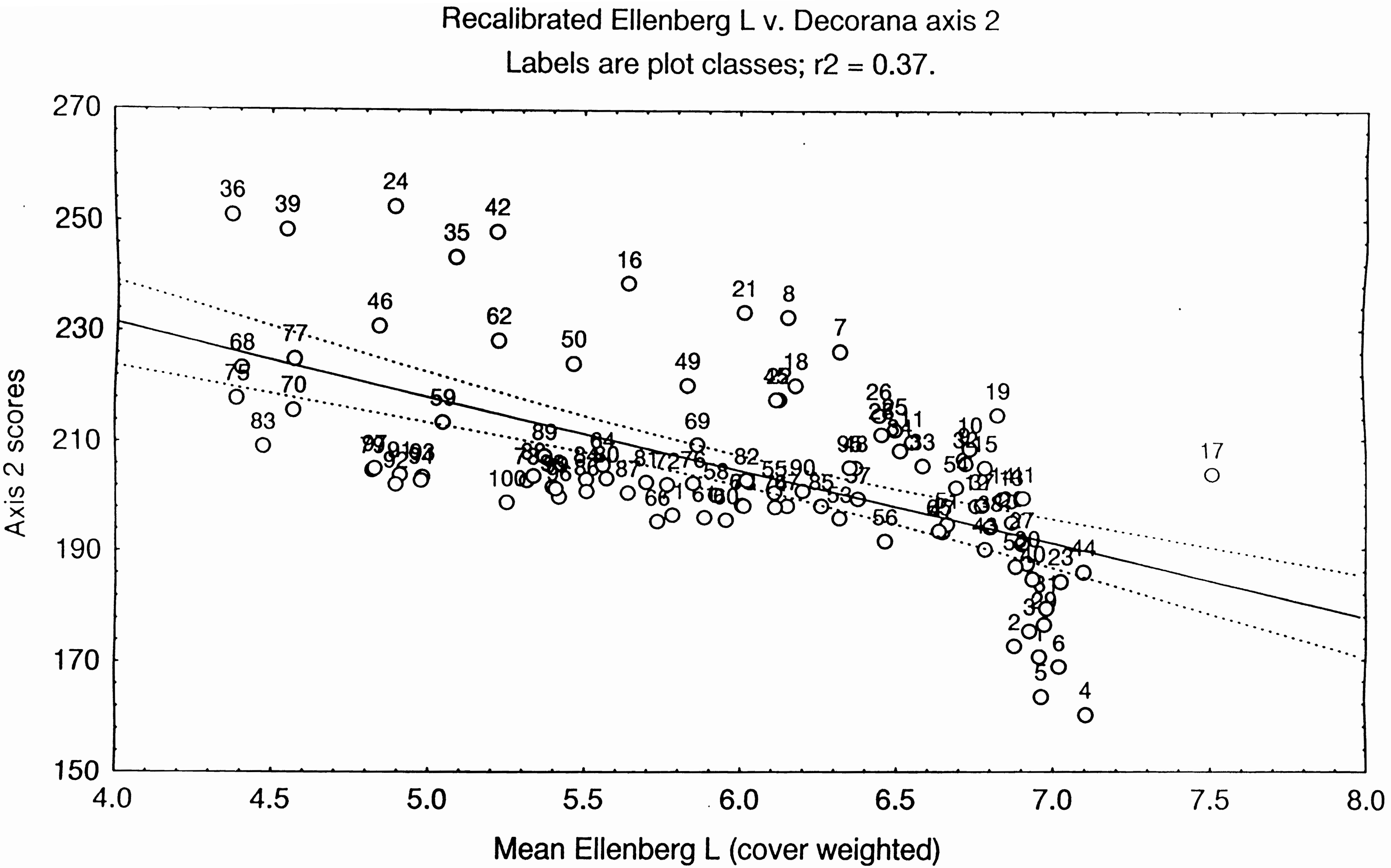


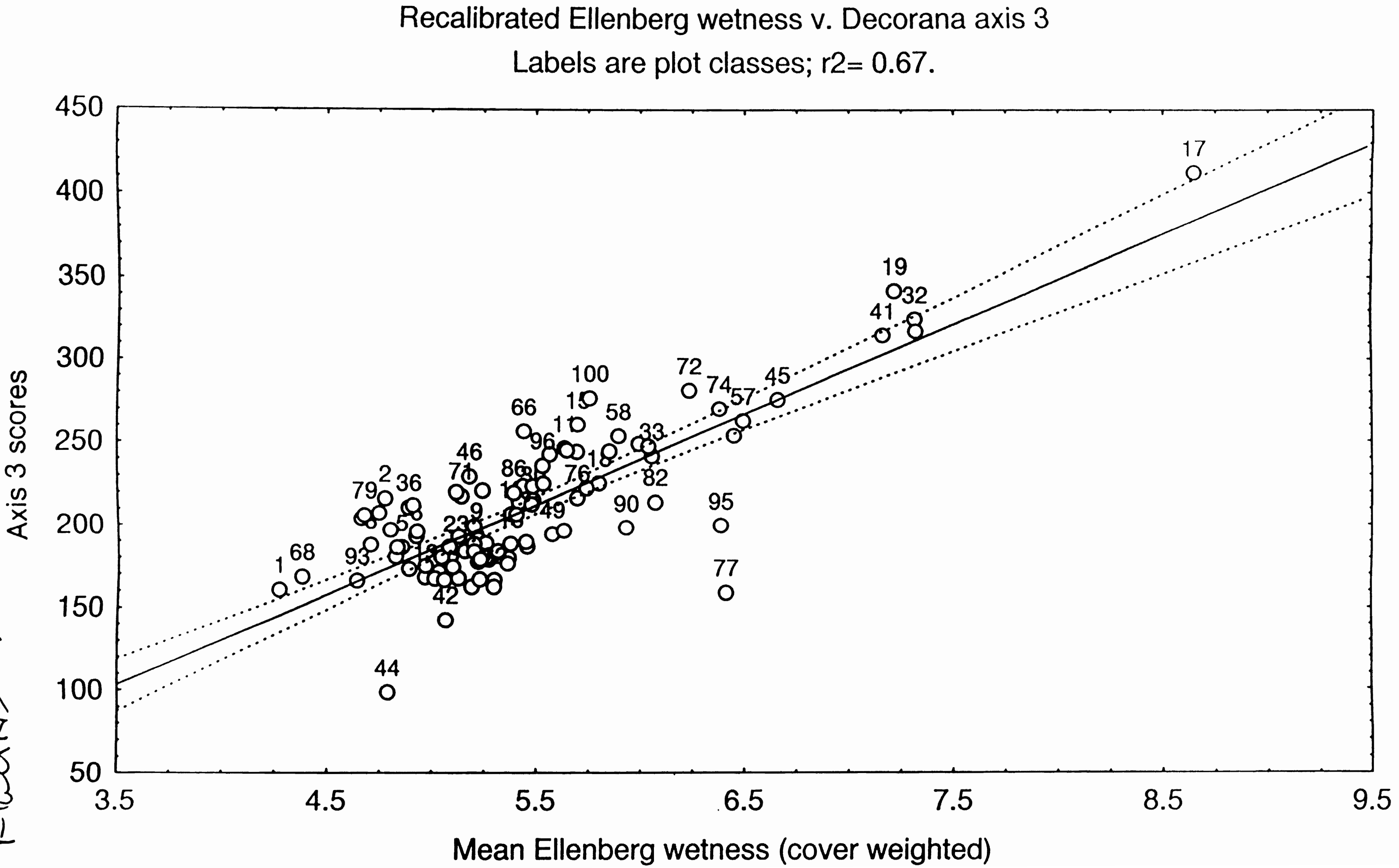
FIGURE 1a



Recalibrated Ellenberg L v. Decorana axis 2

Labels are plot classes; r2 = 0.37.

FIGURE 1(b)



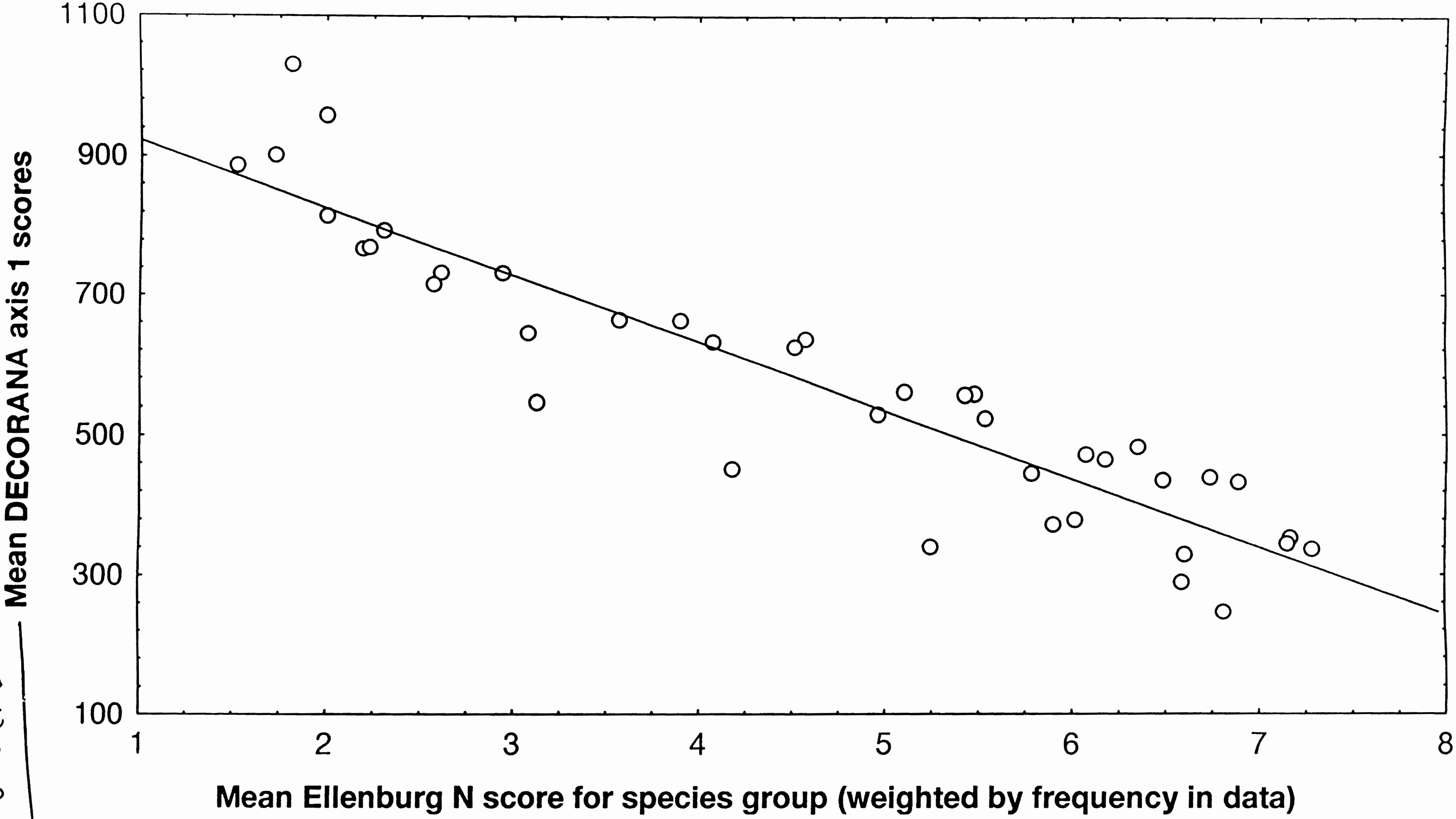
Recalibrated Ellenberg wetness v. Decorana axis 3

Labels are plot classes; r2= 0.67.

Figure 1c

FIGURE 2

Relationship between species group centroids and
mean re-calibrated Ellenburg fertility scores for each group



4. CHANGES IN THE INDICATOR VALUES BETWEEN 1978 AND 1990

4. CHANGES IN THE INDICATOR VALUES BETWEEN 1978 AND 1990

4.1 Graphs of the changes in Ellenberg scores for fertility, acidity, light and moisture are included in this section.

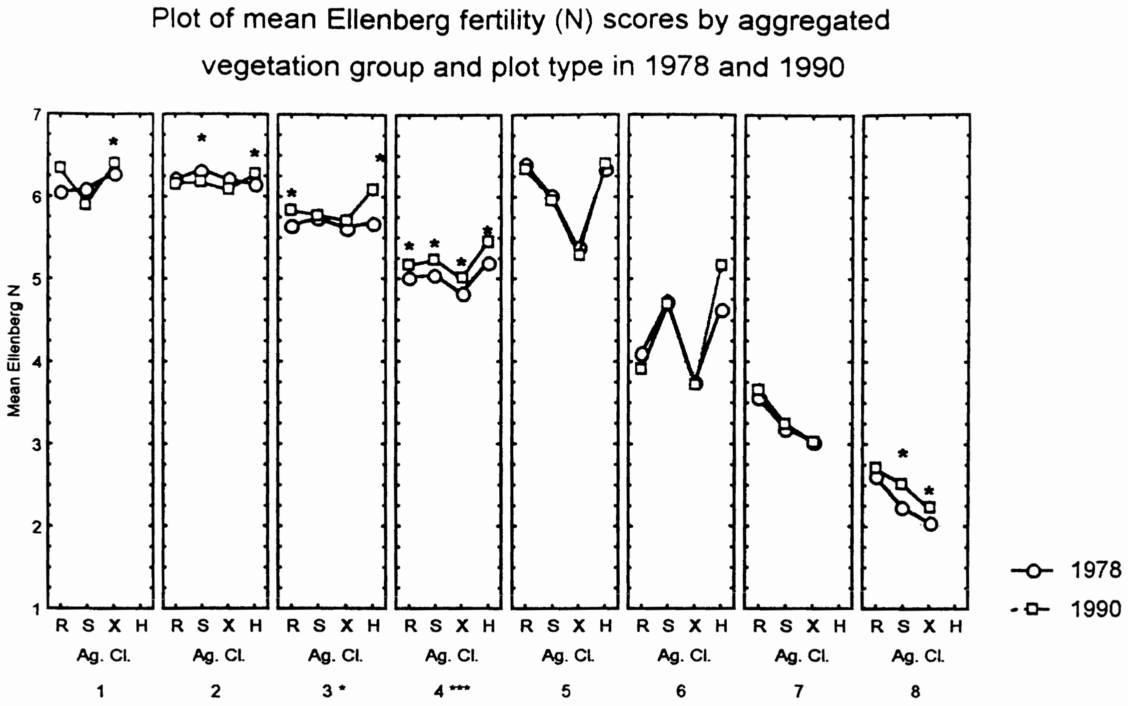
4.2 Changes in fertility: eleven significant changes have taken place between 1978 and 1990 of which all but one (tall grassland vegetation by streamsides) had increased in fertility between 1978 and 1990. The largest increases were in the diverse grasslands and heath/bog categories. This confirms the species changes reported in the CS1990 main report and also the trends reported elsewhere within ECOFACT. The eutrophication throughout the grassland series of hedgerows also supports the conclusions of the initial analysis.

4.3 Eight significant changes were recorded of which all but one (tall grassland vegetation by streamsides - the same category of change as noted in 4.2) had decreased in acidity. The major changes were within the weeds aggregate class and in the heath/bog aggregate class, the former differing from the changes in fertility whereas the latter is identical. The further analysis separating the bogs from other upland vegetation reported below, shows the way in which a dominant category of change can override movements in the opposite direction.

4.4 There are eleven significant changes in the Ellenberg light scores but these are moving in opposite directions within and between different aggregate classes, showing a contrast with the overriding changes in the previous two sections. Within aggregate class 2, fields have become more open, whereas hedgerows have become more dominated by shade-tolerant species. It is important to understand that in grasslands which have become more fertile, then the dense shade cast by the sward can have a similar effect to shading by trees since the smaller light-demanding species are removed from the vegetation. During the field work in the upland study, rosette species such as *Leontodon autumnalis* and *Drosera rotundifolia* were seen to be unable to cope with tall grasses. Within fertile grasslands, roadsides had become more open whereas the open vegetation had moved in the opposite direction. Within the variable grasslands, a highly-significant overall change had taken place, of increased shade-tolerant species although only streams and hedgerows were actually significant. When connected with the increase in fertility, then it seems likely that this change is due to an increasingly dense sward. Within the lowland arboreal aggregate class there was a highly-significant change overall, with all types of plots showing an increase in more light-demanding species. Within the upland arboreal class, only the streamside had changed, in this case becoming more open. Both significant changes in the two upland vegetation classes showed an increase in openness, perhaps related to a shortening of the sward by grazing.

4.5 Of the ten significant changes observed, there was an equal balance between increases and decreases in moisture levels. The highest significance levels were within variable grasslands beside streamsides which increased in moisture levels, which could be a distortion due to the dry summer of 1990, contrasting with a decrease in moisture level within weeds in open fields. In contrast, within both fertile grasslands and diverse grasslands the significant changes in streamsides and open fields on the one hand and between roadsides and roadsides on the other, were both changing in opposite directions suggesting that seasonal effects were unlikely to be involved. Within heath and bog vegetation the evidence suggested a decrease in moisture-loving species within streamsides and open vegetation, whereas within moorland streamsides there was evidence of the opposite showing that complex changes are involved within the same landscape.

Change in mean Ellenberg fertility scores (as recalibrated by M.O. Hill) between 1978 and 1990 in the Countryside Survey data set


Plot of mean Ellenberg fertility (N) scores by aggregated vegetation group and plot type in 1978 and 1990

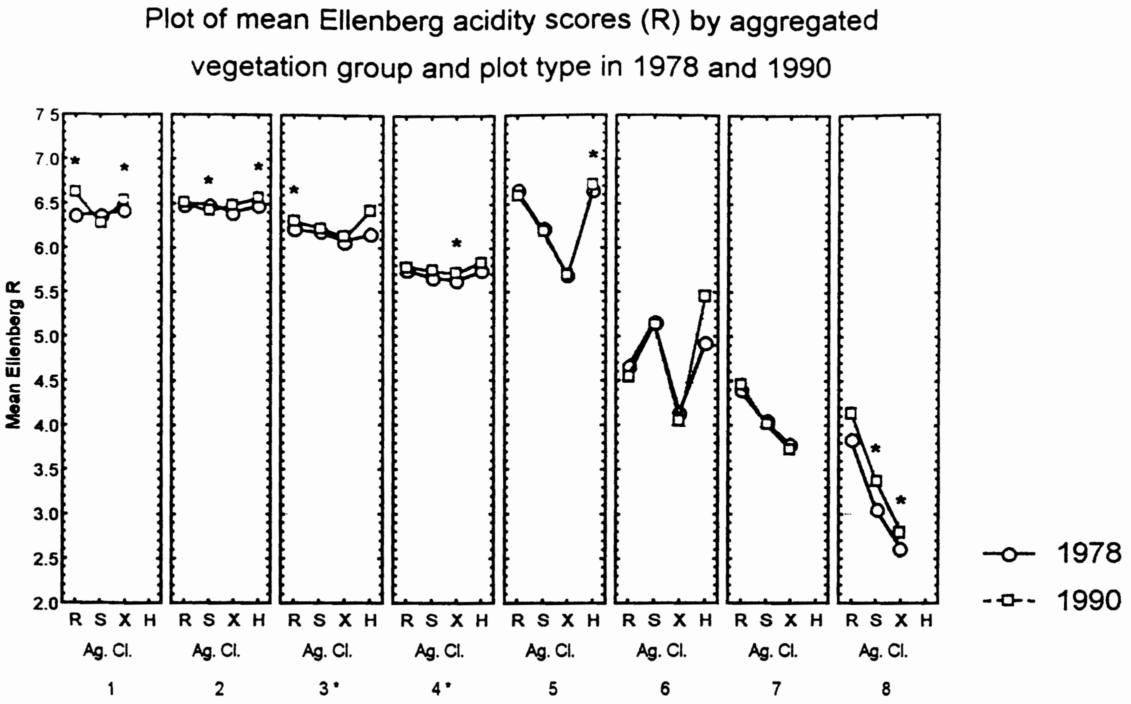
Marks above the values indicate significance ($p<0.05$) of change between 1978 and 1990 per plottype. Marks at the bottom of each figure indicate the level of significance of change over time in that aggregated vegetation group.

Analyses were carried out by GLM (SAS) on log transformed data. Results are as follows:

- a significant ($p<0.001$) overall effect of time, type and aggregated vegetation group on mean Ellenberg fertility score has been found.
- no significant interactions ($p<0.05$) between time, plot type or aggregated vegetation group were detected in the overall analysis.

	R		**S**		**X**		**H**		**Plot type**		**Time**
	N	*sig*	*N*	*sig*	*N*	*sig*	*N*	*sig*	*N*	*sig*	*sig*
A.Cl. 1	8	ns	1	-	221	*	-	-	230	ns	**ns**
A.Cl 2	95	ns	60	*	16	ns	88	**	259	ns	**ns**
A.Cl. 3	124	*	25	ns	202	ns	7	*	358	*	*
A.Cl. 4	78	*	79	*	229	***	31	*	417	***	***
A.Cl. 5	11	ns	30	ns	24	ns	119	ns	184	***	**ns**
A.Cl. 6	5	ns	48	ns	75	ns	6	ns	134	***	**ns**
A.Cl. 7	24	ns	78	ns	125	ns	-	-	227	***	**ns**
A.Cl. 8	1	-	33	*	253	***	-	-	287	***	**ns**

Change in mean Ellenberg acidity scores (as recalibrated by M.O. Hill) between 1978 and 1990 in the Countryside Survey data set



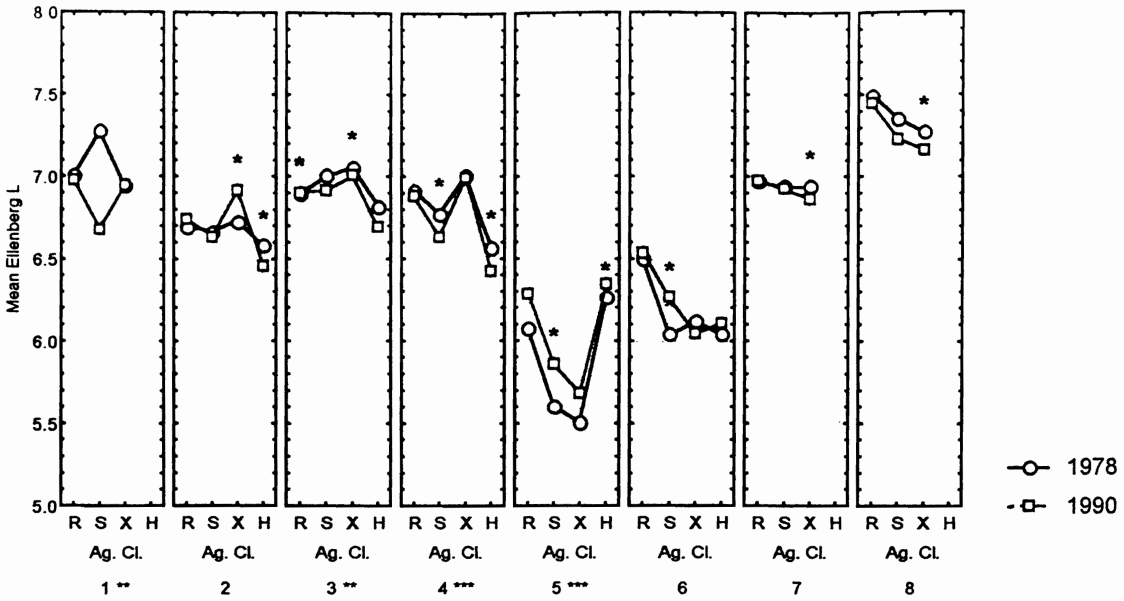
Marks above the values indicate significance ($p<0.05$) of change between 1978 and 1990 per plottype. Marks at the bottom of each figure indicate the level of significance of change over time in that aggregated vegetation group.

Analyses were carried out by GLM (SAS) on log transformed data. Results are as follows:

- a significant ($p<0.001$) overall effect of time, type and aggregated vegetation group on mean Ellenberg acidity score has been found.
- no significant overall interactions ($p<0.05$) were found between time and plottype and aggregated vegetation group and plottype.

	R		**S**		**X**		**H**		**Plot type**		**Time**
	N	*sig*	*N*	*sig*	*N*	*sig*	*N*	*sig*	*N*	*sig*	*sig*
A.Cl 1	8	*	1	-	221	***	-	ns	230	ns	**ns**
A.Cl 2	95	ns	60	*	16	ns	88	**	259	ns	**ns**
A.Cl 3	124	***	25	ns	202	ns	7	ns	358	***	*
A.Cl 4	78	ns	79	ns	229	*	31	ns	417	ns	*
A.Cl 5	11	ns	30	ns	24	ns	119	*	184	***	**ns**
A.Cl 6	5	ns	48	ns	75	ns	6	ns	134	***	**ns**
A.Cl 7	24	ns	78	ns	125	ns	-	-	227	***	**ns**
A.Cl 8	1	-	33	*	253	***	-	-	287	***	**ns**

Change in mean Ellenberg light scores (as recalibrated by M.O. Hill) between 1978 and 1990 in the Countryside Survey data set



Plot of mean Ellenberg light (L) scores by aggregated vegetation group and plot type in 1978 and 1990

Marks above the values indicate significance ($p<0.05$) of change between 1978 and 1990 per plottype. Marks at the bottom of each figure indicate the level of significance of change over time in that aggregated vegetation group.

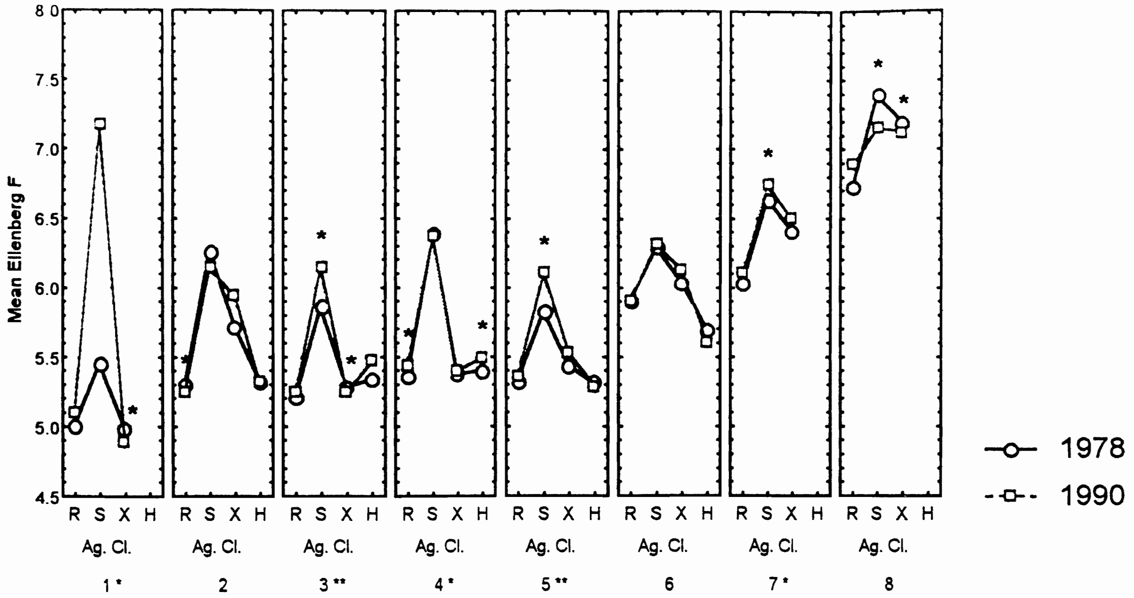
Analyses were carried out by GLM (SAS) on log transformed data. Results are as follows:

- a significant ($p<0.05$) overall effect of time, type and aggregated vegetation group on mean Ellenberg light score has been found.
- no significant overall interactions ($p<0.05$) were found between time and plottype and aggregated vegetation group and plottype.

	R		**S**		**X**		**H**		**Plot type**		**Time**
	N	*sig*	*N*	*sig*	*N*	*sig*	*N*	*sig*	*N*	*sig*	*sig*
A.Cl. 1	8	ns	1	-	221	ns	-	-	230	ns	**
A.Cl. 2	95	ns	60	ns	16	*	88	***	259	***	ns
A.Cl. 3	124	*	25	ns	202	*	7	ns	358	***	**
A.Cl. 4	78	ns	79	**	229	ns	31	*	417	***	***
A.Cl. 5	11	ns	30	**	24	ns	119	**	184	***	***
A.Cl. 6	5	ns	48	**	75	ns	6	ns	134	ns	ns
A.Cl. 7	24	ns	78	ns	125	*	-	-	227	ns	ns
A.Cl. 8	1	-	33	ns	253	***	-	-	287	ns	ns

Change in mean Ellenberg moisture scores (as recalibrated by M.O. Hill) between 1978 and 1990 in the Countryside Survey data set

Plot of mean Ellenberg moisture (F) scores by aggregated vegetation group and plot type in 1978 and 1990



Marks above the values indicate significance ($p<0.05$) of change between 1978 and 1990 per plottype. Marks at the bottom of each figure indicate the level of significance of change over time in that aggregated vegetation group.

Analyses were carried out by GLM (SAS) on log transformed data. Results are as follows:

- a significant ($p<0.05$) overall effect of type on mean Ellenberg moisture score has been found. The overall effect of time and aggregated vegetation group was not shown to be significant.
- significant overall interactions ($p<0.05$) were found between time and plottype and aggregated vegetation group and plottype.

	R		**S**		**X**		**H**		**Plot type**		**Time**
	N	*sig*	*N*	*sig*	*N*	*sig*	*N*	*sig*	*N*	*sig*	*sig*
A.Cl 1	8	ns	1	-	221	***	-	-	230	***	*
A.Cl 2	95	*	60	ns	16	ns	88	ns	259	***	ns
A.Cl 3	124	ns	25	*	202	*	7	ns	358	***	**
A.Cl.4	78	**	79	ns	229	ns	31	*	417	***	*
A.Cl.5	11	ns	30	***	24	ns	119	ns	184	***	**
A.Cl.6	5	ns	48	ns	75	ns	6	ns	134	***	ns
A.Cl.7	24	ns	78	*	125	ns	-	-	227	***	*
A.Cl 8	1	-	33	*	253	**	-	-	287	ns	ns

5. ANALYSIS OFINDICATOR VALUES WITHIN UPLAND VEGETATION

5. ANALYSIS OF INDICATOR VALUES WITHIN UPLAND VEGETATION

5.1 Following discussion in the Technical Sub-Group Meeting held in November of 1996 it had been noted that individual plots or classes could move in totally different directions which when grouped together masked the true direction of change. In particular, the gross changes involving shifts between aggregate classes could mask the true underlying changes going on within vegetation that were staying relatively constant. The changes within upland vegetation had been the most difficult to understand and experience during the upland study had indicated the possibility that drier heathland and bog vegetation, even within the same landscape unit, could be overgrazed or undergrazed respectively. Accordingly it was decided to divide the heath and bog aggregate class into dry heath, moorland and bog, included 52 quadrats, 24 quadrats and 145 quadrats respectively and to analyse the changes between these categories as shown in Table 1.

Table 1. The changes in mean scores for light, moisture, pH and nitrogen in upland quadrats surveyed in 1978 and 1990.

	All quadrats	**dry heath**	**moorland**	**bogs**
Light				
T	-0.63	2.52	-0.71	-1.38
probability	0.53	0.013	0.49	0.17
df	429	98	32	285
Moisture				
T	0.02	1.59	0.66	-1.00
probability	0.98	0.12	0.51	0.32
df	439	101	45	298
pH				
T	1.08	-2.31	-0.62	3.86
probability	0.28	0.023	0.54	<0.001
df	437	96	45	287
Nitrogen				
T	1.04	-3.31	-0.42	3.94
probability	0.30	0.001	0.68	<0.001
df	439	99	45	279

Twostriking series of change are presented within this Table. Firstly, the dry heath has become more open, confirming the losses reported elsewhere of ericaceous species linked to the influence of grazing in reducing sward height. Neither moorland or bogs showed a significant change. This result supported the initial hypothesis that grazing was most likely to of affected the drier heathland than moorland and bogs. However, the second series of changes was not foreseen in that both pH and nitrogen had decreased in the dry heath whereas they had increased in the bogs with the moorlands being unchanged. At first this result seems inexplicable since these types of vegetation were not in a consistent pattern within the landscape as some bogs were situated in valley bottoms, others in small flushes and others as blanket bogs. This suggested that a process was at work related to the soil on which the vegetation was growing. This was confirmed when it was established from other studies that the aerobic character of the dry heath was known from other studies to favour bacteria which were able to utilise atmospheric deposition as an energy source. This in turn leads to nitrogen being lost from the system and acidification taking place simultaneously. By contrast, the saturated peats of bogs are anaerobic and the same type of deposition would lead to the increase in pH and nitrogen level reported in Table 1. It should be noted that the latter effect was completely overridden in the previously generalised graphs since the level of significance is much higher than in the dry heaths.

These results need to be set into context with other research on processes of acidification through nitrogen deposition and will be carried out in conjunction with Dr P Ineson.

6. FARM STUDY

6. FARM STUDY

6.1 In August and September 1996, 25 1 km^2 were visited, stratified firstly according to those showing high change and low change in the Wye College socio-economic study and secondly to cover a random sample of land classes within the four landscape types. Within each square plots were re-visited that had been recorded in 1978 and 1990 and all species recorded together with notes concerning the interpretation of change and the status of plots within the landscape. Full analyses of these data have not yet been completed, but the initial broad general conclusions were reported in the Technical Sub-Group Meeting in November 1996. A brief summary of these conclusions is given below.

6.2 The most important overriding conclusion which is likely to be a principle finding of the whole project may be summarised as follows:

The composition of vegetation at any given point within the landscape is determined by the management practices to which it has been subjected, given the environmental character of that location

Certain exceptions may occur:

- Atmospheric deposition
- Catastrophic events eg flooding

This applies the law of Occam's Razor ie the simplest solution should apply in any given circumstance. For example, an assemblage of weeds within an intensively-managed arable field where the management has been directed towards the production of a single crop is most likely to be the product of that management rather than an external influence such as ozone levels.

6.3 One of the initial objectives was to discuss with the farmers details of the management practices which they had been using. It was found that:

- There was a lack of detailed knowledge concerning the chemicals being used because the chemical companies simply provided the spraying regime without further details;

- The information in the initial discussions diverged from observations in the field showing that the information was not reliable and probably involved positive feedback mechanisms;

- The identification of individual fields and their management is difficult in practice;

- Inevitably farmers do not remember details of what has happened several years ago, which is what is required if details of management practices and their impact are to be determined;

These conclusions have been confirmed in subsequent discussions with MAFF and suggest that this approach is unlikely to be fruitful.

6.4 It was noted during the field work that changes can take place on very different timescales which affect vegetation differentially. There are four principle scales:

- Immediate eg poaching within grassland which can take place within several hours on a wet night and can totally alter the species composition;
- Days, weeks and months eg grazing patterns over a yearly cycle, although this can extend to the next category in years;
- Years eg flailing in hedgerows has been shown to gradually open up the bottom of the hedge, leading to decline in vigour;
- Decades eg canopy closure in a forest stand.

6.5 It was found that plots that have changed greatly in their species composition were mainly due to the following factors:

- Change in land cover class eg barley to grass;
- Direct positive management eg spraying;
- Cumulative management change eg verges;
- Absence of management eg loss of sheep;
- Incremental change eg hedge bottoms;
- Environmental impact eg salt application by roadsides

6.6 Plots that are observed to be stable were mainly due to the following factors:

- Lack of management eg ancient woodland;
- Stable low inputs eg heaths in high mountains;
- Stable intense management eg mowing of grasslands on roadside verges;
- Intense recreational management eg golf courses;
- Stable agricultural management eg the maintenance of pure rye grass swards for silage production.

6.7 One of the principle conclusions was that a range of management practices were either unexpected or were far more complex than had been initially thought. Two examples of these are provided below. Firstly, an example of an unexpected impact, that of the indirect effects of afforestation which was shown to have the following attributes:

- Polarisation of land use;
- Decrease in stream water flow;
- Drying out of flushes;
- Modification of nutrient flow in rivers;
- Fragmentation of areas of semi-natural vegetation;
- Change in the grazing patterns of sheep;
- Isolation of areas of high land surrounded by forestry;
- Effects of clear-felling;
- Increase in deer numbers.

Many of these factors have been discussed in the literature but it had not been appreciated that together they were making such a cumulative impact.

An example of the more complex management than had been expected is shown by verge management which is summarised below:

- Inherent ecological character of the vegetation concerned;
- Variation across the width of the verge which can be from totally unmanaged to high-intensity cutting within one metre;
- The productivity of the vegetation;
- The status of the vegetation at any given time;
- Cumulative effect of management treatments;

- The angle of the verge which, although usually flat, can be very steep, especially in the west country.
- The character of the soil surface since very wet conditions are easily disturbed by flailing;

- The width of the swathe cut at the edge of the road or whether it takes place at all;
- The impact of salt deposition which varies regionally and according to the road characteristics;
- The nutrient effect of oil deposition breakdown;
- The time and frequency of cutting;
- The use of mowers as opposed to flails.

7. UPLAND STUDY

This section includes a report on the state of the main part of this study. In addition, in conjunction with the National Trust in Cumbria, a pro forma was developed to record recreational impact. However, in the 31 km^2 visited during the survey, there were no examples whatever of such impact which has been widely observed in the Lake District and in other upland areas such as the Peak District and Dartmoor. Furthermore, with one exception (the West Highland Way), no walkers at all were seen in any of the sample sites. Whilst this only represents a snap-shot, these results suggest that recreational impact is very site-specific and through the uplands as a whole, is not a widespread problem. The majority of visits by walkers and climbers are to well-known famous locations. Such a conclusion has been previously pointed out in various meetings of the Adventure and Environmental Awareness Group meetings held in Cumbria.

THE IMPACTS OF POLLUTION ON BIODIVERSITY IN THE GREAT BRITISH LANDSCAPE

Howard, D.C., Van de Poll, H. M., Smart, S.M., Hack, V. and Bunce, R.G.H.

Progress report

The spatial variation in nitrogen in two moss species (*Racomitrium lanuginosum* and *Sphagnum recurvum*) and heather (*Calluna vulgaris*).

The aim of this project is to investigate the potential contribution of atmospheric pollutants to the determination of plant geographical distributions and investigate the interactions with other factors such as grazing and local environmental effects. The species were selected for their reported differential sensitivity to atmospheric nitrogen (Baddeley *et al.*, 1994).

As described in the previous progress report, sites for survey were selected using the Countryside Survey 1990 'X' quadrats to identify where the two mosses occurred in a sample square. As only a limited number of sites could be visited, a selection of squares with the highest occurrence of moss in the quadrats recorded in CS90 was made. Squares were chosen initially where only four out of five of the 'X' plot quadrats contained one or both species. A second selection was made using total NO_x deposition in 1992 to guarantee a range of pollutant levels.

Once in the field, difficulties of gaining permission to survey and collect samples and difficulty in locating *R. lanuginosum* led to an alteration of the sampling regime with samples being taken at a number of locations which were not Countryside Survey 1990 sites. The distribution of sites is shown in Figure 1 and the ITE land classes of the sampled squares is shown in Table 1.

Table 1 The distribution of sample sites in ITE land classes. Those squares surveyed in 1990 are separated from those which were revisited

Land Class	*Resurveyed*	*First visit*	*Total*
17	1	2	2
18	2	1	3
19	1	1	2
21	5	4	9
22	3	1	4
23	3	2	5
24	4	3	7

Samples of the three species were collected in the field, where possible immediately neighbouring a quadrat location used in Countryside Survey 1990. Grazing was recorded in terms of species of herbivore in location and quantity of droppings. The local morphology of the landscape was also recorded detailing the position of the species in the context of the immediate neighbourhood.

Once the samples were returned to Merlewood, they were prepared for chemical analysis by the removal of previous years' growth. The material was then fine ground. The Environmental Chemistry Section at ITE Merlewood are performing the chemical analysis and the nitrogen results should be ready by mid-April. Analysis of carbon and phosphorus will be carried out, dependent upon the initial nitrogen analysis, in late spring/summer.

The relationship between the nitrogen levels in different species collected at the same location will be examined in an attempt to identify if the species show is similar response to differing levels of atmospheric pollution. This may not be the case as atmospheric pollutant levels vary over different time-scales (eg day, week and season) and the sensitivity of different species may equally vary over the same time-scales.

The variation of nitrogen levels within a species will be investigated using spatial analysis and geostatistics. Additional datasets, including the Land Cover Map of Great Britain and the field survey data (including soils) from Countryside Survey 1990 (see Barr *et al.* 1993). As just under half of the sites were visited for the first time during the survey of 1997, the analysis will be divided where necessary to maximise the use of available information. So, for example the soils information available for those squares surveyed in 1990 will include a 1:10,000 scale soils map drawn up by either SSLRC or MLURI, will include vegetation information describing the vegetation classes and for some of the squares (those surveyed in 1978 as well), soil characteristics such as pH and organic carbon (determined by loss on ignition). The squares first visited will have information such as the dominant and sub-dominant soils, but only from the 1:250,000 scale published soil maps and the vegetation will be only that recorded during the survey (which was late in the season, to maximise the seasons growth and grazing).

One problem with the analysis will be the atmospheric nitrogen concentration or deposition levels. The surfaces used to describe the levels are generally presented as 20 km x 20 km grids, it is possible to generate surfaces at greater resolution, but the data used to generate the surfaces are spatially sparse. Although the variation within a lowland 20 km square may be small, in complex upland landscapes there is known to be great uncertainty (Smith *et al.*, 1995). The relationship between different samples collected within the same square, and values collected from sites falling within the same 20 km square may give some measure of the problem.

It is hoped that the relationships identified between the different variables will allow a testable hypothesis to be generated which will suggest possible mechanisms and processes. If such a hypothesis can be generated, it may be possible to repeat the sampling in Countryside Survey 2000.

References

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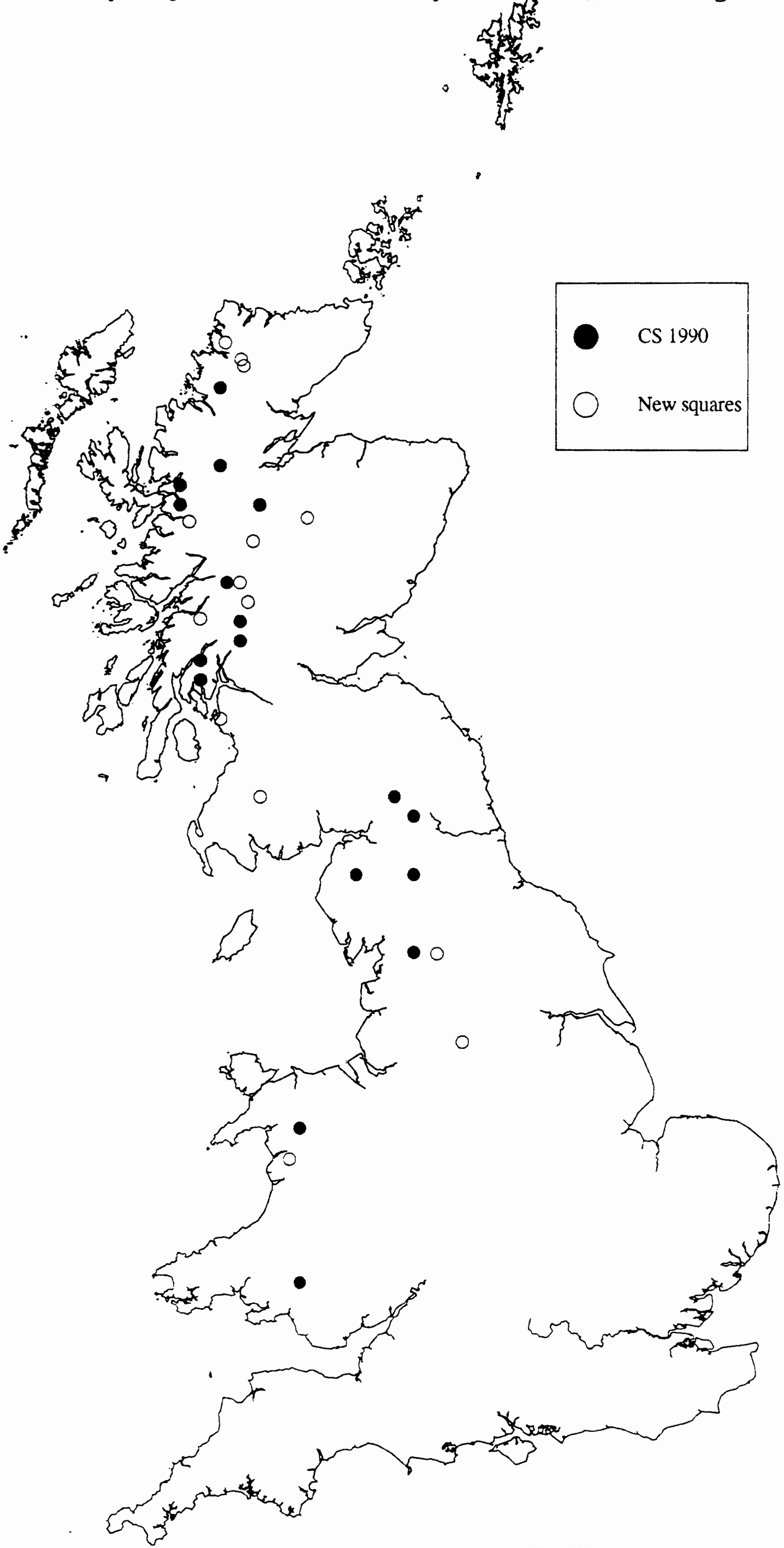
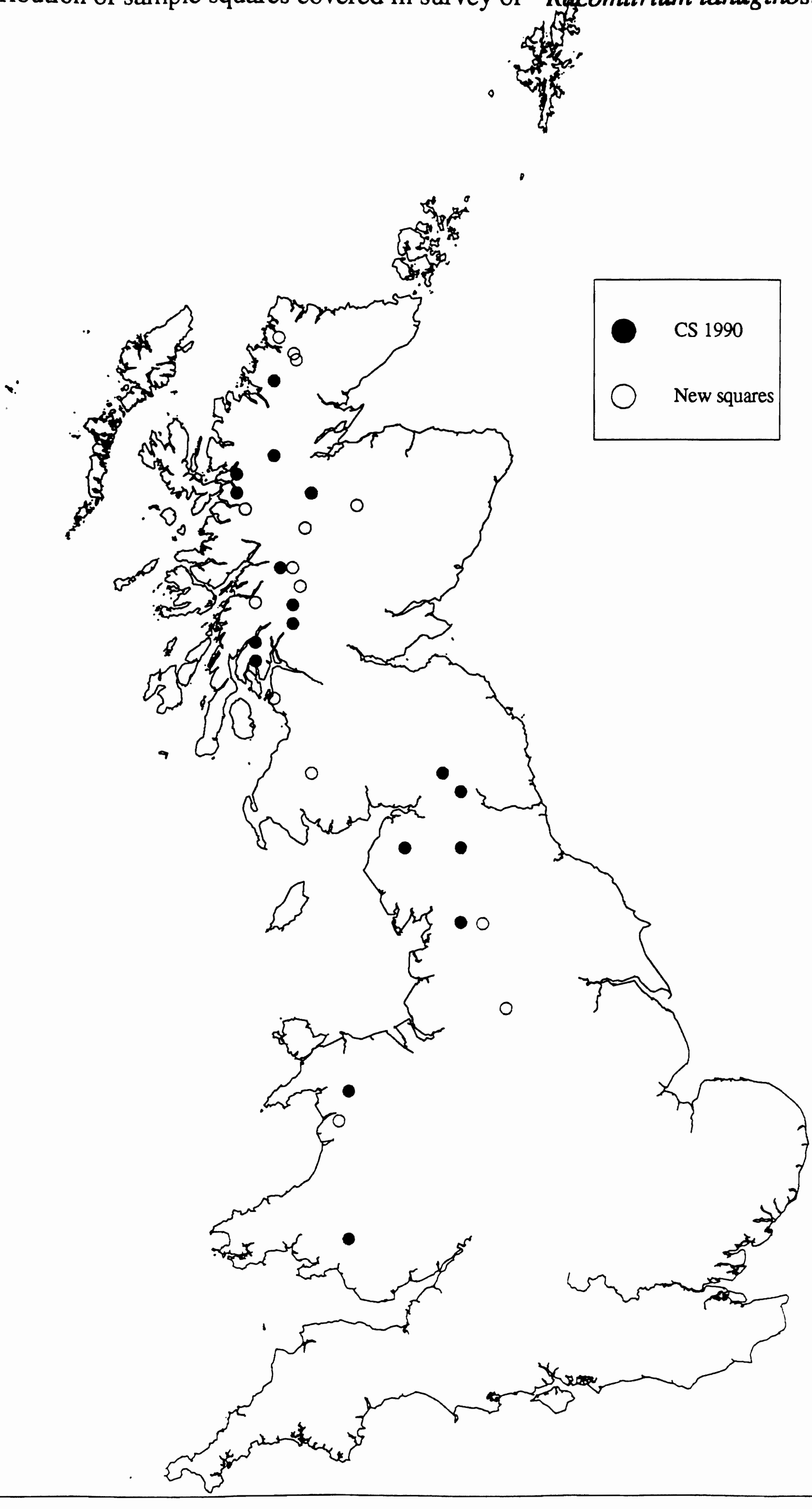
Distribution of sample squares covered in survey of ***Racomitrium lanuginosum***



Distribution of sample squares covered in survey of *Racomitrium lanuginosum*



8. ANALYSIS OF CHANGE IN FUNCTIONAL TYPES

The report of these changes is included in this section.

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. This may provide better 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 of an analysis of the 1978 data from plots that were classified as belonging to the particular ecotope group in 1978 and the 1990 data from the plots that were classified as belonging to the same 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 of the 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.

		Plot type				
Landscape type	Ecotope group	Hedges	Road verges	Streamsides	Main plots	All plots
Arable	Crops (1)	*	*	*	(2)	**4**
	Tall grassland (2)	**8**	**6**	(2)	*	(6)
	Eutrophic g'land (3)	*	(0)	(1)	(0)	(0)
	Lowland g'land (4)	*	*	**5**	**8**	**7**
	Lowland wds/hdgs (5)	**5**	*	**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)	(6)
	Lowland g'land (4)	(4)	(3)	**7**	**5**	(5)
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	(2)	*	0
	Upland g'land (7)	*	*	(2)	(3)	(1)
	Bogs/heaths (8)	*	*	(7)	(1)	(0)
Pastural	Crops (1)	*	*	*	(1)	(1)
	Tall grassland (2)	(1)	(2)	(2)	*	(0)
	Eutrophic g'land (3)	*	(2)	(1)	(1)	(3)
	Lowland g'land (4)	(2)	**6**	**5**	(3)	**9**
	Lowland wds/hdgs (5)	(3)	*	(5)	*	(2)
	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)	*	*	*	**2**	**11**
	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)	*	*	*	(1)	(2)
Tall grassland (2)	(7)	(2)	(2)	*	(2)
Eutrophic g'land (3)	*	(0)	*	(3)	(2)
Lowland g'land (4)	(4)	(6)	(4)	(6)	(9)
Lowland wds/hdgs (5)	**2**	*	*	*	**4**
Acid woods (6)	*	*	(9)	*	**11**
Upland g'land (7)	*	*	(0)	(8)	(6)
Bogs/heaths (8)	*	*	*	(5)	(3)

Table 1. 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)	*	*	*	**8**	**8**
	Tall grassland (2)	(5)	(0)	(0)	*	**6**
	Eutrophic g'land (3)	*	(2)	-	**9**	**4**
	Lowland g'land (4)	*	*	(1)	(0)	(1)
	Lowland wds/hdgs (5)	**4**	*	-	*	(4)
	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)	-	**5**	-	(6)	(1)
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	(1)	*	(3)
	Upland g'land (7)	*	*	(1)	(6)	(5)
	Bogs/heaths (8)	*	*	-	(0)	(1)
Pastural	Crops (1)	*	*	*	(0)	(0)
	Tall grassland (2)	(2)	(2)	-	*	(3)
	Eutrophic g'land (3)	*	(0)	-	(1)	
	Lowland g'land (4)	-	**8**	**7**	(1)	(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)	3
	Bogs/heaths (8)	*	*	(6)	(3)	(1)

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

Table 2. 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)	*	*	*	(3)	**8**
	Tall grassland (2)	**8**	(6)	(5)	*	(5)
	Eutrophic g'land (3)	*	**7**	**2**	(3)	(4)
	Lowland g'land (4)	*	*	(0)	**6**	(6)
	Lowland wds/hdgs (5)	**4**	*	(0)	*	**8**
	Acid woods (6)	*	*	*	*	*
	Upland g'land (7)	*	*	*	*	*
	Bogs/heaths (8)	*	*	*	*	*
Marginal upland	Crops (1)	*	*	*	*	*
	Tall grassland (2)	(0)	*	*	*	*
	Eutrophic g'land (3)	*	(2)	*	(3)	(5)
	Lowland g'land (4)	(1)	**12**	(5)	(2)	(6)
	Lowland wds/hdgs (5)	*	*	*	*	*
	Acid woods (6)	*	*	(0)	*	(5)
	Upland g'land (7)	*	*	(2)	(1)	(3)
	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)	(2)	**6**	**10**	(3)	**12**
	Lowland wds/hdgs (5)	(1)	*	(5)	*	**11**
	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)	(4)
	Upland g'land (7)	*	*	(6)	(3)	(2)
	Bogs/heaths (8)	*	*	**5**	(2)	**9**

All landscape types	Plot Type				
Ecotope Group	Hedges	Road verges	Streamsides	Main plots	All plots
Crops (1)	*	*	*	**11**	**13**
Tall grassland (2)	**9**	(7)	(4)	*	(2)
Eutrophic g'land (3)	*	(5)	*	(1)	(5)
Lowland g'land (4)	(3)	**12**	**11**	(4)	**12**
Lowland wds/hdgs (5)	(1)	*	*	*	**12**
Acid woods (6)	*	*	**9**	*	(5)
Upland g'land (7)	*	*	(4)	(2)	(6)
Bogs/heaths (8)	*	*	*	**6**	**10**
Grand Total					

Table 3. 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.

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

Table 3 contains the results of the analysis of data from plots grouped according to the ecotope group into which they were 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 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, predictive traits of species ecology (e.g. leaf mineral nutrient contents). 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 variables. 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. Increases in 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. Changes are masked by the lack of change or contradictory changes in other landscape types, when all landscape types are analysed together. Changes in both road verges and hedges 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 intensively managed therefore unlikely to be further changed. The only change is seen in the marginal uplands where intensification may be less advanced but 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, as 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' theory 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 its own processes of change, both streamside and road verge plots having correlations that suggest inconclusively processes of dereliction or eutrophication. The ecotope group for the whole landscape type suggests strongly the process of eutrophication. This is a very prominent 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 diverse habitats. There is also an indication of dereliction, a process indicated for all streamside plots.

Upland grassland showed 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 5 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 change being largely due to change in a limited part of the landscape.

Eutrophic grassland again shows very little change except for 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 changing between ecotope groups. 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 to road verges in the pastural and marginal upland landscapes, to streamsides in the pastural landscape, and also when all of such 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 slight indication given in many smaller groupings all indicate the same processes, lending weight to the conclusion.

Lowland woods and hedges. Relatively few plots were available for analysis in the individual landscape types, however both showed increases of large, competitive species. The results for all plot types in the pastural landscape 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 finally confirmed in the 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 caused by the proportion of these plots that changed enough to shift between ecotope groups by 1990, those that didn't shift staying quite constant.

Upland grassland shows very little functional changes. The large numbers of correlations in the marginal uplands and summary groups are collections of distribution related traits not indicative of any 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 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. 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.

Tall 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 is 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 consistent processes of changes 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.
- Dereliction of **eutrophic grassland** in the pastural landscape and in road verges.
- Dereliction of **eutrophic grassland** streamside plots in the arable landscape.
- Eutrophication and dereliction of **tall 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**.

9. VERGE STUDY

The summary report presented at the Technical Sub-Group Meeting is included in this section. It is proposed to continue the recording during the coming summer.

EcoFact 6A - Understanding the causes of change in biodiversity in linear features; a study of Cumbrian roadside verges.

Introduction

The contribution of linear features to national biodiversity has been widely recognised although with a focus largely on hedgerows, field boundaries and watercourses. Roadside verges have, by comparison received relatively scant treatment although of the 1271 species and aggregates recorded in the CS90 survey 58% were recorded at least once on roadside verges.

Regarding change between 1978 and 1990, analysis of countryside survey road verge plots revealed a trend towards verge types typical of overgrown conditions and a reduction in the representation of species groups associated with unimproved grasslands. Also a statistically significant drop in mean species number per verge plot from 15 to 13 was detected in arable landscapes.

In the light of these findings a study was set up to elucidate the effects of management practices and the nature of the vegetation itself on the trajectory of vegetation change. Cumbrian road verges are ideal since from 1992 to 1994 a survey of all roadside verges (excluding trunk roads and motorways) was carried out by Cumbria County Council. The key results were threefold:

1) An inventory of roadside verges according to ITE verge type.
2) A series of management prescriptions for each verge type designed to enhance and maintain plant species richness and the floristic character of each type whilst also fulfilling road safety requirements.
3) A series of 'special' verge segments designated to reflect the particular rarity or diversity of the plant assemblages present based upon comparison with the total range of variation in Cumbria.

This framework enabled us to make a random selection of road verges containing 'special' segments where both the management and the vegetation type of the whole junction to junction section was known. Table 1 shows management prescriptions and vegetation types and indicates that verge type dictates cutting frequency and timing. The only management differences attending designation as 'special' is that a full width cut is required every two years rather than four if undesignated. To ease practical implementation of the management prescriptions the smallest length of verge to be managed homogenously was defined by the council as a node to node section of road ie. from one junction to another. Only a part of the length of a section so specified may be 'special' although the entire section will be managed as if it were.

Methods

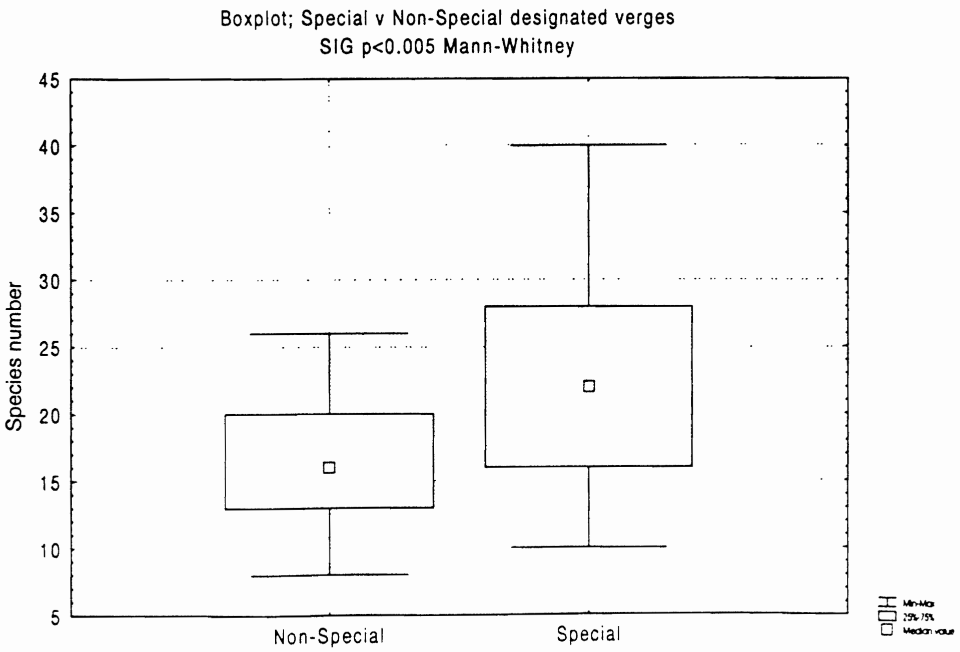
Thirty verges containing 'special' segments were randomly selected from throughout the county. As can be seen from the location map the distribution of selected verges appears skewed towards the east region. In fact 75% of all special verges are in the east since this reflects the greater exposure of limestone in this region. Only six out of eleven verge management types and therefore vegetation types were represented since the remaining five types were not considered eligible for selection as 'special' verges. The other two key criteria for selection were that the verges should contain quadrats sampled by the council surveyors in the 1992 survey, also that part of the verge be undesignated to enable comparison between 'special' and non-'special' in terms of vegetation characteristics and trajectory under the same treatment.

Vegetation recording followed the standard countryside survey method for linear plots. Within each designated and undesignated section three quadrats were located repeating the 1992 quadrats in the same location where present. Quadrats measured 1x10 metres with the road edge marking one 10 metre edge of each. Rooted presence of all species was recorded and a cover value estimated to the nearest 5%. Additional species present in a 1x10 metre width adjacent to the first plot moving away from the road were also recorded. Additional measurements were made of litter, vegetation height, disturbance and adjacent boundary details.

To acquire a more accurate species record each plot was visited in May and again in July. To assess the structural impact of the seasonal management cycle plots were visited at the end of September at which time leaf litter, bare ground and sward height were re-recorded. The cut swathe width was also measured and photographs taken.

A preliminary comparison of special and non-special verges

Designation of special verges by county council surveyors was carried out after rapid evaluation of each verge in terms of its ITE type, apparent species richness or/and the additional presence of uncommon species such as *Dactylorhiza* spp. An initial comparison of species richness between special and non-special verge segments confirmed that differences in verge quality could, in our dataset, be expressed at least in part by differences in plant species numbers within representative quadrats. The graph below gives a comparison based upon May data. A significant difference (p<0.01) was also obtained when July species numbers were compared.



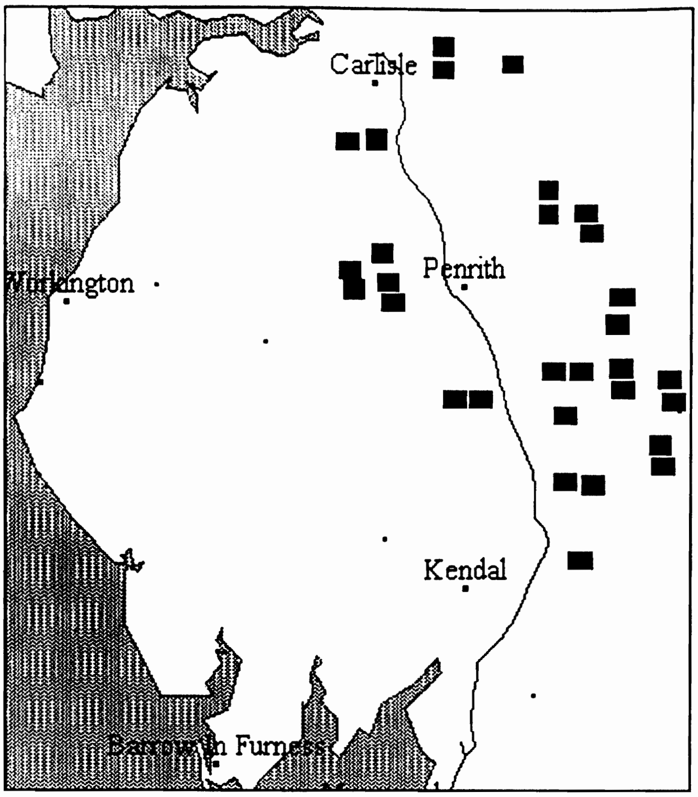
Further analyses

1) The trajectory of the vegetation in each verge segment, both designated and undesignated, will be analysed by ordination of quadrat data from 1992 and 1996. Interpretation of changes will be assisted by testing for correlations between weighted quadrat scores for key plant attributes eg. canopy height, CSR strategy with the position of plots on ordination axes.

2) Differences in species richness both in space and time will be further explored using analyses of variance.

3) Structural changes due to management will be summarised and used to elucidate results from 1).

Map showing approximate location of verges sampled for EcoFact 6a



10. HEDGEROW TRANSECTS

A brief report on the status of this study is included in this section.

Hedgerow transects

Objective

The results of a student project to analyse changes in species composition in Cumbrian hedgerows between 1978 and 1990 have already provided insights into the factors driving observed trends whilst taking into account spatial differences in species composition between plots. Since the hedgerow itself represents an environmental and botanical gradient often related most strongly to management factors a more detailed analysis of within-plot variation may reveal with added clarity ecological patterns associated with hedegrows that have changed through time as well as being different in space. The objectives are therefore as follows:

- To characterise the botanical gradient extending away from the centre of a random sample of Cumbrian hedgerows.
- To relate this gradient to environmental conditions so that variation can be attributed to abiotic conditions and management effects.

Methods

During the summer of 1996 linear plots originally recorded from Cumbrian hedgerows in 1978 were resampled. A total of 82 plots were recorded and within each two transects were laid out perpendicular to the line of the hedge with one end starting from the centre of each. Species abundance was recorded along each transect alongwith estimates of bare ground, litter and bryophyte cover.

Proposed analyses

Analysis of the more detailed within-plot transect data will incorporate the following:

- Description of hedgerow data by Cumbrian vegetation classes
- Description of transect data in terms of species richness, individual species abundance and Ellenberg scores
- Multivariate analysis of transect data
- Multivariate correlation of transect variables with transect attributes such as distance from centre of hedge, vegetation height and adjacent management

11. RIVER HABITATS STUDY

During the field work programme for the River Corridors Survey carried out by the Institute of Freshwater Ecology (IFE) for the Environment Agency, two types of information were collected for this project in addition to the standard procedure.

- The management characteristics of the vegetation by the stream were recorded in a standard way so that information would be available to co-ordinate with the data on changes on riverside vegetation between 1978 and 1990. For example, vegetation by streamsides where the animals graze right up to the waters edge is very different from the vegetation on ditches within arable land.

- A standard CS1990 riverside quadrat 1 x 10 m^2 was recorded in the centre of the management unit so that the management characteristics could be subsequently linked to the plot classes of the unified classification within which the changes were linked.