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INTERIM REPORT
(Modules 1 & 2)

ECOLOGICAL FACTORS CONTROLLING BIODIVERSITY IN THE BRITISH COUNTRYSIDE (ECOFACT)

Module 1 **Measuring the Quality of Botanical Diversity in the Wider Countryside and**

Module 2 **Development of Links to Other Surveys and Classifications**

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CONTENTS

1. Summary of Progress

1.1 This section itemises the work programmes for the three modules covered by this report together with the principal objectives and the progress that has been made on the various items. Inevitably in such a complex work programme some items have proceeded quicker than expected, but conversely others have experienced some delay. The Technical Sub Group for Modules 1 and 2 met on the 14 May 1996 when a presentation was made of the progress on the project. It was agreed subsequently with DOE that the present interim report would summarise the results to date and would be supported by appendices which would be made available to anyone who requires further detail. The objectives below are as included in the tender document to the DOE. The project started on 1 September, months remain before completion of the first years work.

1.2 Module 1A

1.2.1 Objectives

- To improve the measure of change in species composition.
- To describe ecological associations within vegetation.
- To characterise the changes in terms of plant strategy theory.
- To develop indicators of environmental quality, (ie. species indicative of high quality in particular habitats).
- To provide information to the CIS.
- To develop statistical procedures for estimating errors in vegetation samples.

1.2.2 The main items of work are as follows:

Year One

a. Development of statistics programme;
b. Modification to CIS software to allow input of national estimates based on quadrat data;
c. Construction of classifications;
d. Comparison with environmental data, and land cover
e. Analysis of stock and change for areal and linear features;
f. Estimation of national figures;
g. UCPE : analysis of data in terms of plant strategy theory;
h Consultation with conservation agencies re. 'quality species';
i. Preparation of interim technical report.

Year Two

j. Collate response from consultation exercise;
k Interpretation of UCPE analysis of stock and change data;
l. Interpretation of results for each vegetation category;
m. Comparison of linear and areal features;
n. Application of quality criteria;
o. Development of hypotheses on causes of change as input to

Module 6;

p. Input of results onto CIS;
q. Organise seminar;
r. Hold seminar;
s. Produce final technical report;
t. Produce draft of scientific papers.

Year Three

u. Complete scientific papers.

1.2.3 Progress

a. The statistics programme has been completed.

b. The necessary modifications have been defined and DART computing are currently implementing the changes.

c. The classification has been constructed.

d. Land cover and species frequency have been compared with the classification and the analysis of environmental data is in hand.

e. Stock and change have been analysed for aerial and linear features, but further more detailed, work is required for individual vegetation classes.

f. National figures have been produced for the area covered by vegetation classes together with standard errors and estimates for linear features are in hand.

g. Initial analyses have been carried out, further more detailed work is planned for the autumn.

h. This item of work has been delayed because of staff changes and will now be started in the autumn.

i. Covered by the present report.

j, n, q - u Have not yet been started.

k, l, m, n & o Work has already commenced on these items, some of which is as reported in the present document.

1.3 Module 1B

The work on this Module, funded by NERC, has been delayed because of staff changes, however, some initial analyses are included.

1.4 Module 2A

1.4.1 Objectives

- To provide vernacular descriptions of CS1990 vegetation categories.

- To provide a comparison of the classifications produced in CS1990 with those from other surveys.

- To compare the vegetation classes with quadrat data recorded in Northern Ireland (NI).

1.4.2 Work Programme

Year One

a. Develop multivariate methods for allocating new data to existing classifications;
b. convert statistics to a general-purpose computer programme;
c. produce descriptions of CS1990 vegetation classification;
d. liaison with Dr Andrew Malloch to obtain NVC source data in a suitable format;
e. use statistics programme to allocate CS1990 classes to NVC;
f. use statistics programme to allocate N Ireland quadrats to CS1990 classes;
g. compare CS1990 plot classes with JNCC Phase 1/Biodiversity targets/Habitats directive classifications, based on interpretation of definitions;
h. produce interim technical report.

Year Two

i. Liaise with DART Computing to make necessary amendments to LUCID software;
j. interpret NVC/CS1990 comparison; enter new information onto LUCID.

1.4.3 Progress

a. A variety of multivariate methods have been compared and two have been selected from the comparisons.

b. Work is currently proceeding with DART Computing to produce the general purpose programme.

c. The CS 1990 vegetation classes produced in the Main Report have been compared with phase one habitat survey categories. In discussion with DOE it was decided not to proceed further with descriptions of these classes, but to concentrate the effort on the classes produced in Module 1A (item g. below).

d. & e. Discussions with Dr Andrew Malloch and Dr John Rodwell have revealed that the source data is not a suitable format for direct comparison using the statistical procedure 2.13.4 in section 2.13. The existing MATCH and TABLEFIT programmes cannot therefore be improved. The subcontract to Lancaster University has therefore been modified to enable Dr John Rodwell to participate in the Technical Sub Group for Modules 1 and 2 and to comment on the relationship between the classes produced in Module 1A and the NVC.

f. Dr Alan Cooper is currently carrying out a joint analysis of Northern Ireland and GB quadrats in order to determine the relative overlap between the vegetation.

g. Work is in progress to compare the classes produced in Module 1A with other relevant classifications.

h. Covered in the present document.

i. Discussions have been held with DART Computing and appropriate amendments to LUCID software are in hand.

j. Work has commenced on the comparison of the classes used on Module 1A with NVC and further detailed analyses will be carried out in due course.

2. Methodology

Foreword

2.1. The main objective of these Modules is to define the range of variation and change within the vegetation of the wider countryside and to relate this to other classifications concerned primarily with semi-natural, relatively undisturbed vegetation. Within much of lowland Britain, such vegetation is fragmented, or occurs within designated areas. However, previous work in the Ecological Consequence of Land Use Change (ECOLUC) project showed that considerable botanical capital still remained in such landscapes, especially in linear features. The sampling approach employed, described in the CS 1990 Main Report, is designed to determine the relative contribution of these elements.

2.2 Within the uplands the vegetation is relatively undisturbed, so that there is a greater degree of correspondence between the relevant CS 1990 main plot classes and say, the National Vegetation Classification categories. By contrast, much of the vegetation on intensively farmed agricultural land is highly disturbed. There also will inevitably be differences between the classes produced because of the contrast between random sampling and the selection of relevées within selected, homogeneous vegetation units.

2.3 The difference between the intuitive approach, developed on the continent and phytosociology and quantative vegetation science was extensively discussed in the literature of the 1960's. The random sampling procedures used in CS 1990, inevitably miss many areas of vegetation of high floristic interest to phytosocologists. For example the gradient of vegetation within a lake margin may proceed from aquatic vegetation, with water lilies, through reed beds, to fen and woodland within 10 metres. Whilst these zones would be treated separately for phytosociological analysis, they are likely either to be missed by random sampling or an individual quadrat may straddle the intuitive boundaries between them. Module 8 of the ECOFACT programme is concerned with the different approaches to vegetation monitoring and analysis and further explores the different objectives and procedures followed.

2.4 The main part of the present Interim Report describes the procedures and initial results of the analysis of vegetation and change in the wider countryside (Module 1A). The approaches to developing links with existing vegetation classifications are also described, in which analogous procedures to those developed under the Land Cover Definition Project (LUCID) are to be used. The principal results currently achieved are presented in the present Interim Report, with supporting appendices being available on request.

2.5 The main procedures and concepts followed in the statistical analyses of the vegetation data are described in the CS 1990 Main Report. In summary, TWINSPAN was used to classify the sample quadrats into relatively homogeneous classes, which were then aggregated intuitively into groups of classes depending upon their relative positions on the first DECORANA axis. The entire data set includes both those plots sampled in 1978 and 1990, as well as all the additional plots only recorded in 1990, in order to determine shifts between classes and to produce the matrix of change. Separate classifications were constructed for random plots, verges, hedgerows and stream sides.

2.6 The sample plots are classified into relatively homogenous plot classes according to their species composition. All species, including taxonomic aggregates are used for this purpose but only the taxonomically sound species (category 1) are used to assess change in species number. The plot classes may then be described, either by their vegetation characteristics or by the environments in which they are growing. In the same way as the plots can be classified, so can the species be classified into groups (species groups), that show similar ecological amplitudes, with respect to the major environmental factors. Both can then be ordered according to the principal gradient within the vegetation data, so that the species groups and plot classes are ordered in the same way to give structure to the tabulations. As the principal gradient is from vegetation typical of highly disturbed nutrient rich situations to stable vegetation in nutrient poor conditions, so the arable fields contain species groups consisting of weeds whereas at the other extreme moorland contains species groups of plants from the uplands. This procedure is the same as that used in phytosociology and is as represented graphically in the CS 1990 Main Report. The species groups have not yet been constructed and are part of the next phase of the work programme.

2.7 The same general procedures were followed in the present analyses with two main exceptions described below. Firstly, whilst analysing the data for the calcareous landscape in the Threatened Habitats project, data from roadside verges were incorporated with samples drawn from open countryside in order to determine whether fragments of chalk grassland remained in the landscape outside the main land cover parcels. Although these quadrats were of a different size it was found that species composition overrode this difference and that the verges had affinities with overgrown, tall grassland rather than from herb rich vegetation in calcareous situations. The verges therefore had little to contribute to the capital of chalk grassland even although some deep road cuttings have rich assemblages. The success of this combined analysis of vegetation at the landscape level, to determine the contibution of different elements in the landscape, led to the decision to assess the potential of incorporating all quadrats from CS 1990 into a unified analysis. Such a procedure is designed to identify similar assemblages of species in different landscape elements and to provide therefore a useful measure of biodiversity, at the vegetation level. Furthermore, it would result in a single classification with which users could gain familiarity rather than the four different classifications used in the CS 1990 Main Report.

2.8 Accordingly, a combined analysis of all quadrats recorded in 1978 and 1990 was carried out in what is termed, "the unified classification". The results from this analysis were readily interpretable with the inherent characteristics of the species composition of the plants overriding differences in quadrat size. Sensitivity tests were considered, but were difficult to design and the stability shown in the first two analyses carried out led to the decision discussed further in 3.1.5.

2.9 A variety of procedures have been used to determine the number of final classes to accept from the TWINSPAN analysis. The most consistent procedure and the one most applicable to different analyses, is to set a minimum size for members of a class, and then to stop the division if the number falls below that size. The principal alternative of examining the variance within the classes is impractical because different parameters within the classes show different variances. The above procedure has the advantage that it could be applied in exactly the same way to both the GB data set for DOE (under Module 1A) and the England and Wales data set for MAFF(under Module 1C, not covered in this report) and will also be used for the SOAEFD Module . Inevitably, the number of final classes will differ but will reflect the degree of variation within the data since the analytical procedure in general divides areas of high botanical variation more finely. The division was allowed to the third level, of eight classes before this procedure was applied and then terminated at the sixth level, with those classes with over 300 plots being taken to the eighth division.

2.10 The second difference to the CS 1990 procedure was that, in order to have a standard procedure to apply to the three major analyses, an agglomerative statistical procedure was used to group the TWINSPAN classes into smaller, more general groups of classes according to their ecological affinities. Ward's minimal variance was adopted for this purpose, using the first three DECORANA axes with the aggregation being taken to a number of groups (termed hyper-classes) considered as appropriate according to the structure of the hierarchy (eight in the DOE analysis and six in the MAFF analysis). In discussion with DOE, it was decided in addition to use expert judgment to determine an intermediate number of classes that would match as closely as possible the categories used in the Biodiversity Steering Group Report. In this way strict numerical rules are applied to classes subjected to statistical analysis, but judgment is used to match divisions that are comparible to an existing classification.

2.11 Whilst a relatively large number of final classes is required to express the variation within the data, many of the classes do not have sufficient plots to determine change between 1978 and 1990. As in the CS 1990 main report therefore the major analysis of change have been carried out using the hyper-classes structure within the four landscape types determined by aggregation of the ITE land classes. Subsequent data may be extracted from some of the larger classes that have an adequate number of plots to enable statistical comparisons to be carried out. The unified classification allows comparisons of change to be carried out at the landscape level, rather than as previously by different elements, such as hedges. One of the conclusions of the CS 199 Main Report was that the characteristics of the species being lost, were similar between elements e.g. meadows were lost from fields, hedges and streams. If such trends were consistent across landscapes, then it would be expected that the observed changes would increase in their level of statistical significance. The results reported below will discuss this hypothesis in relation to the work programme, but the next stage in the analysis will need to examine the elements separately, in order to determine whether the trends are in the same direction. The unified classification will be instrumental in providing a common basis for such comparisons.

2.12 The procedure for determining the standard errors associated with estimates of the land cover is described in Appendix 1 of this report. Previously the vegetation classes have only been reported as the number of plots present within them. However, within each kilometre square there are five plots which are representative of the vegetative area available which depends upon how much land is covered by urban, water or sea. The procedure that has been developed for the estimation of the relative areas occupied by the vegetation classes uses the relative weights by kilometre squares, accumulates the variance by land class and then determines the standard error for GB. The principles of the procedure are the same as those described for land cover given in the CS 1990 Main Report and are currently being incorporated into the CIS to enable regional estimates of the relative cover of vegetation classes to be determined. The same principles apply to the estimation of the proportion of vegetation classes in linear features except the weightings are determined by relative lengths of the feature concerned. The targeted plots for nature conservation cannot be assessed in this way since they are not placed at random. The procedure is discussed further in Appendix 1.

2.13 In discussions held during the preparatory work for this Module it has become clear that there are a variety of different levels at which comparisons can be made between classifications. These levels are partly determined by the requirements of the comparison and partly by the level of detail available concerning the base data. Vegetation data are continuously variable and therefore, except in exceptional circumstances, there are no gaps between groups of individuals that form a given class compared with a neighbouring class. There is an extensive literature identifying analytical procedures appropriate to vegetation classification, incorporating philosophical and statistical considerations, which are familiar to vegetation scientists, but not to users unfamiliar with such analytical procedures. Differences between classes may be due to data collection methods, the domain covered by the sample or by analytical procedures. Figure 1. shows a base classification defined in a series of classes on the first two axis of an ordination using the classic procedure of expressing the space occupied within the vegetation class. On top of this basic classification two other classes, A and B have been superimposed. Class A, fits within the range of one of the initial classes i.e. it reflects a finer division within the range of that class. Class B, overlaps several different classes and therefore is not mutually exclusive to any one class. This diagram presents the central problem of Module 2 in which the objective is to demonstrate the links between different classifications. There are four principle levels which need to be considered:

2.13.1. Intuitive comparison using expert judgement. This approach can be carried out at a variety of levels of detail. For example some classifications have only a one line description of a vegetation class whereas others have a wealth of supporting information. The comparisons carried out for land cover definitions reported in LUCID provide an example of the way such comparisons can be formalised. The report on Northern Ireland in the present project (Appendix 2) is a example of this approach. The proliferation of classifications without adequate supporting data lead to difficulties in making comparisons and inevitably there is rarely any quantative measure of the degree of similarity between classes.

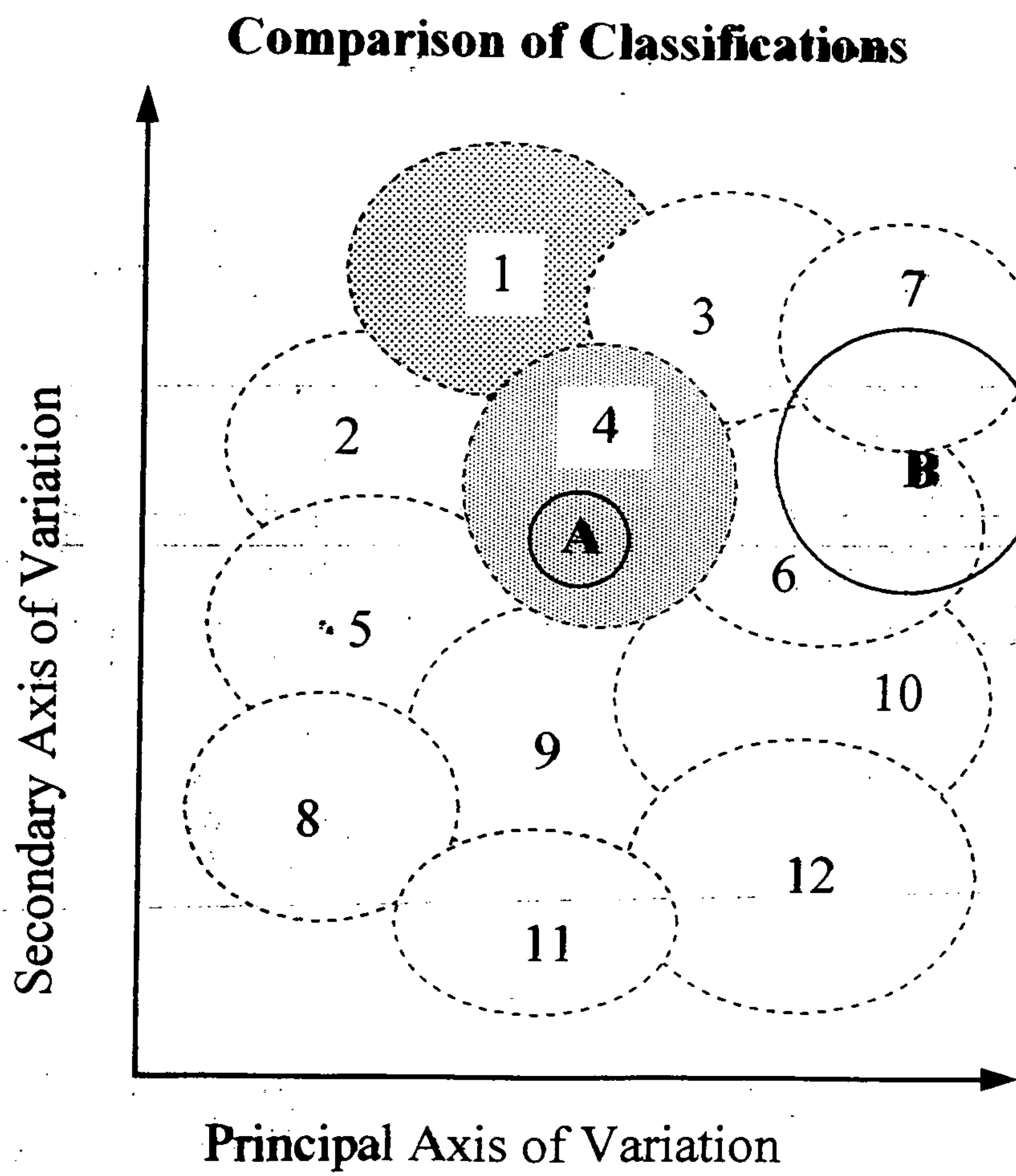
2.13.2. Distance measures can be used if the average composition of a class is known in terms of species frequency or from constructed association tables which may include information on constancy. The MATCH and TABLEFIT Programmes use this approach which inevitably ignores the internal variability present between the component vegetation samples combined within a given class either from analysis or by interpretation.

2.13.3. Ordination scores from the initial analysis can be held relatively easily within a data base management system. The composition of a new vegetation sample can then be determined by using these scores in order to make a comparison between the composition of a new plot with the existing unified analysis. A computer procedure (Convex hulls) is being developed to present such comparisons graphically and will be available eventually on the CIS.

2.13.4. A statistical analytical procedure allowing for variability between samples is necessary to effect a full statistical comparison. A variety of techniques have been considered in the present project and the procedure involving classification and Regression Trees has been selected as being the most efficient in computing time and statistical robustness. A general purpose computer programme to execute this procedure is currently being developed.

Figure 1.

Diagrammatic representation of a base classification compared with two classes derived from different data sets. One and four are shaded to indicate that the outlines are made up of constituent points representing plots.



therefore be used as a good measure of biodiversity, as described in the CS 1990 Main Report. The preparatory work in ECOLUC described the three main levels used in assessing biodiversity within vegetation, all of which depend on the analysis of the basic species data.

- Vegetation classes.
- Species groups.
- Species number.

In some landscapes, as reported in the Threatened Habitats Project, these will coincide, but in others they will differ in ranking.

3.1.2 The classification produced 100 classes with a further class consisting of plots from saltmarsh vegetation; the latter was omitted from the classification, as in the CS 1990 procedure, because they are so different from the rest of the population. Another class is taken up of plots which fell onto bare ground; these need to be included in the calculations of vegetation area since they occupy a proportion of the sample. The classes are ordered according to their position on the first axis of the DECORANA ordination, rather than in the sequence that comes from the TWINSPAN output, this is because within such a large analyses vegetation classes with similar ecological affinities may occur in widely different parts of the hierarchy. For example some vegetation classes from arable fields occurred within the first division of the TWINSPAN classification, whereas others were identified in later sections of the hierarchy.

3.1.3 The programme for calculating the error terms associated with the calculated area covered by the vegetation classes gave figures for class one of 3834 km square with a standard error of 843 and for class ninety-four 2825 km square with a standard error of 541. These figures are similar to those attached to the landcover estimates in the CS 1990 Main Report and are the first produced for vegetation classes at a national level. The estimates for the remaining classes are currently being carried out.

3.1.4 The dendrogram of the Ward's method clustering of DECORANA scores is given in Figure 2. The eight hyper-classes were the level below which fragmentation took place. Provisional names have been attached to the hyper-classes, but further discussion is required before they are finally determined. The final level of the dendrogram suggest that there is a degree of similarity between some of the classes, but it was decided to keep them separate as they were likely to be different in some aspects of their species composition. Interpretation of the species frequency and cover data described below also suggest that this number of classes (100), although technically required to express the variation may be too difficult to interpret to match traditional classifications in a readily available format. In discussion with the DOE, it was concluded that an intermediated level of classification was required to provide a link with the Biodiversity Action Plan recommendations and the recent Steering Group Report, as mentioned in the methodology section. This intermediate level will be defined using ecological judgement.

3.1.5 As mentioned in the methodology section, it is useful to examine the relative positions of the classes upon the first two axes as determined by the ordination procedure DECORANA (Figure 3). These axes are abstracts, but can be interpreted in terms of the ecology of species at either end of the gradient. The axes are constructed only in terms of their species composition and do not contain any environmental information, although most ecologists interpret them in environmental terms. In the GB analysis the primary gradient is from vegetation from arable fields through to short term grasslands, lowland grasslands, upland grasslands and, at the opposite extreme, heath and bog. Within the arable fields the vegetation is made up of species from highly disturbed and nutrient rich soils whereas at the opposite extreme it is made up of species from nutrient poor peats and podzols. The secondary gradient identifies woodland vegetation at one extreme whereas at the other the vegetation from arable fields and heath and bogs are in a similar position on the gradient since neither has an affinity with woodland cover. Figure 3 presents the position of the 100 classes on the first two axes with the eight hyper-classes being separated by arbitrary lines, which tend to over emphasise visually the differences between them. These points represent the centre of all the sample plots which fell into each of the classes in order to simplify the overall picture. If the full spread of points were included, there would be a great degree of overlap between the classes, as shown in Figure 1. Nevertheless both hyper-class one and eight are separated to some degree from the other classes, suggesting that there are major differences between these two and the other six classes. This is supported in ecological terms since in the former case the vegetation is the result of cultivation practices whereas in the latter the vegetation received no inputs from agriculture, only a loss of nutrients by leaching and removal of sheep. A similar separation was reported in the Cumbria Survey carried out in 1975. The third axis identifies a small group of classes which are linked by association with high water levels. These three gradients i.e. nutrient level, shade and water level can be recognised in the main vegetation analyses and it is interesting to note their pre-eminence within the totality of British vegetation.

3.1.6 A critical question posed at the initial stage of interpretation was whether the unified analysis adequately represented the variation within the plots or whether the difference in quadrat size overrode ecological affinities. The simplest way to examine this was to compare the frequency of the principal types of plots i.e. whether they were at random, by hedges, streams, verges or targetted within the classes. The interpretation of these diagrams, one example of which is shown in Figure 4 and the remainder in Appendix 3, confirmed that there were complex mixtures of different plot types within many of the classes, although some classes tended to be dominated by certain categories. These could be explained ecologically, as demonstrated in Figure 5 in which the hyper-classes one and eight are almost completely dominated by the random plots which would be expected, as these extremes cover extensive areas of open countryside throughout GB. By contrast hyper-class two, the tall grasslands, is usually associated with linear features which fits knowledge of its ecology. Similarly hyper-class seven constitutes mainly of the targeted plots, suggesting that in the uplands these plots were selected in upland grassland or flushes which are more species rich than the surrounding heaths and bogs, within which they are intimately mixed.

3.1.7 As mentioned in the Methodology Section, the classes are arbitrary points along a continuum. An illustration of this is shown in Figure 6 where the average cover of some of the most important species in British vegetation has been smoothed across the classes. Within this diagram *Lolium*, occurs at the eutrophic end of the gradient, but shows considerable overlap with *Arrhenatherum*, although not necessarily within the same quadrats. *Agrostis capillaris* covers almost the entire range of classes whereas *Calluna* and *Eriophorum vaginatum* only occur in the more upland classes. The wide ecological range of species with high cover emphasises the difficulty in using dominant species to identify vegetation classes which are determined by the full species compliment.

3.1.8 Any given kilometre square will contain combinations of the different vegetation classes and the patterns may be described firstly within the landclasses and secondly within the four landscape types described in the CS 1990 Main Report. Figure 7 shows the frequency of the classes within the four landscape types and indicates the complexity that is present within the series. The arable landscape has a degree of overlap, mainly between Classes 41 and 57, with upland landscapes, but otherwise the two extremes are mutually exclusive. The marginal uplands contain a wide range of vegetation classes expressing the contrasts between the vegetation of the valley bottoms and the upland areas, and the surrounding matrix of upland vegetation. One class 41, a lowland grassland, is present in appreciable quantities in all four landscapes, reflecting the fact that it can occur in a wide variety of situations. The heights of the columns also demonstrate the abundance of the relative extent of the classes, thus class 15, which is typical of overgrown roadsides, is the most common in arable landscapes but is also present in significant numbers in the pastural landscape. Similarly class 31, a highly modified eutrophic grassland, is the most abundant in pastural landscapes and is also widely present in arable landscapes . When full descriptions are available of the classes (as shown in Figure 10) these will be used to describe the landscapes in terms of their detailed vegetation composition.

3.1.9 In the ECOLUC Report various presentations of vegetation data were given to express the degree of variation within British landscapes, but a completely integrated view could not be presented. The unified classification enables this analysis to be carried out and is presented in Figure 8, where the landclasses are ordered from those containing lowland vegetation to those with upland characteristics. Surprisingly, even in the intensively management arable landscapes of the lowlands of E. Anglia (landclasses 12, 4, 11 and 3) there is a similar degree of variation to the remainder of the lowlands. This is because small fragments of vegetation still remain in the landscape in the various plot types and as expressed by the variation within the vegetation classes. The four land classes containing the largest number of plot classes are all within the pastural landscape (15, 16, 5 and 6). The major division is however between the lowlands and the marginal upland and uplands that i.e. that from landclass 17 up to 30. These latter have distinctly fewer plot classes present compared with the lowland series, although individual land classes e.g. 17, 28 and 29 have larger numbers than some individual ones in the lowlands. If mean figures alone had been presented at the landscape level, this variation would have been omitted. This breakdown is explored further below in the analysis of the different categories of plot.

3.1.10 Figure 9 shows the comparison between land classes of the average number of plot classes for the different elements of vegetation. Most of the plot types are similar in their level of diversity - this is very surprising especially when it is considered that the targeted plots were specifically placed in areas of more superficially diverse vegetation. This consistency is perhaps due to the variation in vegetation at the landscape level being too complex to appreciate using intuititive judgement. Further analysis is required because it could well be that some of the plot types may contain vegetation types unique to that situation, which are not present elsewhere in the landscape. For example in a non-wooded arable landscape the only likely vegetation with woodland affinities is likely to reside within hedgerows. The exception to this general pattern is that the boundary plots in the uplands show less variability, reflecting the open nature of moorland landscapes. The lower level of diversity overall in the uplands corresponds with the overall variation in occurrence of plot classes discussed in paragraph 3.1.9 and again the division after landclass 17. Thus, the present analysis at the landscape level supports the generally held belief that there is more variation in the lowlands even though it is compressed into linear features and fragmented sites, rather than forming extensive areas.

3.1.11 Figure 10 presents a demonstration of a layout which is designed to provide a basic description of the vegetation classes. One of the limitations of the CS 1990 Main Report was in the lack of adequate descriptions of the numerically derived vegetation classes. The trial layout of Figure 10 will be used as a basis for discussion with the DOE and with the conservation agencies on the best format to enable interpretation of the results. The relevant sections of Module 2A, which will provide the links between these classes and other available classifications e.g. Phase 1 Survey will also be incorporated into the descriptions in due course. The short description included at present is based on intuitive interpretation, but in due course will be fully quantitative e.g. the linkage of a particular vegetation class and soil type will be made by the overlaying of the locations of the plots with the soil maps produced by the ground survey.

3.2 Interpretation of Change

3.2.1 Table 2 presents the gross changes in species number between 1978 and 1990 in all paired plots, regardless of whether the individual plot had changed classes. There are 40 combinations of landscape types and vegetation hyper-classes compared with 30 combinations in the comparable table of the CS 1990 Main Report, since there are eight hyper-classes as opposed to six aggregated groups previously. Hyper-class one is directly comparable with the crops group of CS 1990. Hyper-class two represents a new aggregate since this type of vegetation is not represented in the open landscapes which were included in the comparable table in the CS 1990 Main Report. Hyper-class three is comparable to the improved grassland, hyper-class four to the semi-improved grassland, hyper-class seven to the upland grass mosaics and hyper-class eight to the heaths and bogs. The single woodland class in CS 1990 Main Report is divided into lowland wood and hedges (five), on the one hand, and acid woodlands (six) on the other. It must also be borne in mind that in this analysis, using the unified classification all plots are considered together, regardless of their position in the landscape.

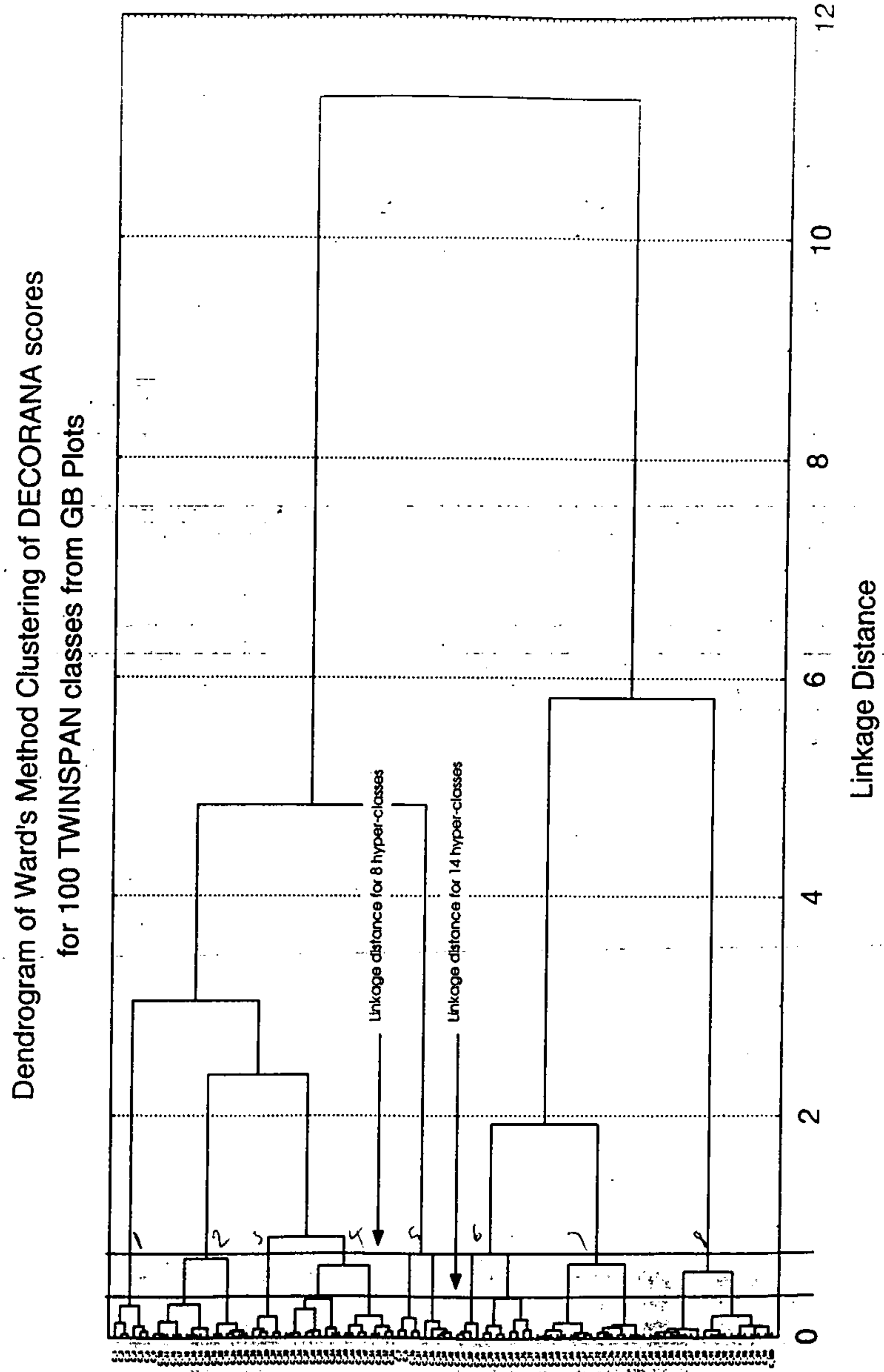
3.2.2 The results show that ten of the cells have increased in significance level or have crossed the boundary into being significant, whereas previously there was only an indication of the direction of change. Furthermore, the direction of change in virtually all cases is the same as in the previous analysis. This result suggests that changes are taking place at the landscape level since the direction of change in different elements must be in the same direction, otherwise they would cancel each other out. As commented previously, species typical of meadows are known to have been lost from hedges, stream sides and grasslands. It may be that the processes causing these changes are convergent, or on the other hand that different processes end up with the same result. For example eutrophication of stream sides may cause an increase in species such as *Urtica* at the expense of more sensitive species such as *Valeriana*, whereas an increase in nitrogenous fertiliser application to a field would cause a similar change. The next stage therefore is to analyse the landscape elements separately and to integrate the results with the analyses currently being undertaken in Module 6.

3.2.3 The major new finding is that the separation between the two woodland hyper-classes has revealed that the lowland woods and hedges are gaining species, whereas the acid woodlands are losing species very significantly. This result was masked in the CS 1990 Main Report since the loss of species in woodlands as a whole overrode the differences between the two contrasting situations. Taken in conjunction with the results from the analysis concerning plant strategy theory described below, this finding suggests that the creation of a separate Module 1B was justified and that a work programme could well be necessary to further investigate these changes. Hyper-class two shows the smallest degree of change, perhaps because it was already overgrown in 1978 and is relatively stable. Within the upland context there is a marked divergence between the upland grassland as opposed to the heaths and bogs with the former having lost species, whereas the latter has gained species significantly. This is perhaps due to the same process of change acting on different starting points in vegetation terms since these hyper-classes are intimately mixed within a common matrix in the uplands. Whilst this is true of the uplands and GB as a whole, a difference has emerged between the pastural and marginal upland landscapes in that under the new aggregation, significant losses in both these classes are reported in the pasture landscape, but significant gains in the marginal uplands. The underlying structure of these changes will be analysed further in the next stage of the analysis.

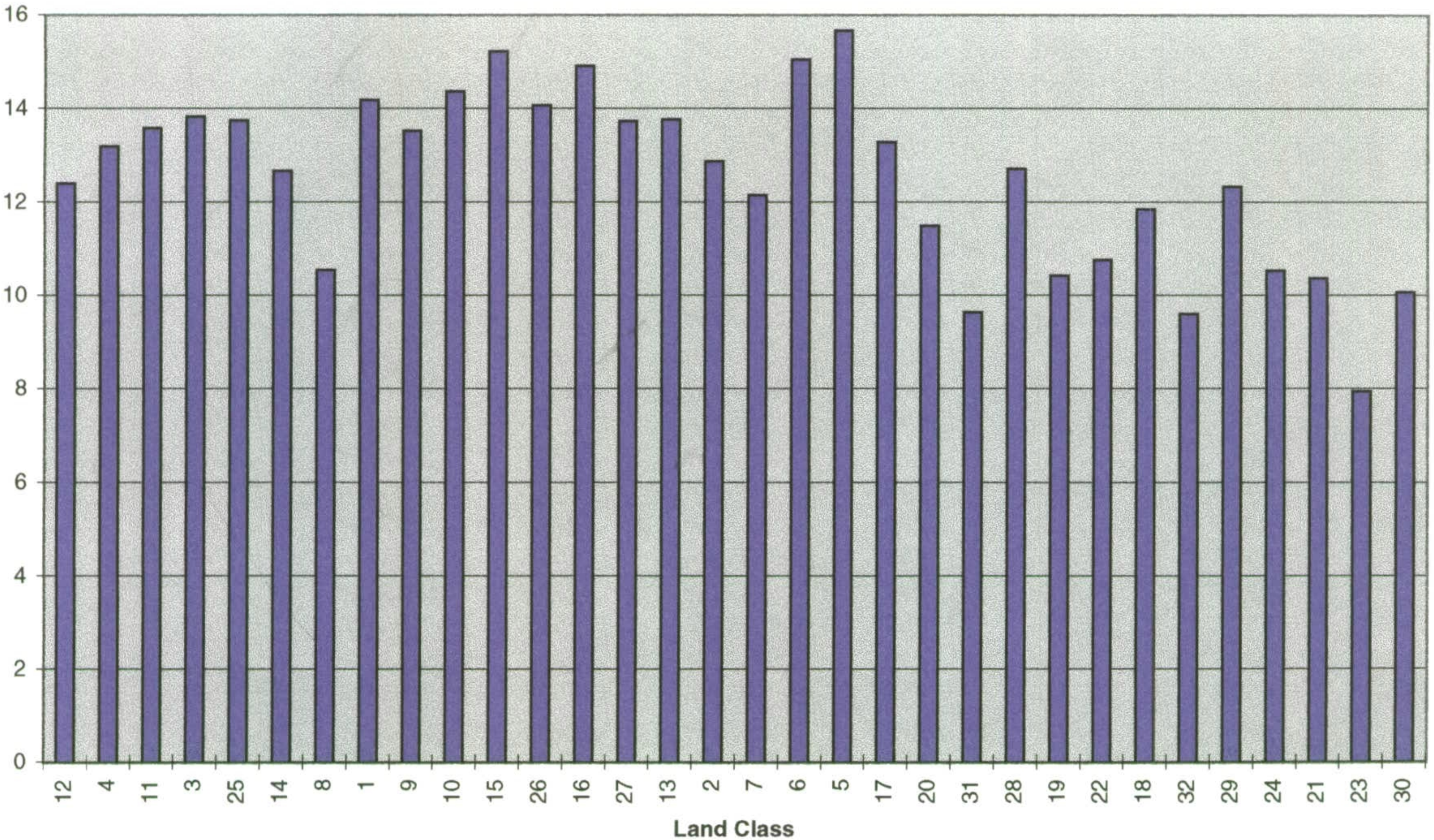
3.2.4 Table 3 shows the significant changes in individual species which have taken place between 1978 and 1990 and which underly the changes in species number reported in the previous section. Within the crops hyper-class 10, individual species have declined significantly between 1978 and 1990. With two exceptions, these are all broadly weeds confirming the shift, previously reported towards graminaceous weeds - although there has been no actual overall increase in species such as *Alopecurus myosuroides*. There are few changes within the tall grass hyper-class, confirming the suggestion made above that this category is relatively stable. In the eutrophic grasslands hyper-class, although there was no significant overall loss of species a considerable number have changed significantly suggesting that changes have taken place not linked to species loss. In the lowland grasslands 23 species have changed significantly in frequency, in all cases in a negative direction. Whilst some of these species are not likely to be considered of conservation significance e.g. *Ranunculus repens,* others such as *Lotus corniculatus* are of importance to conservation and reflect the loss of meadow species previously reported. The pattern of change in the woodland categories is far from clear with some evidence of species indicative of disturbance e.g. *Bromus sterillis* expanding in the lowland woods and *Agrostis stolonifera* expanding in the acid woodlands, perhaps indicating eutrophication. In the upland grasslands the situation may well be confused by the impact of afforestation and newly afforested quadrats in 1978 need to be removed from the analysis before further conclusions can be drawn. Within the uplands it is interesting that the *Ericaceous* species, *Calluna* and *Erica tetralix* have declined, whereas *Carex binervis* and *panicea* have increased.

3.2.5 Table 4 shows the significant changes in cover between 1978 and 1990. Relatively few species achieve significant cover, over 5%, and the number of species involved is therefore small. As expected the covers in the crop hyper-class are very low with some evidence of an increase overall in the cover of grassland species, perhaps due to undersowing. Within the tall grassland hyper-class there are 11 species which have changed significantly, all but two have increased in their cover and all are species from eutrophic or overgrown situations - linking to the conclusions subsequently described in the section of plant functional strategies. Within eutrophic grasslands there have generally been reductions in cover which could be due to the increasing use of silage, which leaves fields more frequently bare of cover than traditional hay making. The woodlands show a similar pattern of decline in species frequency with a majority of species showing the same patterns. There are few changes within the upland grasslands and in the moorlands the most striking changes are the decrease in four *Ericaceous* species. As with the previous section further analysis is required to separate the changes between the different elements in the landscape.

Figure 2. Dendrogram of Ward's Minimal Variance Clustering Procedure of the DECORANA scores for the 100 classes of the unified classification.



Average Number of Plot Classes per 1 km sqr for each Land Class



This is the [illegible]

Figure 4. Relative proportions of different plot types in 12 examples of the 100 classes of the unified classification. R & V = roadside plots, S & W = streamside plots, B = boundary plo H = hedge plots, X = random plots and Y = targeted plots.

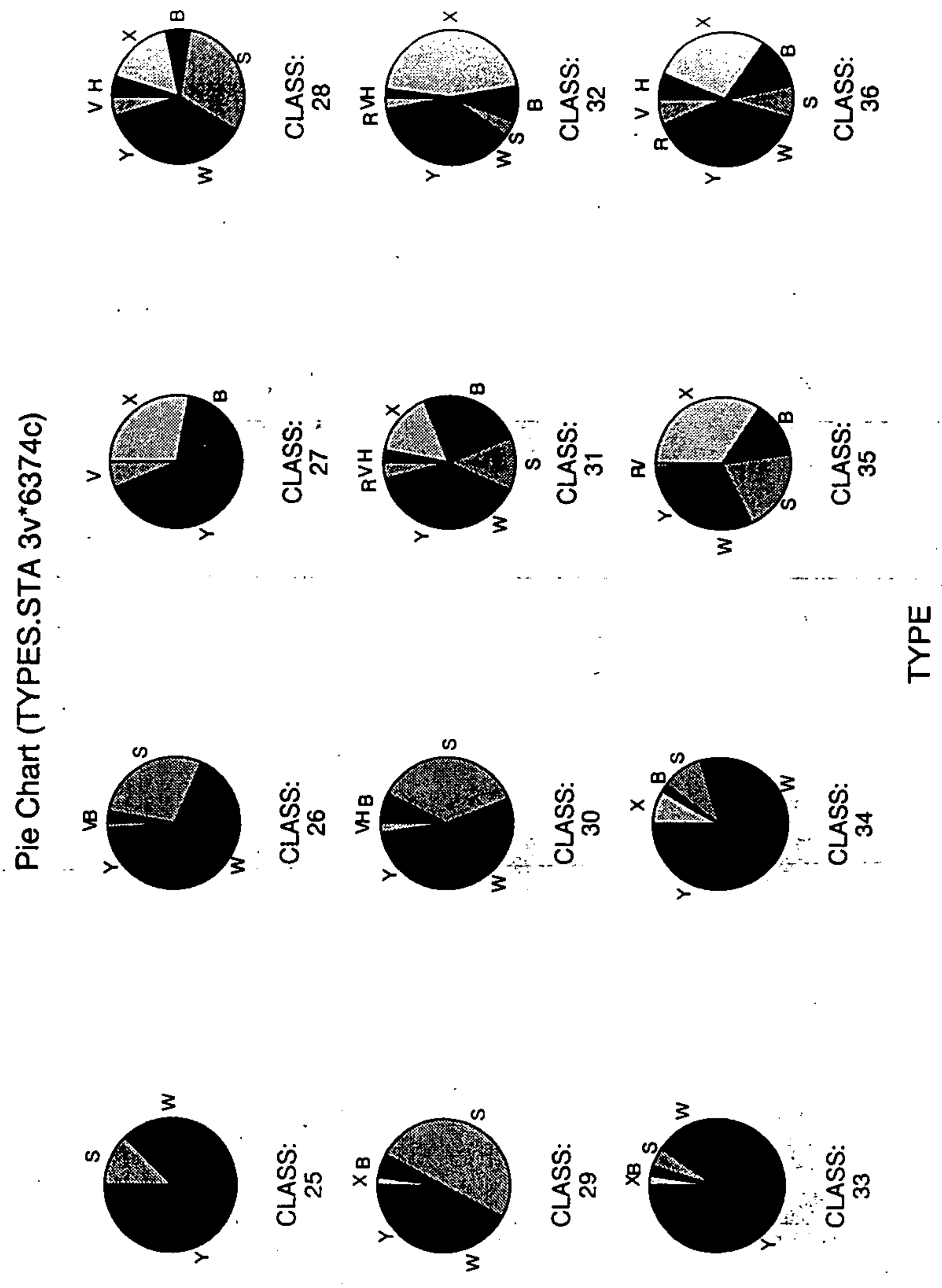


Figure 5. The dominant plot types of Figure 3 plotted onto average scores for the first two DECORANA axis of the unified classification. X = random, Y = targeted, R = roadside, H = hedge, S = streamside and B = boundary.

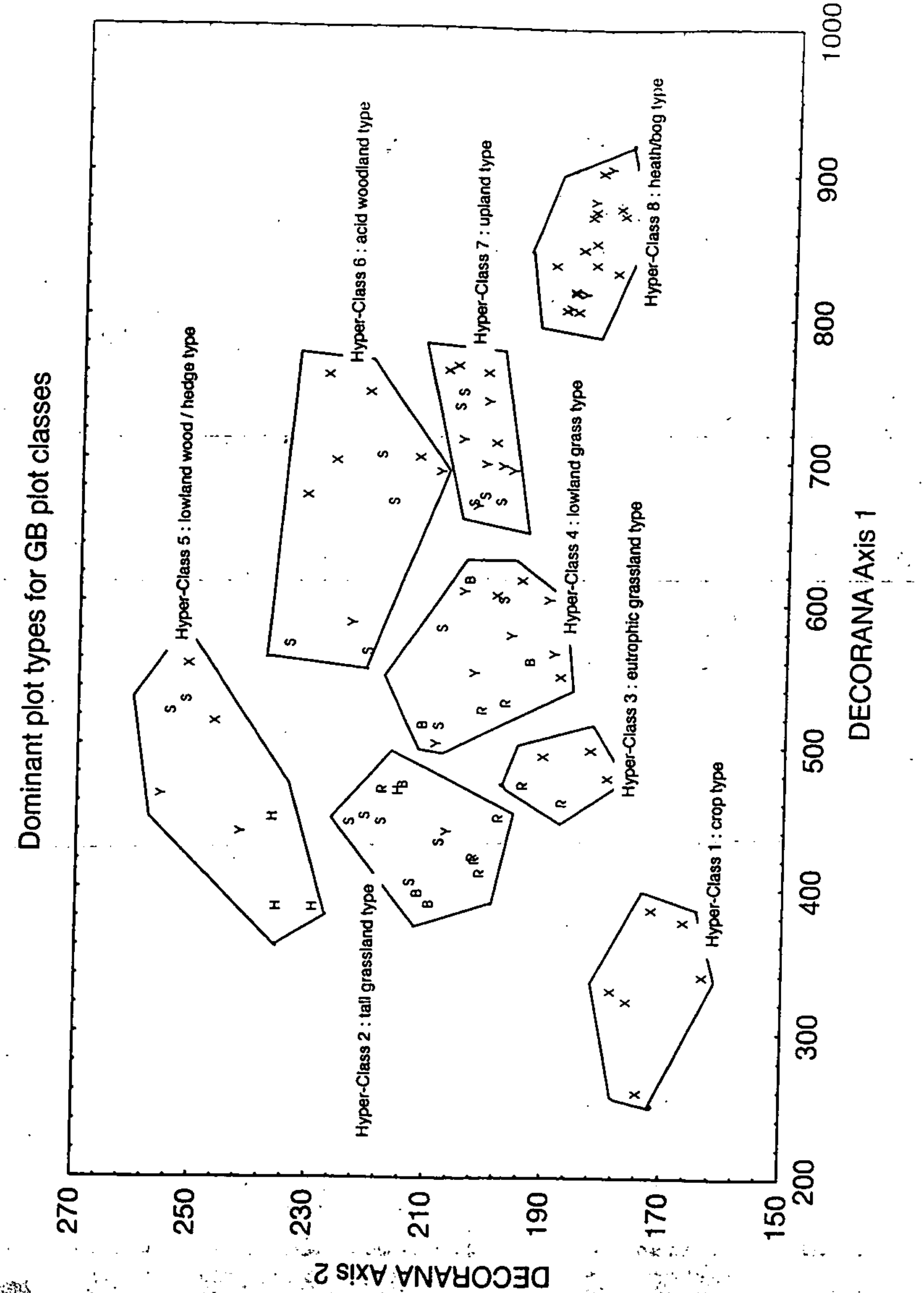
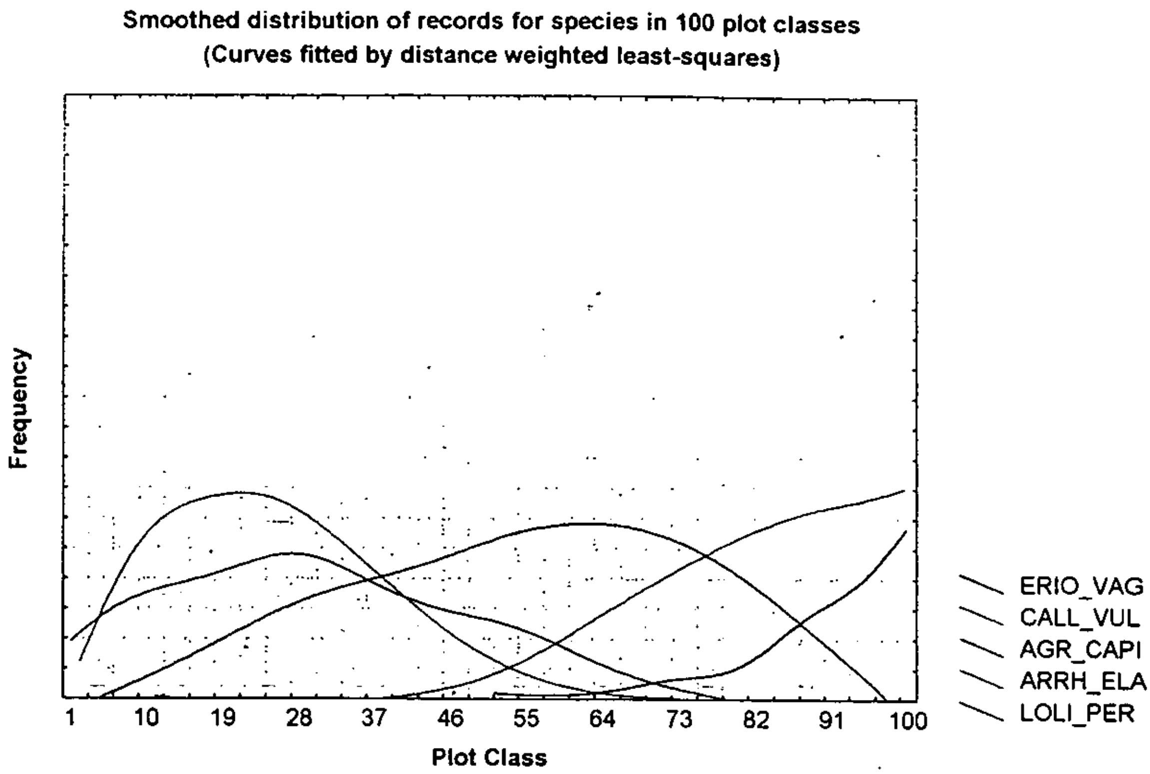


Figure 6.



Smoothed distribution of records for species in 100 plot classes
(Curves fitted by distance weighted least-squares)
Frequency
1
10
19
28
37
46
55
64
73
82
91
100
Plot Class
ERIO_VAG
CALL_VUL
AGR_CAPI
ARRH_ELA
LOLI_PER

Figure 8. Average number of plot classes in the kilometre square of the 32 land classes added in a lowland to upland series.

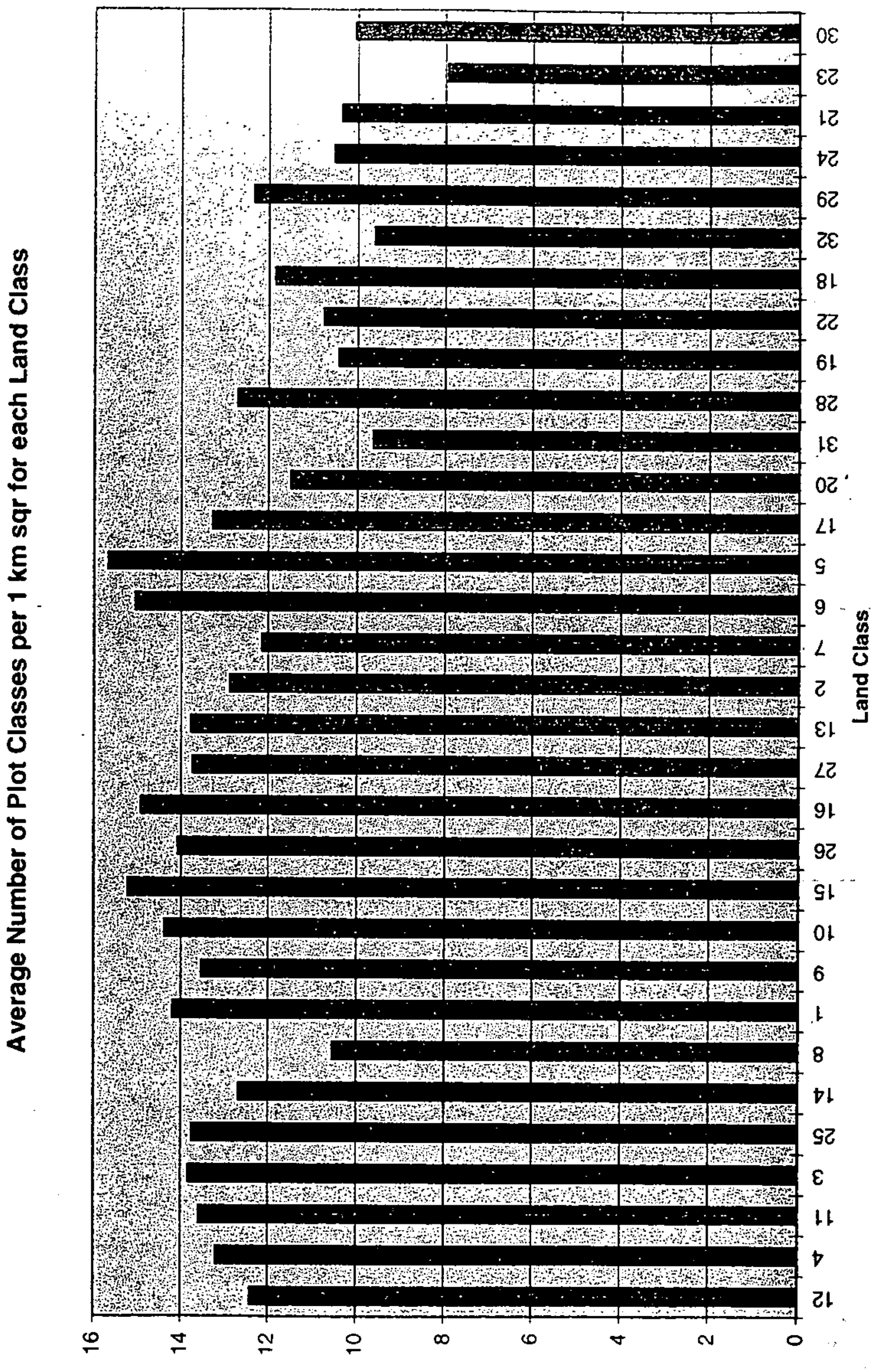


Figure 9. Average number of plot classes by plot type in the 32 land classes added in a lowland to upland series.

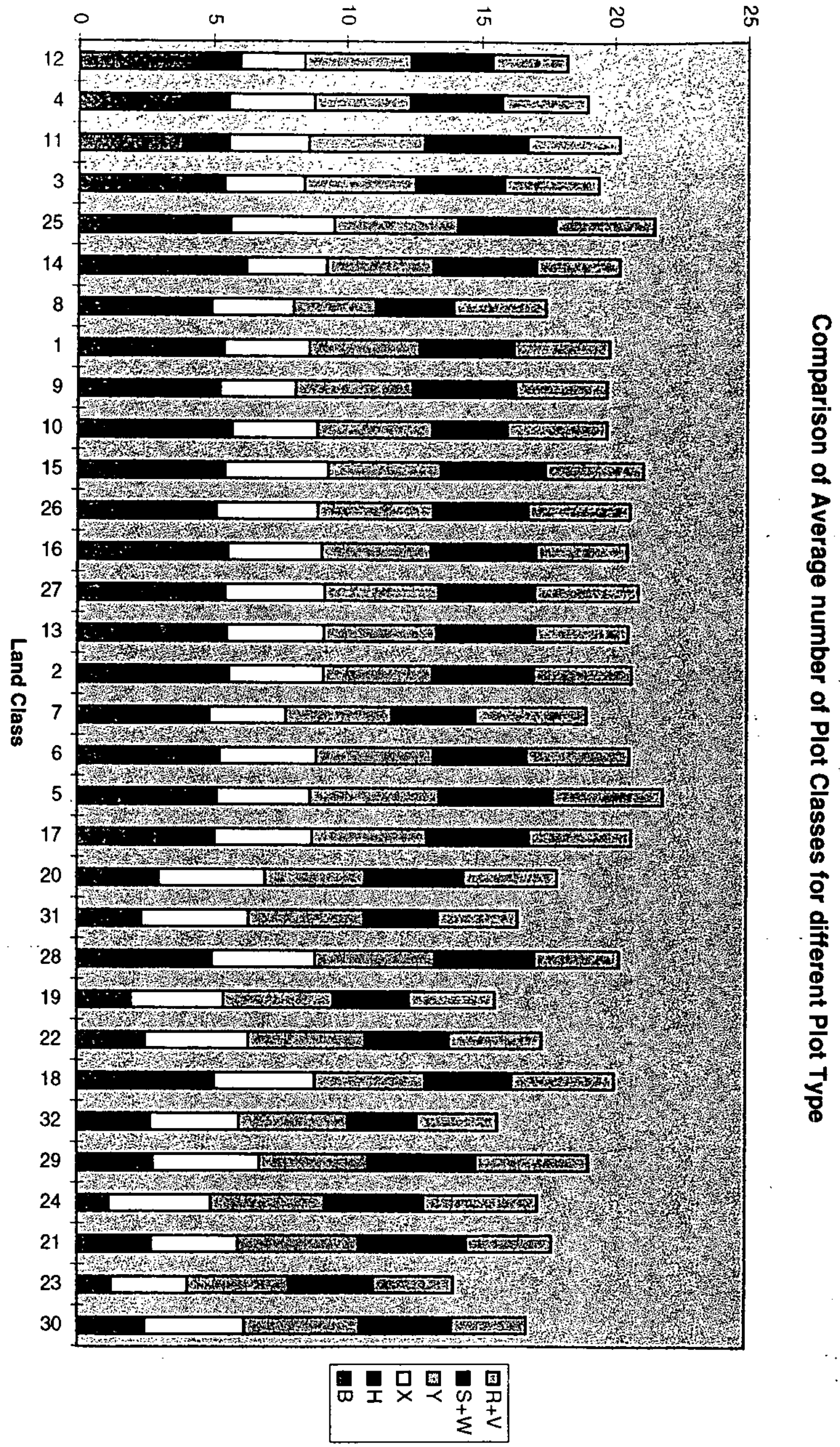


Table 2.

Gross change (1978-1990) in species numbers in all paired plots.
Class Groups based on TWINSPAN analysis of all plots.

Landscape	Class Group	No. of Plots	Mean Species 1978	Mean Species 1990	Change in Mean	Prob. by Paired T Test	
GB							
	1	195	7.25	6.61	-0.64	0.162	
	2	227	13.32	13.83	0.51	0.264	
	3	319	12.50	12.50	-0.00	0.994	
	4	369	21.19	18.55	-2.63	0.000	***
	5	150	12.53	12.79	0.26	0.667	
	6	122	20.82	16.50	-4.32	0.000	***
	7	210	22.10	20.74	-1.36	0.065	*
	8	270	17.63	18.65	1.02	0.033	*
Arable							
	1	124	7.03	5.43	-1.60	0.005	**
	2	118	12.07	12.67	0.60	0.283	
	3	130	13.26	11.61	-1.65	0.007	**
	4	89	20.28	17.10	-3.18	0.000	***
	5	76	10.76	12.92	2.16	0.013	**
	6	12	25.08	20.58	-4.5	0.427	
	7	5	29.60	23.60	-6.4	0.118	
	8	8	11.25	15.50	4.25	0.009	**
Pastural							
	1	65	7.71	8.34	0.68	0.371	
	2	100	14.39	15.04	0.65	0.406	
	3	147	11.89	12.71	0.82	0.162	
	4	165	21.01	17.56	-3.44	0.000	***
	5	71	14.34	12.45	-1.89	0.025	*
	6	46	16.48	12.70	-3.78	0.002	**
	7	27	24.26	19.96	-4.30	0.013	*
	8	18	16.50	13.06	-3.44	0.026	*
Marginal Upland							
	1	4	7.5	14.25	6.75	0.058	*
	2	9	17.89	15.56	-2.33	0.098	*
	3	32	12.06	14.29	2.29	0.055	*
	4	35	12.06	14.29	2.23	0.055	*
	5	3	14.33	17.33	3.00	0.272	
	6	25	20.80	13.84	-6.96	0.001	***
	7	65	17.77	20.37	2.60	0.027	*
	8	35	12.05	14.29	2.29	0.055	*
Upland							
	1						
	2						
	3	10	9.60	11.80	2.2	0.128	
	4	19	22.32	21.00	-1.32	0.538	
	5						
	6	39	24.64	21.44	-3.21	0.129	
	7	113	23.74	21.03	-2.72	0.013	**
	8	209	18.90	19.98	1.07	0.057	**

Table 3

Significant Changes in Species Frequency between 1978 and 1990 by hyper-class and by landscape type AG = arable landscape, PA = pastural landscape, MA = marginal upland and UP = upland.

Hyper Class	Landscape	Species	Direction of change	Significance level
1	AG	*Stellaria media*	-	**
1	AG	*Poa annua*	-	**
1	AG	*Polygonum aviculare*	-	**
1	AG	*Matricaria matricarioides*	-	**
1	AG	*Elymus repens*	-	*
1	AG	*Convolvulus arvensis*	-	**
1	AG	*Veronica persica*	-	**
1	AG	*Polygonum persicaria*	-	**
1	PA	*Polygonum aviculare*	-	**
1	PA	*Stellaria media*	-	**
1	PA	*Matricaria matricarioides*	-	**
2	AG	*Festuca rubra*	+	*
2	PA	*Elymus repens*	+	*
2	PA	*Heracleum sphondylium*	-	*
2	PA	*Rumex obtusifolius*	-	*
3	AG	*Lolium perenne*	-	**
3	AG	*Dactylis glomerata*	-	*
3	AG	*Trifolium repens*	-	**
3	AG	*Poa annua*	-	**
3	AG	*Ranunculus repens*	-	**
3	AG	*Holcus lanatus*	-	*
3	AG	*Cerastium fontanum*	-	**
3	AG	*Plantago major*	-	*
3	AG	*Phleum pratense*	-	*
3	AG	*Rumex obtusifolius*	-	*
3	PA	*Lolum perenne*	-	**
3	PA	*Trifolium repens*	-	**
3	PA	*Poa annua*	-	**
3	PA	*Agrostis stolonifera*	+	**
3	PA	*Stellaria media*	-	*
3	PA	*Elymus repens*	+	*
4	AG	*Cerastium fontanum*	-	**
4	AG	*Plantago lanceolata*	-	*
4	AG	*Agrostis capillaris*	-	*
4	MA	*Ranunculus repens*	-	**
4	MA	*Plantago lanceolata*	-	**
4	MA	*Bellis perennis*	-	*
4	PA	*Holcus lanatus*	-	**
4	PA	*Trifolium repens*	-	**
4	PA	*Cerastium fontanum*	-	**
4	PA	*Ranunculus repens*	-	**
4	PA	*Agrostis capillaris*	-	**
4	PA	*Plantago lanceolata*	-	*

4	PA	*Taraxacum agg.*	-	*
4	PA	*Cynosurus cristatus*	-	**
4	PA	*Bellis perennis*	-	**
4	PA	*Achillea millefolium*	-	*
4	PA	*Phleum pratense*	-	**
4	PA	*Trifolium pratense*	-	*
4	PA	*Prunella vulgaris*	-	**
4	PA	*Lotus corniculatus*	-	**
4	PA	*Centaurea nigra*	-	**
4	PA	*Plantago major*	-	*
5	AG	*Elymus repens*		**
5	AG	*Bromus sterillis*	+	**
5	PA	*Arrhenathrum elatius*	-	*
5	PA	*Elymus repens*	+	**
6	PA	*Agrostis capillaris*	-	**
6	PA	*Digitalis purpurea*	-	*
6	PA	*Athyrium filix-femina*	-	*
6	PA	*Agrostis stolonifera*	-	*
7	MA	*Nardus stricta*	-	*
7	UP	*Anthoxanthum odoratum*	-	**
7	UP	*Galium saxatile*	-	**
7	UP	*Agrostis capillaris*	-	**
7	UP	*Festuca ovina*	-	**
7	UP	*Plantago lanceolata*	-	**
7	UP	*Carex binervis*	+	*
7	UP	*Carex pilulifera*	-	**
7	UP	*Eriophorum angustifolium*	+	*
7	UP	*Viola riviniana*	-	**
8	UP	*Calluna vulgaris*	-	**
8	UP	*Erica tetralix*	-	**
8	UP	*Trichophorum caespitosum*	-	*
8	UP	*Eriophorum angustifolium*	-	*
8	UP	*Carex panicae*	+	*
8	UP	*Succisa pratensis*	+	*
8	UP	*Juncus bulbosus*	+	**
8	UP	*Agrostis capillaris*	+	**
8	UP	*Carex binervis*	+	**

Table 4

Significant Changes in Species Cover between 1978 and 1990 by hyper-class and by landscape type AG = arable landscape, PA = pastural landscape, MA = marginal upland and UP = upland.

Hyper Class	Landscape	Species	Direction of change	Significance level
1	AG	*Matricaria matricarioides*	-	*
1	PA	*Lolium perenne*	+	***
1	PA	*Trifolium repens*	+	**
2	AG	*Agrostis stolonifera*	+	**
2	AG	*Arrhenathrum elatius*	-	**
2	AG	*Elymus repens*	+	*
2	AG	*Festuca rubra*	+	**
2	AG	*Galium aparine*	+	***
2	AG	*Hedera helix*	+	*
2	AG	*Sambucus nigra*	+	**
2	PA	*Arrhenathrum elatius*	-	***
2	PA	*Bromus sterilis*	+	**
2	PA	*Hedera helix*	+	***
2	PA	*Mercurialis perennis*	+	*
2	PA	*Rubus fruticosus*	+	**
2	PA	*Urtica dioica*	+	*
3	AG	*Alopecurus geniculatus*	-	**
3	AG	*Dactylis glomerata*	-	**
3	AG	*Holcus lanatus*	-	*
3	AG	*Lolium perenne*	-	***
3	AG	*Phleum pratense*	-	*
3	AG	*Rubus fruticosus*	+	*
3	AG	*Trifolium pratense*	-	*
3	AG	*Trifolium repens*	-	*
3	PA	*Agrostis stolonifera*	+	**
3	PA	*Cirsium arvense*	+	*
3	PA	*Elymus repens*	+	*
3	PA	*Festuca rubra*	+	**
3	PA	*Lolium perenne*	-	*
3	PA	*Phleum pratense*	-	***
3	PA	*Poa annua*	-	***
4	AG	*Anthoxanthum odoratum*	-	*
4	AG	*Galium aparine*	+	**
4	AG	*Urtica dioica*	+	*
4	PA	*Agrostis capillaris*	-	**
4	PA	*Crataegus monogyna*	+	*
4	PA	*Festuca ovina*	-	**
4	PA	*Holcus lanatus*	-	*
4	PA	*Hypochoeris spp./Leontodon spp.*	-	*
4	PA	*Phleum pratense*	-	*
4	PA	*Rubus fruticosus*	+	*
4	PA	*Rumex acetosa*	+	*
4	PA	*Taraxacum agg.*	-	*

4	PA	*Urtica dioica*	+	*
4	MA	*Agrostis stolonifera*	+	***
4	MA	*Cynosurs cristatus*	-	*
4	MA	*Dactylis glomerata*	-	*
4	MA	*Festuca ovina*	-	**
4	MA	*Holcus lanatus*	+	**
5	AG	*Agrostis stolonifera*	+	**
5	AG	*Bromus sterilis*	+	*
5	AG	*Dactylis glomerata*	+	*
5	AG	*Elymus repens*	+	**
5	AG	*Galium aparine*	+	**
5	AG	*Hedera helix*	+	**
5	PA	*Agrostis stolonifera*	+	*
5	PA	*Crataegus monogyna*	+	*
5	PA	*Elymus repens*	+	*
5	PA	*Hedera helix*	+	*
5	PA	*Holcus mollis*	-	*
5	PA	*Lolium perenne*	+	*
5	PA	*Rubus fruticosus*	+	**
6	PA	*Agrostis capillaris*	-	*
6	PA	*Agrostis stolonifera*	+	*
6	PA	*Festuca ovina*	-	*
6	PA	*Quercus spp.*	+	*
6	UP	*Erica cinerea*	-	*
6	UP	*Galium saxatile*	+	*
6	UP	*Pteridium aquilinum*	-	**
7	MA	*Agrostis capillaris*	-	***
7	MA	*Calluna vulgaris*	-	*
7	MA	*Festuca vivipara*	+	*
7	UP	*Agrostis capillaris*	-	**
7	UP	*Danthonia decumbens*	-	*
7	UP	*Eriophorum angustifolium*	+	*
7	UP	*Festuca ovina*	-	**
7	UP	*Nardus stricta*	-	*
8	MA	*Calluna vulgaris*	-	**
8	MA	*Trichophorum caespitosum*	-	**
8	UP	*Agrostis capillaris*	+	***
8	UP	*Agrostis vinealis*	+	**
8	UP	*Calluna vulgaris*	-	*
8	UP	*Erica cinerea*	-	ns
8	UP	*Erica tetralix*	-	*
8	UP	*Molinia caerulea*	-	*
8	UP	*Northecium ossifragum*	+	ns
8	UP	*Vaccinium myrtillus*	-	*

4. The Functional Analysis Applied to Countryside Survey Data

An initial analysis was carried out using the CS 1990 Main Report categories in order to gain familiarity of the procedures and to assist with the interpretation of the results. This analysis is included in Appendix 4, but is not included here since it is considered more appropriate to concentrate on the interpretation of the hyper-classes as interpreted above. Even so, the hyper-classes in some cases contain plant species with such a wide range of initial strategies that it has been concluded that some comparisons should be carried out using the individual constituent plot classes.

4.1 Strategy Theory and Functional Analysis

Strategy theory classifies plant species into functional types based on their responses to gradients of productivity and disturbance, taking into account the strategies of plants in both the established and regenerative phases of their life cycle. The extremes on the gradients of productivity and disturbance are occupied by competitors (under conditions of high productivity and low disturbance), stress tolerators (plants that can withstand continuously low productivity imposed by nutrient stress) and ruderals (exploiting severely disturbed, productive habitats). These three functional types are located at the corners of a triangular ordination with intermediate types in between (19 types in total). Each type therefore has C, S and R co-ordinates, that can be calculated for each plant species in the flora using a dichotomous key. The C, S and R co-ordinates (radii) therefore relate to and can be defined by a whole set of attributes that contribute to a species' ability to survive under given conditions of productivity and disturbance.

4.2 Functional analyses rely on empirical relationships between measurable plant attributes and ecological processes, such as the relationships described above. For example, plant species having higher potential relative growth rates are found in sites of higher fertility. If a site is subjected to increased nutrient input, then species with certain attributes will increase, whilst others with a different set of attributes will decrease. Equally, analyses of the vegetation present at a site at two points in time may show that certain plant attributes have increased whilst others have decreased. This can lead to hypotheses regarding the processes of change that would produce such a functional change in the plant species present at that site over that period of time.

4.3 Strategic composition of the vegetation hyper-classes derived by including all plots surveyed in both 1978 and 1990 are shown in Figure 11. This therefore includes linear as well as main plots.

- *Crops.* Dominated by ruderals and competitive ruderals with virtually no stress tolerators suggests the highly disturbed nature of this vegetation.
- *Tall grassland.* The highest percentage of competitive, ruderal and generalist strategies suggest a productive and moderately disturbed system.
- *Eutrophic grassland.* Essentially the same general composition as tall grassland. Virtually no stress tolerators suggests a highly productive habitat.

- *Lowland grassland.* A more evenly distribution of strategies. More stress tolerators and generalist species suggests a lower productivity habitat.
- *Lowland woods / hedges and acid woods.* The general pattern is the same as lowland grassland although the acid woodland appears to be less productive as it has a greater percentage of stress tolerators.
- *Upland grassland.* The distribution of strategies is skewed towards the stress tolerant end of the graph suggesting a less productive system.
- *Bogs and heaths.* Mainly composed of stress tolerators, stress tolerant competitors and stress tolerant ruderals with virtually no competitors and ruderals. This suggests a highly undisturbed and unproductive system.

4.4 The data were analysed in two ways to detect shifts occurring at different scales. Firstly, all the plots that occurred in a hyper class in 1978 were analysed with all those that occurred in the class in 1990. This therefore included plots that occurred in that hyper class in only one year. Secondly, only those plots that occurred in the hyper class in both years were analysed. The two approaches yielded different results in some cases. These differences in results for the same hyper-class can be explained as follows. The classes are taken to lie on a continuum of intensity of management. Changes in management may tend to shift plots up the continuum. This may be detected by looking at the hyper class in both years. However, within a hyper class, a small subset of plots may be subjected to management that drives change in the opposite direction. This could be detected by looking at smaller subsets of plots within the hyper class ignoring those plots that have undergone major change and moved to another hyper class. For example acid woodland may be subjected to extensive eutrophication sufficient to cause many plots to shift to the lowland woodland hyper class by 1990. These changes would be seen by taking the whole hyper class in each year. However a subset of acid woodlands may not suffer eutrophication and may suffer slight dereliction. This may only be seem by looking at only those plots that stayed as acid woodland between 1978 and 1990.

4.5 Table 5 shows the analyses for all plots that occurred in the hyper-class in each year. Table 6 shows analyses of only those plots that stayed in the same hyper-class in 1978 and 1990. For each hyper-class, plots were divided into landscape types and different plot types (main plots and linear plots) to gain a clearer picture of the changes occurring. Changes are expected to be different in hedges than in the centre of adjacent fields. For clarity only those divisions showing the most complete story are presented.

4.6 *Crops.* In the arable landscape species with a high S-radius decreased. Short lived species with a high R-radius and short lived seed banks with less lateral spread, heavier seeds and taller canopies increased see Tables 5 and 6. Species data show this to be due to huge increases in *Galium aparine* and *Anisantha sterilis*. These are both large seeded autumn / winter germinating annuals. This shift is thought to be due to the huge shift from spring sown to autumn sown cereals favouring autumn germinating annual weeds. The changes suggested were essentially similar in the two methods of analysis. No process of change was detected in the pastural landscape.

4.7 *Tall grassland.* Hedge plots in the arable and pastural landscape (see Table 5) are showing increases in long-lived species with greater lateral spreads that flower later, are less ruderal and characteristic of more shady habitats, whilst species of arable habitats are decreasing. This suggests dereliction of the vegetation. The results for road verge plots n the arable landscape (see Table 6) however indicate a different story..Decreases in species of shady and wooded habitats and increases in species of trampled habitats with a long lived seed bank hint at increases in disturbance. No correlations were found for tall grassland main plots.

4.8 *Eutrophic grassland*. Virtually no significant correlations occurred. Those that occurred may have occurred by chance. Eutrophic grassland may well have undergone its extensive change prior to 1978 and any further consistent change has not occurred.

4.9 *Lowland grassland*. Consistent shifts are in Table 5. Species with a high S-radius, of shady and wooded habitats are declining. Species of trampled and wet habitats with a high C-radius, greater lateral spread and specific leaf area are increasing. This suggests eutrophication of this system. Within this dataset, a similar pattern is seen most strongly when the pastural landscape is analysed separately, although the field distribution correlations are not so good. Table 6 shows that when plots that stayed in the same hyper-class between 1978 and 1990 are analysed, the consistent change seen is in the pastural landscape linear plots i.e. hedges. Here the changes seen suggest dereliction.

4.10 *Lowland woods and hedges*. Table 5 shows taller species with higher leaf nitrogen and C-radius, characteristic of more species poor habitats, increasing; this suggests eutrophication and dereliction of the system. No more complete set of correlations was found by splitting the dataset. Table 6 shows the results for linear plots in the arable and pastural landscape i.e. lowland hedges. Species showing increases have higher C-radius, higher leaf nutrient contents, taller canopies, greater lateral spread, later flowering and are characteristic of species poor waste areas whilst decreasing species have low R-radii and S-radii. This is a clear indication of eutrophication and dereliction.

4.11 *Acid woodland*. The indication of change (see Table 5) is clear cut with very high significance levels. Species of higher C-radius, higher specific leaf area and greater canopy height and lateral spread and which are characteristic of species poor, shaded and wooded habitats are increasing, whilst species of higher S-radius, grazed and trampled habitats are decreasing. This strongly indicates eutrophication of this system coupled with dereliction. Nutrient input to this non-agricultural system could be partly by atmospheric deposition of nitrogenous compounds.

4.12 Upland grassland. Significant increases in short lived species of grazed and trampled habitats are seen in Tables 5 and 6. Table 5 also indicates reductions in taller species of higher C-radius. These changes tend to suggest increased disturbance possibly due to increased grazing pressure. Earlier functional analyses showed increases in stress tolerators, again possibly as a result of grazing where more palatable, less stress tolerant species are preferentially removed.

4.13 *Bogs and heaths*. No sets of correlations were obtained that indicated any consistent process of change. (See Tables 5 and 6). This is interesting as changes did occur in upland grassland which often occurs as a single management unit with bogs and heaths.

4.14 Current analyses therefore indicate the following processes of change.

- Change to autumn sown cereals in *crops* in arable landscape.
- Dereliction in *tall grassland* lowland hedges.
- Increased disturbance in *tall grassland* arable landscape road verges.
- Eutrophication of *lowland grassland.*
- Eutrophication and dereliction of *lowland woods and hedges.*
- Eutrophication and dereliction of *acid woodlands.*
- Increased disturbance of *upland grasslands.*

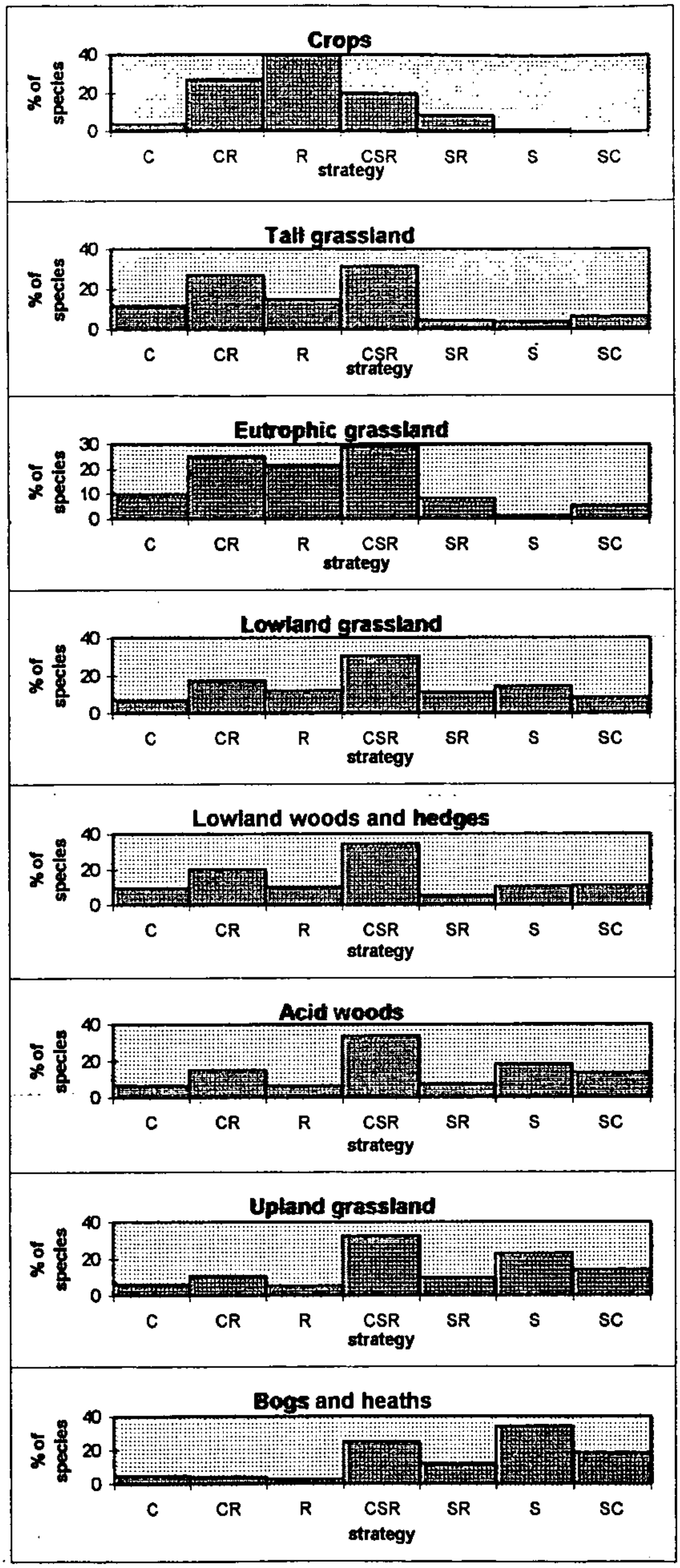


Fig. 1. Strategic composition of the 8 vegetation hyper-classes showing percentage of the total number of species that occurred in the hyper-class in either year, that were of each strategy.

Table 5. Analysis of changes in functional strategies between 1978 and 1990 for all plots that occurred in the hyper-class for each year.

Hyper class	crops	crops	tall grassland	tall grassland	eutrophic grassland	lowland grassland	lowland grassland	lowland woods / hedges	acid woods	upland grassland	upland grassland	upland grassland	bu he.
Landscape type	arable	pastural	arable pastural	arable	all	all	pastural	all	all	all	marginal upland	upland	
Plot type	all	all	hedge	road verges	all	all	all	all	all	all	all	all	
Field distribution attributes													
upland lowland	n/s	n/s	n/s	*	n/s	n/s	*	n/s	n/s	n/s	n/s	n/s	
correlation				ve			+ve						
calcareous non	n/s	n/s	n/s	n/s	*	n/s	n/s	n/s	n/s	n/s	n/s	n/s	
correlation					+ve								
wet habitats	n/s	n/s	n/s	n/s	n/s	***	***	n/s	n/s	n/s	n/s	n/s	:
correlation						+ve	+ve						
skeletal habitats	n/s	n/s	n/s	*	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n
correlation				-ve									
arable habitats	n/s	n/s	*	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	:
correlation			-ve										
grazed habitats	n/s	n/s	n/s	n/s	*	n/s	n/s	n/s	***	*	n/s	n/s	n
correlation					+ve				-ve	+ve			
cut habitats	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n
correlation													
trampled habitats	n/s	n/s	n/s	*	n/s	*	n/s	n/s	*	**	n/s	n/s	t
correlation				+ve		+ve			-ve	+ve			
pastures	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	***	n/s	n/s	n/s	n
correlation									-ve				
spoils	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	*	n/s	n/s	n
correlation										-ve			
wasteland	n/s	**	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	c
correlation		+ve											
shaded habitats	n/s	n/s	*	*	n/s	*	n/s	n/s	***	n/s	n/s	*	
correlation			+ve	-ve		-ve			+ve			+ve	-
wooded habitats	n/s	n/s	n/s	**	n/s	*	n/s	n/s	***	n/s	*	*	
correlation				-ve		-ve			+ve		-ve	+ve	-
habitat pH	n/s	n/s	n/s	n/s	n/s	**	*	n/s	n/s	n/s	n/s	n/s	n
correlation						+ve	+ve						
species richness	n/s	n/s	n/s	n/s	n/s	n/s	n/s	*	***	n/s	n/s	n/s	n
correlation								-ve	-ve				
Attributes from floras													
Life length	n/s	n/s	*	n/s	n/s	n/s	n/s	n/s	n/s	*	n/s	*	n
correlation			+ve							-ve		-ve	
Start of flowering	n/s	n/s	*	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n
correlation			+ve										
Length of flowering	n/s	n/s	**	n/s	n/s	n/s	*	n/s	n/s	n/s	n/s	n/s	n
correlation			-ve				-ve						
Canopy height	*	n/s	n/s	n/s	n/s	n/s	**	*	***	*	n/s	n/s	n
correlation	+ve						+ve	+ve	+ve	-ve			
Lateral spread	n/s	n/s	*	n/s	n/s	*	*	n/s	**	n/s	n/s	n/s	n
correlation			+ve			+ve	+ve		+ve				
Hard attributes													
C-radius	n/s	n/s	n/s	n/s	n/s	***	***	**	***	**	n/s	**	n
correlation						+ve	+ve	+ve	+ve	-ve		-ve	
S-radius	*	n/s	n/s	n/s	n/s	**	***	n/s	**	n/s	n/s	n/s	n
correlation	-ve					-ve	-ve		-ve				
R-radius	*	n/s	*	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n
correlation	+ve		-ve										
seedbank longevity	n/s	n/s	n/s	**	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n
correlation				+ve									
Specific leaf area	n/s	n/s	n/s	n/s	n/s	*	**	n/s	***	n/s	n/s	n/s	c
correlation						+ve	+ve		+ve				
seed weight	*	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n
correlation	+ve												
leaf Calcium	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n
correlation													
Leaf Nitrogen	n/s	n/s	n/s	n/s	n/s	n/s	n/s	*	*	n/s	n/s	n/s	:
correlation								+ve	+ve				
Leaf Phosphorus	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n
correlation													

Correlations between species attributes and proportional change in abundance between 1978 and 1990. A +ve correlation indicates that species with a high value for that attribute are increasing most whilst those with a low value are decreasing most. Asterisks indicate significance levels: * 0.05-0.011, ** 0.05 - 0.002, *** < 0.002.

Data analysed are the 1978 data for all those plots that occurred in the hyper class in 1978 and the 1990 data for all those plots that occurred in the hyper class in 1990.

Table 6. Analysis of changes in functional strategies between 1978 and 1990 for only those plots that stayed in the same hyper-clas

Hyper class	crops	crops	tall grassland	eutrophic grassland	lowland grassland	lowland woods hedges	upland grassland	bogs heaths
Landscape type	arable	pastural	arable	all	pastural	arable pastural	all	all
Plot type	all	all	linear plots	all	linear plots	linear plots	all	all
Field distribution attributes								
upland lowland	n/s	n/s	n/s	n/s	**	n/s	n/s	n/s
correlation					-ve			
calcareous non	n/s	n/s	*	n/s	n/s	n/s	**	n/s
correlation			-ve				-ve	
wet habitats	*	n/s	n/s	n/s	n/s	n/s	*	n/s
correlation	-ve						+ve	
skeletal habitats	n/s	n/s	n/s	n/s	n/s	n/s	*	n/s
correlation							-ve	
arable habitats	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
correlation								
grazed habitats	n/s	n/s	n/s	n/s	*	n/s	*	n/s
correlation					-ve		+ve	
cut habitats	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
correlation								
trampled habitats	n/s	n/s	*	n/s	n/s	n/s	*	n/s
correlation			+ve				+ve	
pastures	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
correlation								
spoils	n/s	n/s	n/s	n/s	n/s	n/s	*	n/s
correlation							-ve	
wasteland	n/s	n/s	n/s	n/s	n/s	*	n/s	n/s
correlation						+ve		
shaded habitats	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
correlation								
wooded habitats	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
correlation								
habitat pH	n/s	n/s	*	n/s	n/s	n/s	n/s	n/s
correlation			+ve					
species richness	n/s	n/s	n/s	n/s	n/s	*	n/s	n/s
correlation						-ve		
Attributes from floras								
Life length	*	n/s	n/s	n/s	**	n/s	*	n/s
correlation	-ve				+ve		-ve	
Start of flowering	n/s	n/s	*	n/s	n/s	*	n/s	*
correlation			+ve			+ve		+ve
Length of flowering	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
correlation								
Canopy height	**	n/s	n/s	n/s	**	*	n/s	n/s
correlation	+ve				+ve	+ve		
Lateral spread	**	n/s	n/s	n/s	**	*	n/s	n/s
correlation	-ve				+ve	+ve		
Hard attributes								
C-radius	n/s	n/s	n/s	n/s	***	***	n/s	n/s
correlation					+ve	+ve		
S-radius	***	n/s	n/s	n/s	n/s	*	n/s	n/s
correlation	-ve					-ve		
R-radius	*	n/s	n/s	n/s	*	*	n/s	n/s
correlation	+ve				-ve	-ve		
seedbank longevity	*	n/s	n/s	n/s	n/s	n/s	n/s	n/s
correlation	-ve							
Specific leaf area	n/s	n/s	n/s	*	n/s	n/s	n/s	n/s
correlation				+ve				
seed weight	*	n/s	n/s	n/s	n/s	n/s	n/s	***
correlation	+ve							-ve
leaf Calcium	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
correlation								
Leaf Nitrogen	n/s	n/s	*	n/s	*	**	n/s	n/s
correlation			+ve		+ve	+ve		
Leaf Phosphorus	n/s	n/s	*	*	n/s	*	n/s	n/s
correlation			+ve	-ve		+ve		

Correlations between species attributes and proportional change in abundance between 1978 and 1990. A +ve correlation indicates that species with a high value for that attribute are increasing most whilst those with a low value are decreasing most. Asterisks indicate the significance level; * 0.05-0.011, ** 0.01-0.002, *** <0.002.

Data analysed are the 1978 and 1990 data for those plots that were classified as belonging to the same hyper-class in both years.

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