Advisory Group Notes

The Ecological Consequences of Land Use Change

Progress reports and illustrative material

12th April 1988

CONTENTS

Foreword

The following document presents progress reports and illustrations of completed work since the last advisory group meeting. Documents presented at the last meeting eg on the soils data now available have not been repeated.

Ecological Consequences of Land Use Change

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REMOTE SENSING PROJECT

ECOLOGICAL CONSEQUENCES OF LAND USE CHANGE

REMOTE SENSING

INTERIM PROGRESS REPORT

APRIL, 1988

1 BACKGROUND

The objectives of this component of the ECOLUC project are to review the present capability and future potential of remote sensing (both satellite imagery and aerial photography) as a means of detecting and quantifying changes in land cover and to propose a practical and feasible system for monitoring these changes.

Three major technical objectives can be identified:

- to determine the range of land cover types capable of discrimination using second-generation satellite imagery (Landsat-TM and SPOT).

- to develop techniques for using this imagery to map the distribution of land cover and to detect changes.

- to develop methods for deriving quantitative remotely-sensed measures of the state and dynamics of the land-cover mosaic for use in ecological modelling applications.

The ITE Land Classification System provides a basis for deriving national estimates of land cover from a very limited sample. However, changes in land cover are often small-scale and localized; the sample size would need to be increased significantly if it is to be sensitive to such change. Satellite remote sensing offers the potential for increasing the sample size at low cost, compared with alternatives such as field mapping or aerial photography.

In this study, attention has been concentrated in eight land classes, predicted to be the most susceptible to changes in land use. The areas of interest have been designated as 10km x 10km areas, centred on 6 randomly-located 1km squares in each land class.

The work is being undertaken jointly by the National Remote Sensing Centre and by the NERC Remote Sensing Applications Centre at ITE, Bangor.

2 DATA AVAILABILITY AND PRE-PROCESSING

2.1 Satellite Data

Suitable examples of both Landsat Thematic Mapper (TM) and SPOT imagery are available, but interest has been concentrated on TM imagery because this provides more extensive coverage over a longer time period and because the larger number of spectral bands has advantages in discriminating land cover. The imagery has been geometrically registered to the British National Grid and sub-scenes extracted, corresponding to the study sites.

2.2 Field maps

The field survey carried out by ITE during the summer of 1987 provided detailed ground information for 2 1km squares within each 10km x 10km area. Similar information is available for a single 1km square in the same area from field surveys carried out in 1978 and 1984.

This ground information provides a basis for developing and testing image classifications, but the plan to acquire ground reference data contemporary with recent imagery was frustrated by the limited number of cloud-free image acquisitions during 1987.

2.3 Aerial Photography

Aerial survey of approximately half the 1km squares in the 1987 field survey has provided good quality 1:10 000 scale coverage to supplement the field maps. Small-scale photography from 1980-81 covers all the 10km areas in England and Wales.

3 DISCRIMINATION AND CLASSIFICATION OF LAND COVER TYPES

There are significant differences in the problems encountered in land cover classification in lowland and upland areas. Therefore the upland and lowland land classes included in this project have been considered separately.

3.1 Lowland Study

In lowland land classes (3, 10, 11) the most common of the land cover types in a target list identified in the framework of the ECOLUC project are as follows:

Cultivated -	Cereals	Woodland -	Broadleaf
	Oilseed rape		Coniferous
	Other crops		Scrub
Grassland -	Ley	Developed land	
	Improved	Quarries	
	Permanent	Open water	

(i) Cultivated land

Cultivated areas exhibit a wide range of spectral characteristics during the main part of the growing season. Consequently it is impractical to use automatic methods to identify the class as a whole. Autumn imagery gives the best opportunities, when it is possible to classify cultivated land as the aggregate of bare ground and green crops (notably sugar beet). Oilseed rape is easily classified on imagery from mid-May to mid-July.

(ii) Grassland

The various types of grassland mapped by the field programme cannot be reliably distinguished from their spectral properties alone using remotely sensed imagery. Leys and improved grassland often have similar visible and infra-red reflectance properties and may overlap with the spectral signatures of the better managed permanent grassland. The appearance of grassland is dominated by differing management practices (eg grazing intensity, cutting for hay and silage).

In view of these fundamental problems, it is suggested that satellite imagery should be used primarily to distinguish grassland from other land cover types and that mapping of the various types of grassland must depend on supplementary field survey. Autumn images are best for this purpose, when grassland and sugar beet can be distinguished using TM band 5, but other growing crops may still give rise to confusion. Classification accuracy improves significantly if multi-season imagery is used.

(iii) Woodland

Classification of spring, summer or autumn imagery can be used to identify woodland, including the separation of mainly broadleaved and mainly coniferous types. Late summer imagery is optimal for distinguishing different woodland types.

(iv) Developed land

The field survey included small areas of woodland, small fields and gardens in this category. Classification of remotely-sensed imagery cannot reproduce these results, because of the high spectral diversity. Automatic classification inevitably attributes a proportion of developed land to grassland or woodland. For some purposes (eg estimation of bird habitats), this may be acceptable.

(v) Quarries

Quarries can be readily identified from satellite imagery using visual techniques, but automatic classification is inappropriate because of the high diversity in reflectance.

(vi) Open Water

Water can be easily classified from imagery of any date using infra-red bands.

3.2 Upland Study

Within the upland classes (6, 17, 20) the most common of the land cover types encountered were:

Grassland - Ley
Improved
Permanent
Agrostis/fescue

Bracken

Wetland - Eutrophic wetland
Bog

Woodland - Broadleaf
Coniferous

Moorland - Grass moor
Dwarf shrub

Supervised maximum-likelihood classification of each of these upland classes was attempted, using the 1987 field survey results as reference data. Training sets were chosen at random from within the surveyed areas. In general, the results of this approach were unsatisfactory, partly because the training data were unrepresentative. Detailed investigations were therefore undertaken into the spectral separability of the various land cover types using the field survey maps for reference.

Figure 1 shows that, within a 1km square, good separation can be achieved between heather moorland, woodland, grassland and water using visible and near infra-red channels. The grassland class, though well separated from the other categories, shows high variance, corresponding to a wide range of grassland types that essentially form a spectral continuum.

Figure 2 presents similar data showing the scatter of mean digital numbers (DN's) in channels 3 and 4 for land parcels distributed throughout a complete TM scene (185km x 185km). This scattergram was used to define spectrally distinct classes and to extract training data representative of these. The classes so defined were tested for statistical separability using pairwise divergence analysis. This showed that, with three exceptions, classes could be defined which were spectrally distinct and with a more than 98% probability of correct assignment. The following pairs were confused to some degree:

Agrostis/Fescue	-	Bog	(70% separability)
Grass moor	-	Bog	(86% separability)
Agrostis/Fescue	-	Grass moor	(90% separability)

Given the high variance apparent in Figures 1 and 2, it is clear that automatic classification of natural and semi-natural vegetation will inevitably be a compromise. High accuracy is possible, using high discard thresholds, at the expense of a high proportion of reject pixels. However, the results of divergence analysis suggest that it should be possible to improve the classification accuracy by sub-dividing some classes prior to classification and then, if necessary, recombining them subsequently. This could be particularly helpful where there is a bi-modal distribution - a grassland that may be mown or un-mown, for example.

For purposes of change detection, the preferred strategy is to be selective in the choice of training sites and to set a low discard threshold. This results in a high proportion of unclassified pixels, but is preferable to the alternative of mis-classification which could indicate spurious change.

Although such refinements can be expected to improve the performance of upland land cover classification, it is clear that there is little possibility of automatic separation of individual vegetation communities within the broad structural types. This is because of the spatial complexity and diversity of such canopies. As a result, each pixel in a satellite image typically represents a mixture of vegetation types. This precludes the use of supervised classification techniques that rely on establishing training statistics representative of spectrally homogeneous regions.

A hybrid approach to classification of upland land cover is therefore being explored, in which supervised classification or visual interpretation is employed for those cover types that are clearly separable in feature space and unsupervised clustering for more complex canopies.

4 CHANGE DETECTION

4.1 General

Several different approaches to change detection are being developed and tested.

The first involves comparison (by subtraction) of the results of automatic classification of imagery acquired on two different dates. Results are generally unsatisfactory because mis- classification errors on the two dates usually overshadow the actual changes that have occurred.

A second approach involves the subtraction of images taken in different years to identify areas of change. This has potential value in highlighting changes in upland semi-natural vegetation. It has less value in the context of lowland studies because the resulting maps of change are dominated by differences in agricultural crops in successive years.

The third approach, which is proving far more successful, involves the updating of baseline cover maps using a combination of visual and automated image classification techniques.

4.2 Change detection in the lowlands

Aerial photography taken in the 'baseline year' is used to prepare land cover maps of woodland, developed areas, quarries and water on a 1:50 000 OS base map. In cases where the map revision date is close to the baseline year, the OS map data may require only minor adjustment. Mapping of developed areas is carried out so as to include the gardens, small fields and parks associated with building developments. These maps are digitized and produced as filled polygons in raster format so as to overlay geometrically-corrected TM imagery.

The baseline land cover maps are then revised using satellite imagery acquired at a suitable time interval. The maps are displayed on an image-analysis system as overlays on the image and are edited interactively to produce updated maps. Where appropriate, additional detail (eg crop type, woodland type) can be added at this stage.

A combination of visual and automated image classification techniques is used, with both single-date and multi-date imagery, depending on the land cover encountered. Editing is carried out as a manual process by checking and adjusting the maps against enhanced images and classifications.

Areas of each land cover class and the extent of change can be readily estimated, simply by counting pixels. Losses and gains between each of the cover types can be computed, as well as overall changes in area. If suitable imagery is available in a later time window, the process of updating can be repeated to obtain a second series of land-cover maps, with estimates of the further changes that have taken place.

An example of this approach is illustrated in Figures 1 and 2.

4.3 Change detection in the uplands

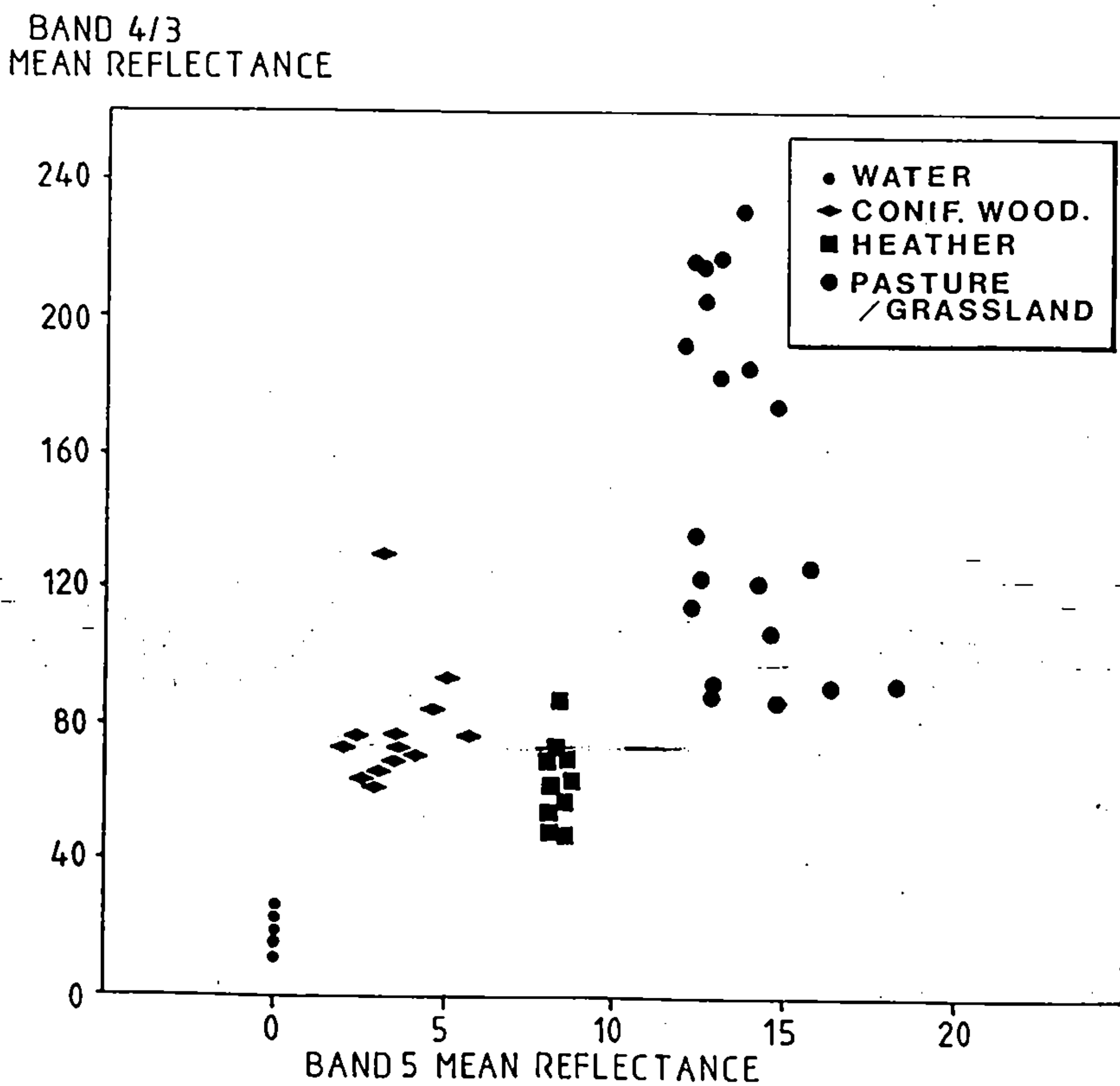
In the upland situation, where agricultural cultivation is less intense and crop rotation is less prevalent, it is possible to observe directly differences in multispectral imagery itself, rather than differences between interpreted products such as classified images. This has the advantage of removing errors due to mis-classification from the change-detection process. However, it is necessary to acquire imagery at comparable seasonal stages.

Because co-seasonal images for the upland sites are comparatively rare, differencing methods are being tested using suitable MSS imagery of North Wales. The particular images are separated in time by about 7 years (1975 to 1982) and are therefore likely to span real changes in land-use. The images have been co-registered and radiometrically corrected and differences in near-infrared radiance have been identified by subtraction. The next stage is to establish, through field visits and by inspection of aerial photography, how the radiometric changes relate to events on the ground.

5 PATTERN ANALYSIS

There is considerable interest in the relationship between the spatial arrangement of landscape units (such as woods and wetlands) and their value as habitat for fauna and flora. Work has recently begun on the development of raster-based techniques for measuring the size, shape and arrangement of parcels of different land cover types. These include parcel size frequency distribution and measures of proximity, contiguity and percentage cover. A development of particular interest in the context of ECOLUC is the measurement of the size and shape of areas of change and their relationship with other units in the vicinity. One example might be to determine the number and size of parcels of woodland loss and the proportion of these that are isolated blocks or parts of larger stands.

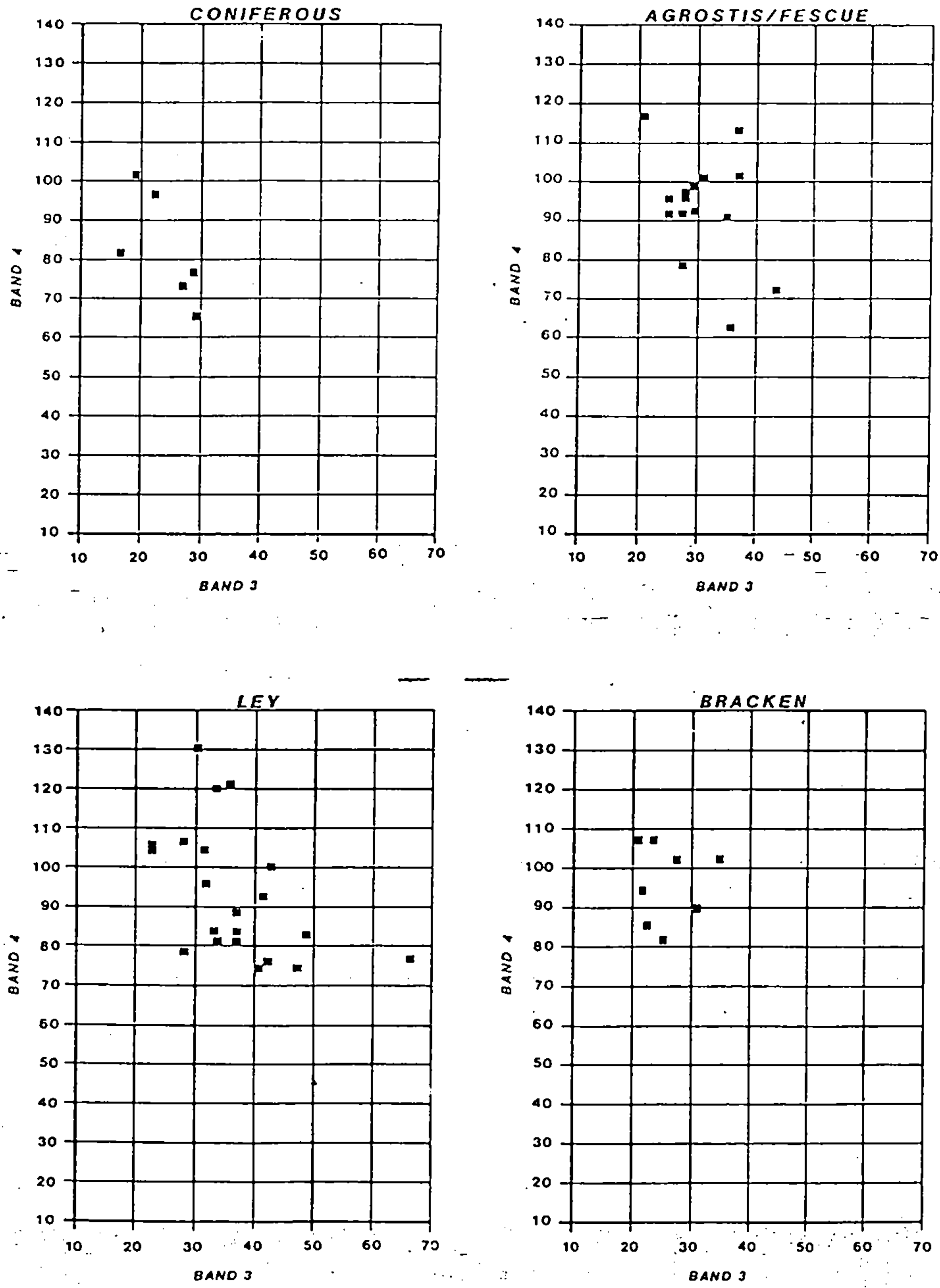
Figure 1



SCATTER PLOT OF MEAN VALUES FOR MOORLAND LANDCOVER TYPES FROM 10KM SQUARES

Figure 2

SCATTERGRAMS FOR SOUTH WALES (bands 3 and 4)



6 THE DIVERSITY OF NATURAL VEGETATION CANOPIES AND THE PROBLEM OF CLASSIFICATION

The problems of characterising natural vegetation cover from its spectral signature have been noted earlier. A study of the distribution of plant species within such canopies provides some insights into these problems. The study was undertaken using data collected by the Nature Conservancy in 1970, covering 871 2m x 2m quadrats, in which the presence and abundance of plant species was recorded. Samples were located at 0.5 km intervals along transects, evenly distributed over the main upland regions of England and Wales.

Tables 1 and 2 summarise the variation that affects the principal upland species. Table 1 demonstrates the fact that, to some extent, the species behave as independent variables, so that any given species may have a very wide range of associates. Table 2 shows that the cover contributed by a species may also be very variable between samples. Pure stands of any one species, or even any pair of species, are uncommon. Samples in which a single species achieves dominance, when they do occur, are no more common than instances of the same species at other cover levels.

Taken together, the Tables suggest that the concept of naturally-occurring associations as entities with fixed attributes is false. Conventional vegetation maps, especially at small scales, cannot provide a reliable description of the vegetation at a given site. Although areas dominated by one or two species may be well-defined, there are always cases without a clear dominant, and these often differ from the description given to the mapped units. The limitations apply equally to automated mapping based on satellite imagery, and must be an important constraint in mapping semi-natural vegetation from multispectral imagery.

7 AVAILABILITY OF IMAGERY

A further constraint on the use of satellite remote sensing as an operational tool for monitoring changes in land cover is the availability of suitable imagery. We have attempted to estimate the statistical likelihood of obtaining cloud-free imagery for a given site in any year, using monthly weather summaries issued by the Meteorological Office. Figure 3 shows the days per month when the cloud cover was 3 oktas or less. The figures are for 1984 (a particularly fine summer). The stations quoted are those closest to the ITE study sites, but they are mainly coastal and therefore not entirely representative of study sites in the hills. In practice, there will usually be fewer good images than the figures suggest, because cloud cover will be more prevalent at higher altitudes.

Table 1

NUMBERS OF COMMON SPECIES CO-OCCURRENCES

		COV>75%	SPECIES COMBINATIONS WITH COVER>25%																				
4	Call vul	67	*	2	1	3	6	34	1	3	-	3	-	-	6	7	27	4	-	11	8	-	4
7	Empet nig	5	2	*	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-
8	Erica cin	0	1	-	*	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	Erica tet	0	3	-	-	*	3	1	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-
28	Ulex gal	1	6	-	1	3	*	-	1	-	1	-	-	-	-	1	4	-	-	-	-	-	-
30	Vacc myr	19	34	1	-	1	-	*	6	2	-	5	-	-	6	24	7	20	-	8	1	-	7
77	Galium sax	4	1	-	-	-	1	6	*	-	-	9	1	-	1	25	-	20	-	-	-	1	5
121	Poten ere	0	3	-	-	-	-	2	-	*	-	2	-	-	-	1	-	-	-	-	-	-	-
164	Agros can	1	-	-	-	-	1	-	-	-	*	1	-	-	-	-	-	1	-	-	-	-	-
167	Agros ten	5	3	-	-	-	-	5	9	2	1	*	1	-	-	29	-	12	-	-	-	1	4
170	Anthox od	0	-	-	-	-	-	-	1	-	-	1	*	-	-	2	-	-	-	-	-	1	1
175	Desch caesp	0	-	-	-	-	-	-	-	-	-	-	-	*	1	-	-	-	-	-	-	-	-
176	Desch flex	4	6	-	-	-	-	6	1	-	-	-	-	1	*	4	5	6	-	3	3	1	2
177	Festuc ov	8	7	1	-	-	1	24	25	1	-	29	2	-	4	*	5	35	-	-	-	-	10
190	Molin caer	55	27	-	-	1	4	7	-	-	-	-	-	-	5	5	*	8	3	3	12	-	2
191	Nardu stri	22	4	-	-	-	-	20	20	-	1	12	-	-	6	35	8	*	-	-	3	-	-
216	Erioph ang	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	*	2	1	-	-
217	Erioph vag	18	11	1	-	-	-	8	-	-	-	-	-	-	3	-	3	-	2	*	1	-	-
221	Trich caesp	1	8	-	-	2	-	1	-	-	-	-	-	-	3	-	12	3	1	1	*	-	-
227	Juncu eff	2	-	-	-	-	-	-	1	-	-	1	1	-	1	-	-	-	-	-	-	*	-
259	Pterid aq	17	4	-	-	-	-	7	5	-	-	4	1	-	2	10	2	-	-	-	-	-	*
	TOTAL	230	= 26 % OF 871 STANDS																				

Table 2

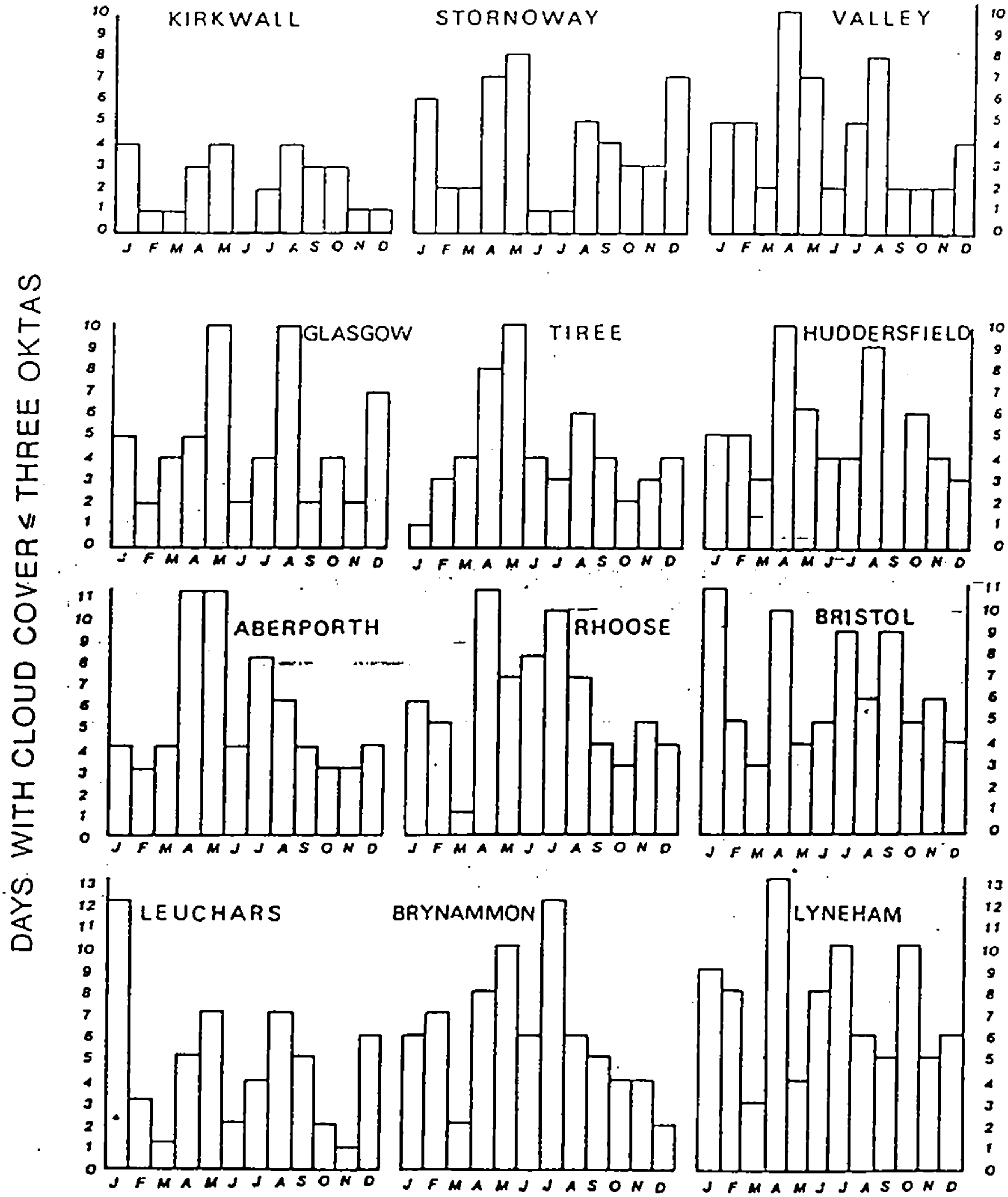
SPECIES OCCURRENCES BY DOMIN VALUE

	DOMIN COVER VALUES								TOTAL
	3	4	5	6	7	8	9	10	
4 Call vulg	175	55	18	26	45	66	42	25	452
7 Empet nig	135	27	3	2	2	0	4	1	174
8 Erica cin	55	15	6	0	2	0	0	0	78
9 Erica tet	166	35	3	3	4	0	0	0	211
28 Ulex gal	39	7	4	4	4	2	1	0	61
30 Vacc myrt	341	95	19	26	46	28	16	3	574
32 Vacc v-i	29	3	1	0	0	0	0	0	33
77 Galium sax	359	72	20	17	9	8	3	1	489
121 Poten ere	441	44	3	4	0	0	0	0	492
129 Rumex acet	72	1	0	1	0	0	0	0	74
146 Thymus dru	19	4	2	1	0	1	0	0	27
148 Trif repens	81	6	3	1	1	0	0	0	92
164 Agros can	293	53	5	3	2	1	1	0	358
167 Agros ten	259	88	18	19	13	12	5	0	414
170 Anthox od	260	55	15	1	3	1	0	0	335
173 Cynos crist	27	6	3	0	1	0	0	0	37
174 Dactyl glom	3	1	0	0	0	0	0	0	4
175 Desch caesp	81	7	1	2	4	0	0	0	95
176 Desch flex	368	101	29	14	10	10	3	1	536
177 Festuca ov	259	136	48	40	58	40	7	1	589
185 Holcus lan	85	3	0	0	1	0	0	0	89
186 Holcus moll	11	1	0	0	0	0	0	0	12
188 Lolium per	8	2	0	0	1	0	0	0	11
190 Molin caer	116	46	21	26	28	45	33	22	337
191 Nardus stri	264	74	28	28	50	42	18	4	508
208 Carex nig	145	12	2	1	2	0	3	0	165
216 Erioph ang	183	19	8	3	5	3	1	0	222
217 Erioph vag	110	32	12	4	24	12	16	2	212
221 Trich caesp	110	47	9	16	10	6	1	0	199
222 Juncus acu	53	8	2	1	2	1	0	0	67
223 Juncus art	3	4	1	0	0	1	1	0	10
227 Juncus eff	195	7	4	3	4	3	1	1	218
235 Luzula syl	19	0	1	0	1	1	1	0	23
259 Pterid aq	54	13	3	6	8	6	6	11	107

Figure 3

MONTHLY CLOUD COVER SUMMARIES

1984



Given the LANDSAT 4 and 5 repeat cycle of 16 days, an average site with (say) 4 cloud-free days in a given month will be imaged under cloud-free conditions only once in four years. In fact, the true figure is likely to be even lower because of failures in image acquisition.

This analysis confirms the practical difficulties in acquiring suitable imagery which have been experienced in this project, and reinforces the view that image availability is likely to be a major constraint for the foreseeable future.

8 CONCLUSIONS AND RECOMMENDATIONS FOR THE FUTURE

The results from the first phase of the project have provided qualitative demonstration of the extent to which different land cover classes can be distinguished using multispectral imagery. It is clear that the number of land cover types that can be classified is considerably fewer than can be mapped in the field. Compared with automatic classification, visual interpretation of imagery is more successful and can be combined with the interpretation of aerial photography to produce estimates of change. This approach will be refined and tested in the second phase of the project. the baseline date against which change is to be measured needs to be defined, though this will largely depend on the dates of suitable aerial photography.

In the case of certain classes of land cover and for detecting certain types of change, the use of various automatic methods is feasible. Where this is possible, it is cost-effective to make use of computer-based procedures in order to minimise the labour- intensive process of manual interpretation. These considerations are particularly important when a census approach is needed covering large areas, rather than an approach which relies on estimates derived from relatively small samples. The extent to which useful information can be derived from automated techniques depends partly on the level of detail required and, in the context of ECOLUC, whether the type of land cover changes that can be obtained by automated methods are important in assessing ecological consequences of land use change. Detailed specifications of the ecological models are needed in order to specify the priorities in this area.

The potential for using satellite data instead of field survey for the routine monitoring of land cover change can only be properly assessed from quantitative measures of classification accuracy. The restricted coverage of ground reference data within the 10km square sites, combined with the lack of imagery in 1987 to coincide with the field survey precluded such accuracy testing. In the second phase of the project, it is planned to acquire additional aerial photography and field data. Futurefield survey will be directed in the light of the results of earlier image classifications.

The paucity of suitable imagery, especially in upland areas, has already been noted. This has been exacerbated by the decision to use widely scattered test sites, representative of a large number of different land classes. In the second phase of the project, a more intensive approach is proposed, perhaps concentrating on fewer land classes in a more restricted area where lack of imagery is less of a problem.

At present, aggregate estimates of change within each 10km square are computed, irrespective of the number and distribution of ITE land classes within the area. Although remote sensing could be used independently of the ITE land classification system to estimate land cover over large areas, there are many environmental and socio-economic parameters that cannot be estimated from multispectral imagery and for which the land classification system provides a convenient sampling framework. It is therefore important to retain the links with the land classification system. This could best be achieved by assigning every square in the study sites to its ITE land class and thus obtaining estimates of land cover and change in each of the land classes represented. By this means, a larger sample could be obtained, enabling estimates of change to be expressed with much greater confidence.

The analysis of landscape pattern will be directed towards study of the pattern of change. From this, it will be possible to determine the frequency with which different types of change occurs, their magnitude and their spatial relationships. The ecological implications of these patterns of change should direct this work, and guidance will be sought from elsewhere in the ECOLUC team. Of particular importance is the choice of an appropriate scale for the analysis of pattern. This may well vary according to the land cover.

CORE PROJECT

SPECIES GROUPS

There are three levels of classification involved in the project :

1. Species groups - these are groups with comparable ecological amplitudes.

2. Vegetation types - these are the traditional way of describing vegetation.

3. Land cover categories - in some cases these may coincide with vegetation types but usually will break them up into further divisions.

Because species groups are more readily understood and have more specific ecological interpretations they will be used primarily as the link between land use change and vegetation. Previous experience of creating such groups using numerical procedures has been satisfactory. However, because management is such a vital component, considerable difficulty has been encountered in producing groups that have a sufficiently limited range. Much of this work has proceeded under the Special Topic for Agriculture and the Environment, with agricultural grasslands being used as a test data set.

As a result of this work two classifications of species are presented :

1. A computer classification (PCA and K means clustering);

2. A supervised classification which was based on 1, but reallocating species which did not fit, eg. *Agrostis canina* in group 10.

The first axis were then used to sort out any further discrepancies. The species in capitals are most common.

The resulting classification has the advantage of being readily interpreted with no apparent illogicalities and has readily attributable names. Furthermore they can be conveniently grouped into a relational diagram, also included, showing the potential movement between groups that could result from land use change, in this case extensification or vice versa.

The distribution of the species groups through the land classes shows well defined patterns - in some cases these are limited to the inherent differences in ecological composition of the land classes, but in others reflect land use change within comparable environments. Further interpretation of these will be used to assess the implications of changes.

Other calculations have been carried out for streams, hedges and verges, and the remaining divisions of the vegetation analysis. Some further work will be done on the automated classification procedure, but the multiple dimensionality of the species data makes it seem likely that the supervised procedure could well be most appropriate. Taken in conjunction with the UCPE database on plant growth strategies, these analyses will enable the potential implications of land use change to be spelt out, both for future senarios and for the past data available from HTS.

Finally, the above information cannot supply data on extinction rates. Further analysis is required from minimal areas within 1 km squares to model possible extinction rates due to the land use change.

ITE SPECIES GROUPS	
VEGETATION TYPE: improved grass	
Method = P.C.A. (37 axes) and K-means clustering. No. of groups = 18 No. of species = 126 Data type = Presence/absence Filename = clust9	INTERPRETATION

group number 1	
BELLIS PERENNIS CERASTIUM HOLOSTEOIDES/VULGATUM/FONTANUM DACTYLIS GLOMERATA HOLCUS LANATUS LOLIUM PERENNE PHLEUM PRATENSE POA ANNUA POA NEMORALIS/TRIVIALIS RANUNCULUS REPENS TARAXACUM AGG. TRIFOLIUM REPENS	Highly Managed Grasslands: Palatable sown species or rapidly colonising species

group number 2	
ACHILLEA MILLEFOLIUM AGROSTIS TENUIS ANTHOXANTHUM ODORATUM CYNOSURUS CRISTATUS FESTUCA RUBRA HYPOCHAERIS SPP./LEONTODON SPP. LOTUS CORNICULATUS PLANTAGO LANCEOLATA RANUNCULUS ACRIS Rumex acetosa	Low Nutrient/ Acidic Grassland: Species indicative of a lack of disturbance or species under low intensity grazing

group number 3	
AGROSTIS STOLONIFERA CIRSIUM ARVENSE Cirsium vulgare PLANTAGO MAJOR RUMEX OBTUSIFOLIUS SENECIO JACOBAEA URTICA DIOICA VERONICA CHAMAEDRYS	Highly Fertilized Poorly Managed Grasslands: Agricultural weed species

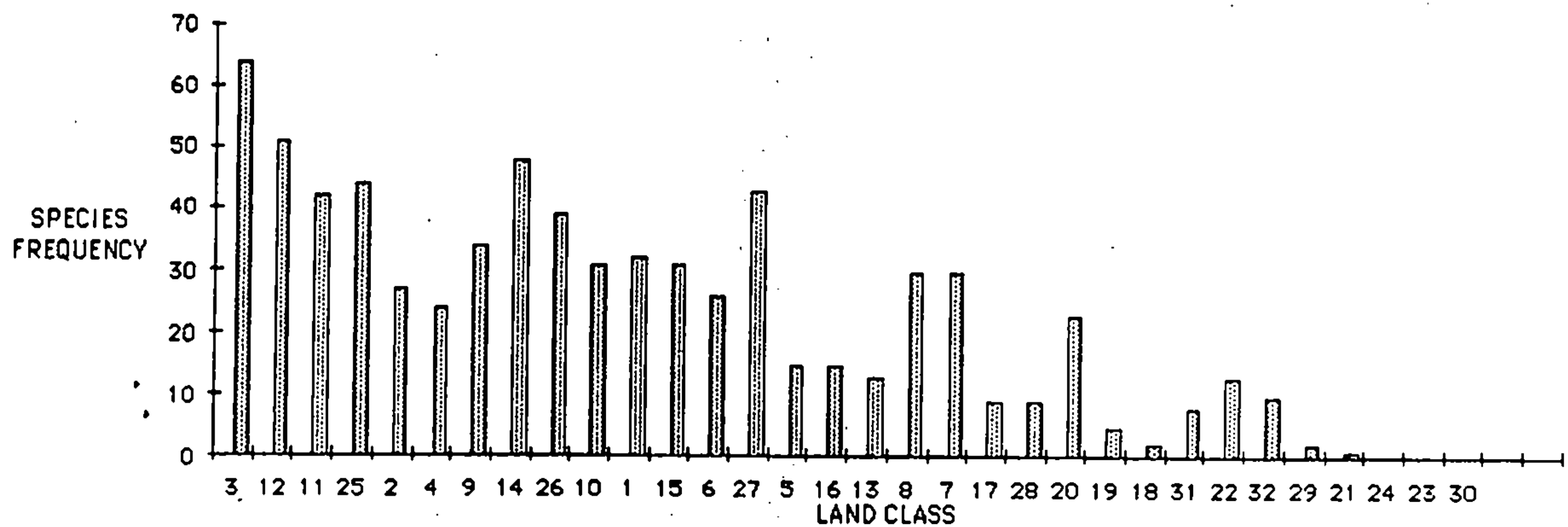
group number 4	
LOLIUM MULTIFLORUM POA PRATENSIS STELLARIA MEDIA	Short Term Leys: Sown species and arable-type weeds

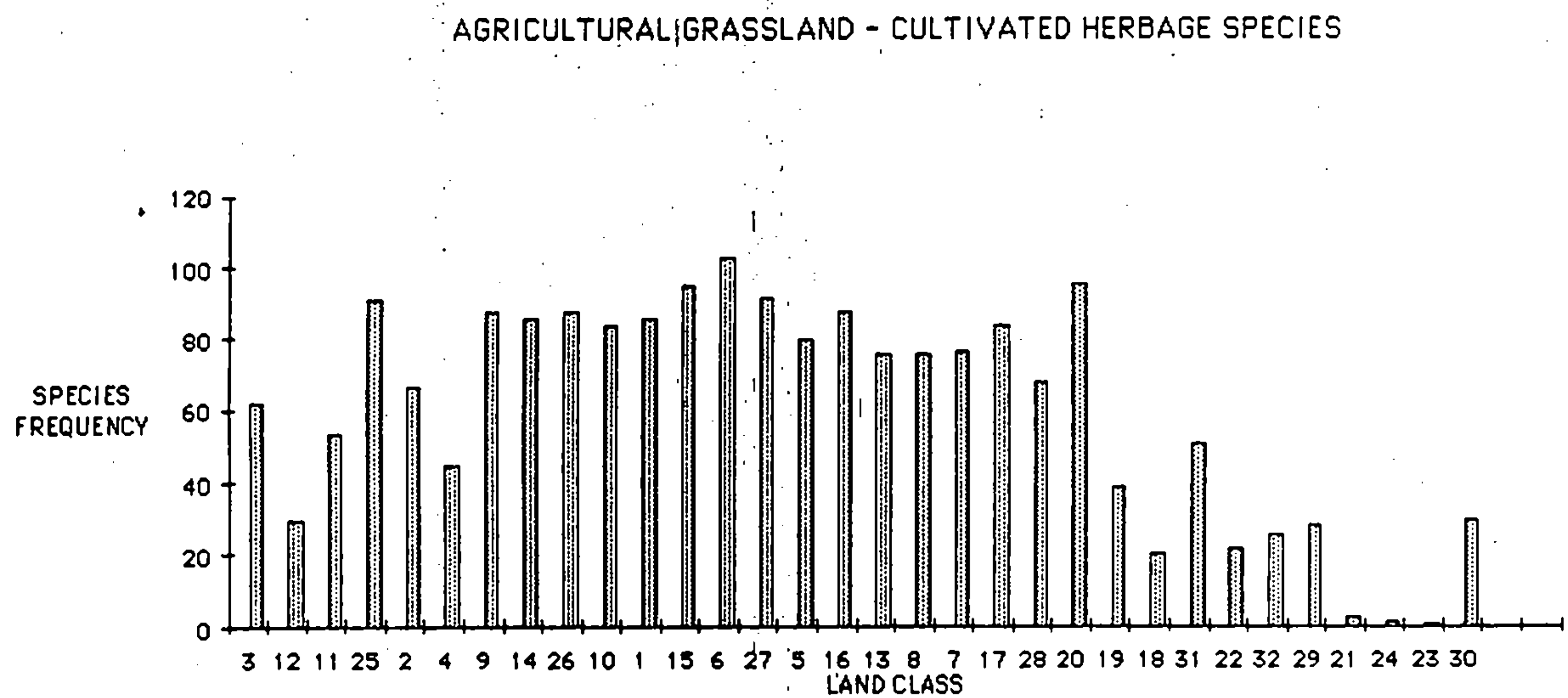
group number 5	
BRACHYTHECIUM RUTABULUM EURYNCHIUM SPP. PRUNELLA VULGARIS RHYTIDIADELPHUS SQUARROSUS RUMEX ACETOSELLA Sagina spp.	Intermedeate Intensity Grasslands: Species indicative of the early stages of a decline in intensity with falling

VERONICA SERPYLLIFOLIA	nitrogen levels.
group number 6	
Agropyron repens Alopecurus pratensis CENTAUREA NIGRA Heracleum sphondylium Lathyrus pratensis Potentilla anserina Ranunculus bulbosus RUMEX CRISPUS TRIFOLIUM PRATENSE	Neglected, High Nutrient Grasslands: More vigourously growing, competitive species.
group number 7	
BROMUS MOLLIS Capsella bursa-pastoris Crepis spp. Geranium molle Rumex conglomeratus/sanguineus Trifolium dubium Veronica arvensis	Old, Disturbed Pastures: Species of old pastures without densely packed swards.
group number 8	
Conopodium majus Festuca ovina Galium saxatile LUZULA MULTIFLORA/CAMPESTRE Potentilla erecta Pteridium aquilinum	Unimproved, Acid Grassland. Species of relatively undisturbed unimproved acid swards.
group number 9	
Alopecurus geniculatus Euphrasia spp. Hieracium spp. Matricaria matricarioides Polygonum aviculare Rhinanthus spp.	Highly Disturbed, High Nutrient Grasslands: Weed species of disturbed grassland
group number 10	
Agrostis canina Cardamine pratensis Equisetum arvense Filipendula ulmaria Juncus articulatus/acutiflora	Poorly Drained Undisturbed Grasslands: Species on gleyed soils
group number 11	
Anthriscus sylvestris Convolvulus arvensis Polygonum persicaria Ranunculus ficaria Spergula arvensis/rupicola Vicia sepium	Short Term Grassland: Weeds of open ground.
group number 12	
Cardamine hirsuta/flexuosa CIRSIUM PALUSTRE Deschampsia cespitosa Epilobium spp. Juncus effusus Stellaria alsine	Impeded drainage, Undisturbed Grassland: Speceis of gleyed soils.

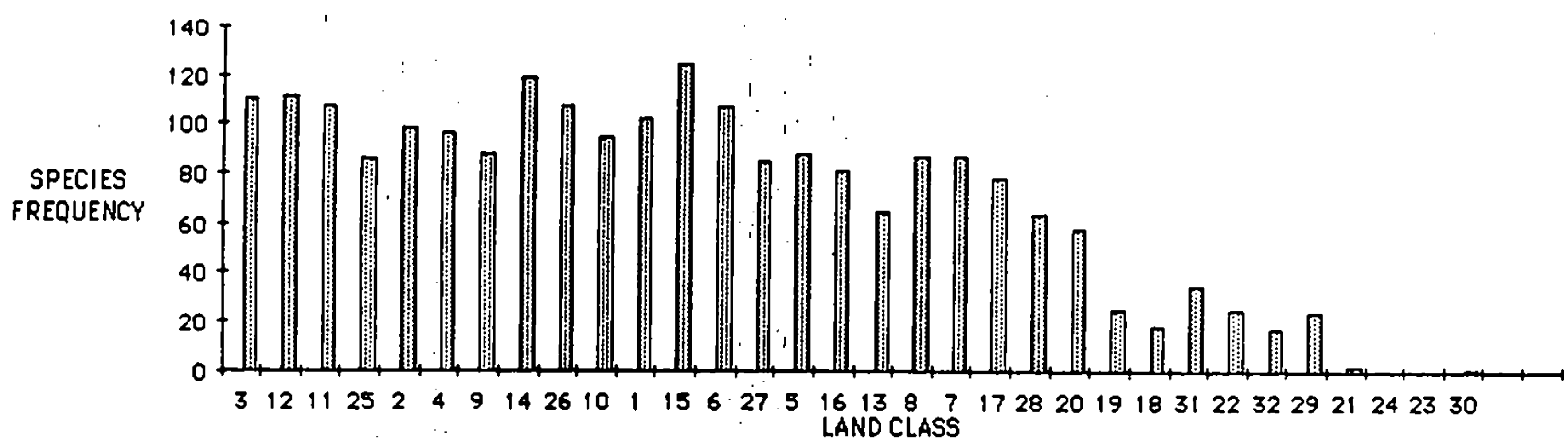
Species	Description
group number 13	
Aphanes spp. Chenopodium album/polyspermum Hordeum vulgare Myosotis spp. Sonchus asper Tripleurospermum maritimum/inodorum Veronica persica	Arable Weeds: Predominately annuals of open, arable or ley fields.
group number 14	
Chrysanthemum leucanthemum Galium verum Glechoma hederacea Medicago lupulina Pseudoscleropodium purum Potentilla reptans Primula vulgaris	Old Mesotrophic Grasslands: Basiphilous species or species of shady banks
group number 15	
Campanula rotundifolia Digitalis purpurea Hieracium pilosella Mnium hornum Mnium undulatum Stellaria graminea Ulex europaeus	Moist, Acid Old Grassland:
group number 16	
Acer pseudoplatanus Arrhenathrum elatius Chamaenerion angustifolium Galium aparine Holcus mollis Pimpinella saxifraga Rubus fruticosus Sambucus nigra	Invading, Colonising Scrub: Basiphilous species
group number 17	
Dryopteris dilatata/carthusiana Endymion non-scriptus Fagus sylvatica Hederea helix Quercus spp. Veronica officinalis	Intermedeate to Acidic Scrub:
group number 18	
Brachypodium sylvaticum Crataegus monogyna Fraxinus excelsior Rosa spp. Viola riviniana Carex flacca Poterium sanguisorba/Sanguisorba minor	Undisturbed, Calcareous Grassland: Basiphilous species

AGRICULTURAL GRASSLAND - ARABLE WEEDS

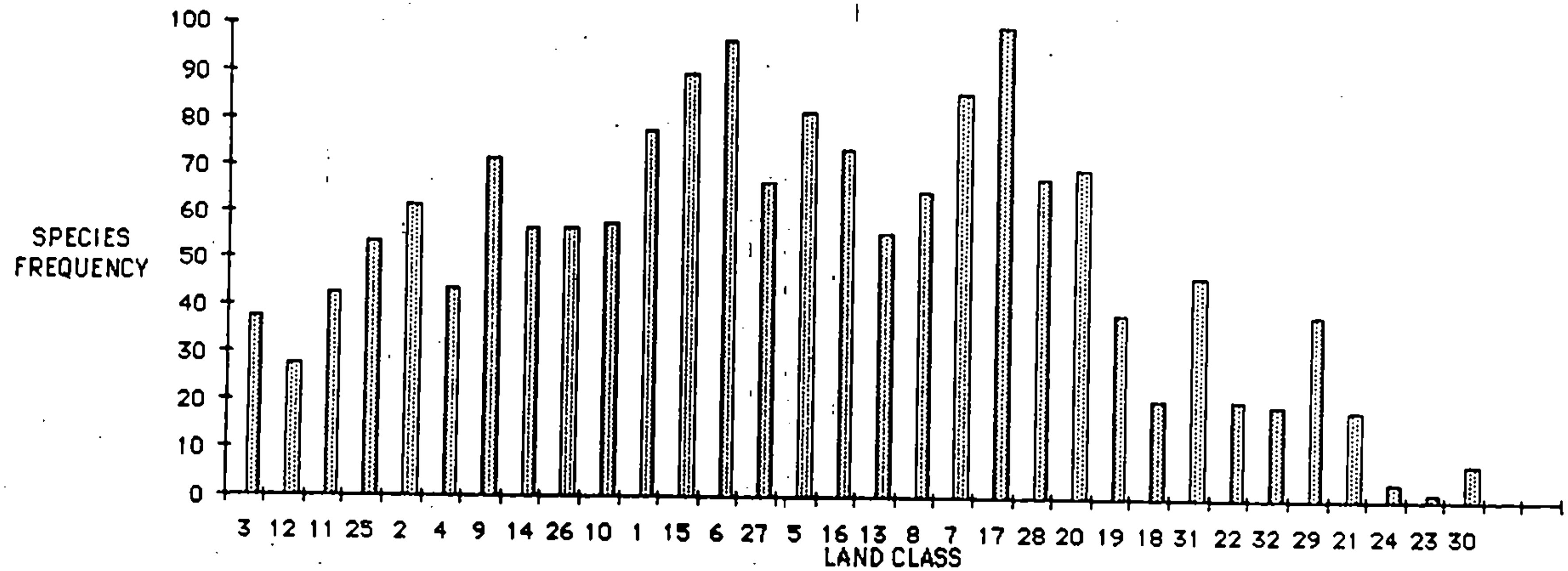


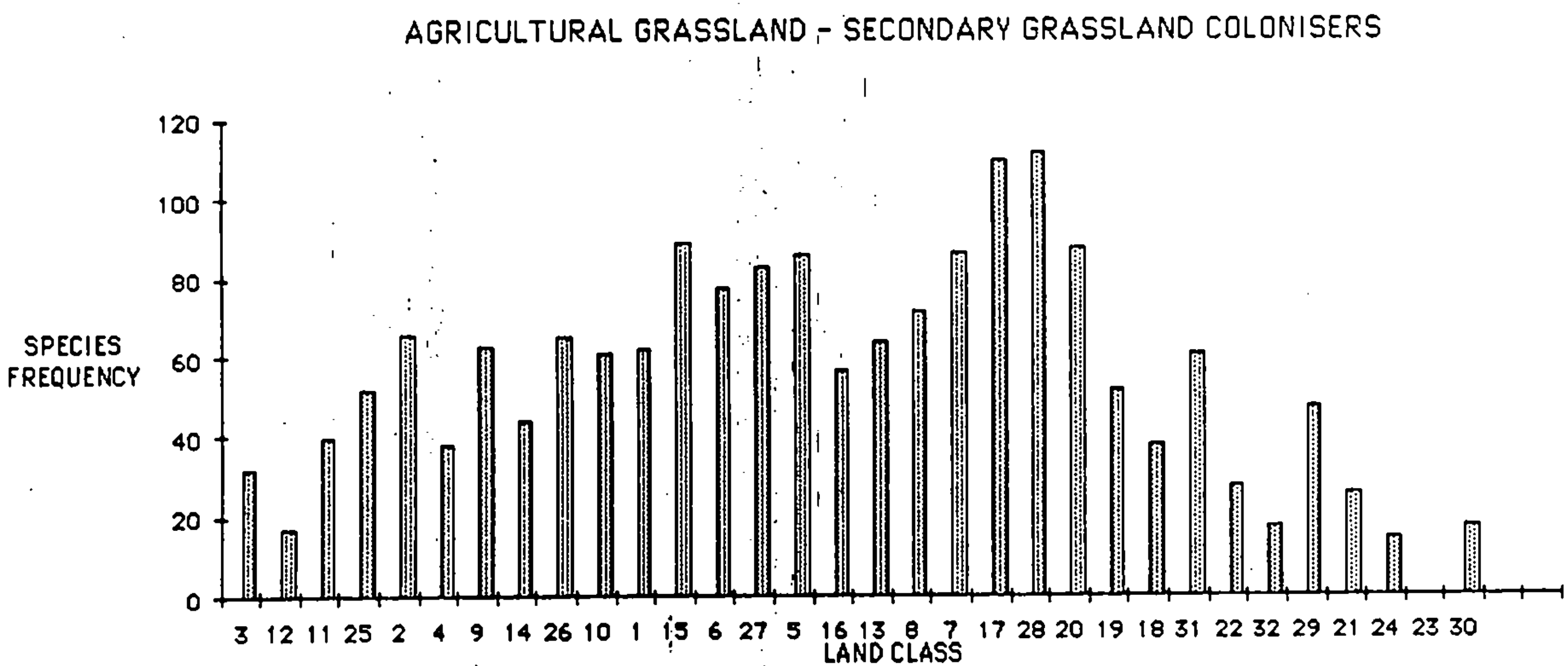

AGRICULTURAL GRASSLAND - CULTIVATED HERBAGE SPECIES
SPECIES FREQUENCY
120
100
80
60
40
20
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS

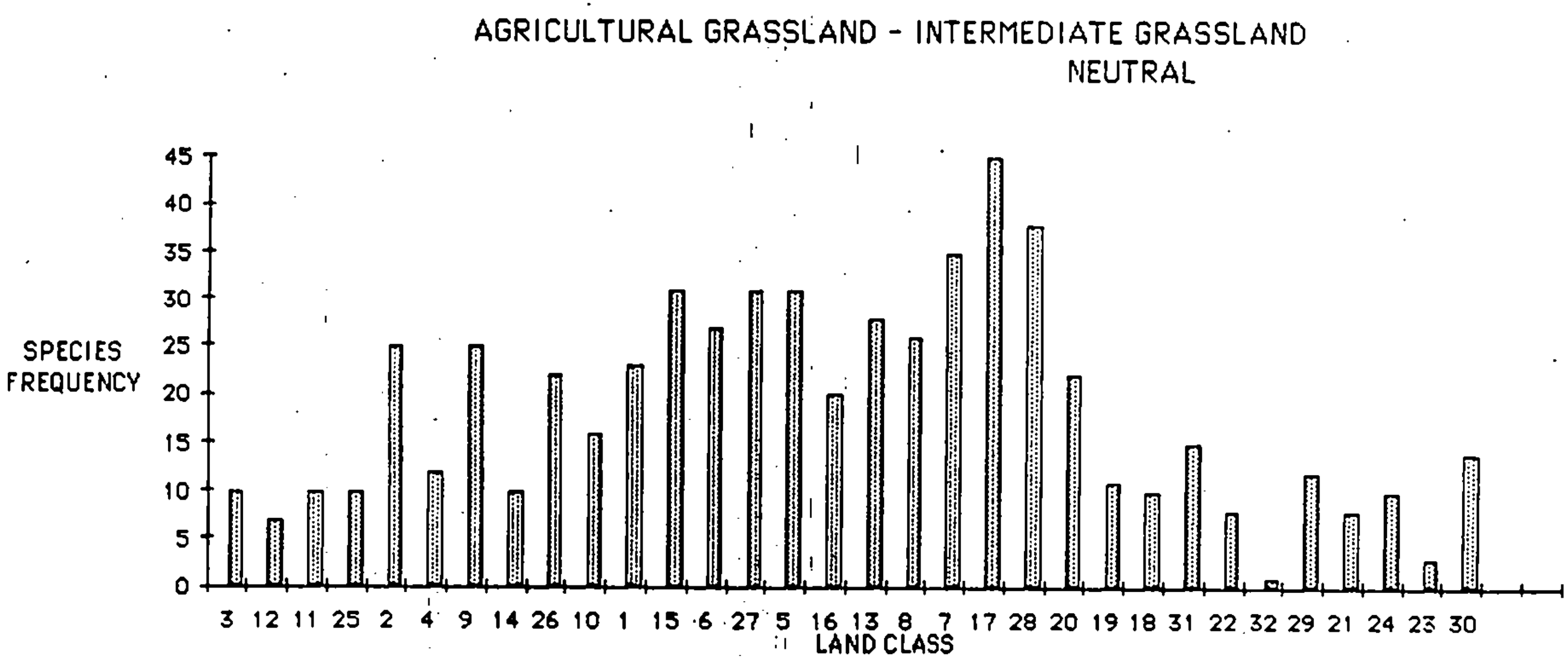
AGRICULTURAL GRASSLAND - INITIAL GRASSLAND COLONISERS
HIGH NITROGEN



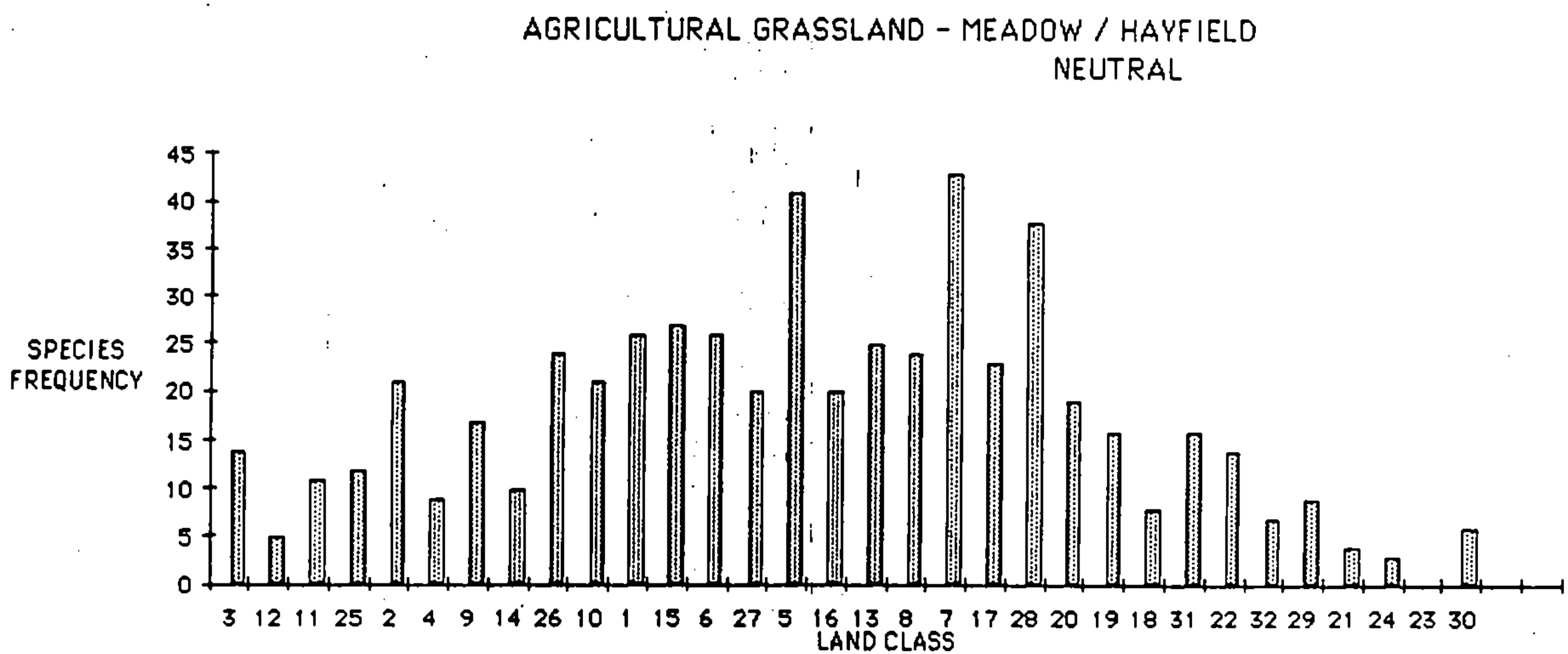
AGRICULTURAL GRASSLAND - EARLY GRASSLAND COLONISERS



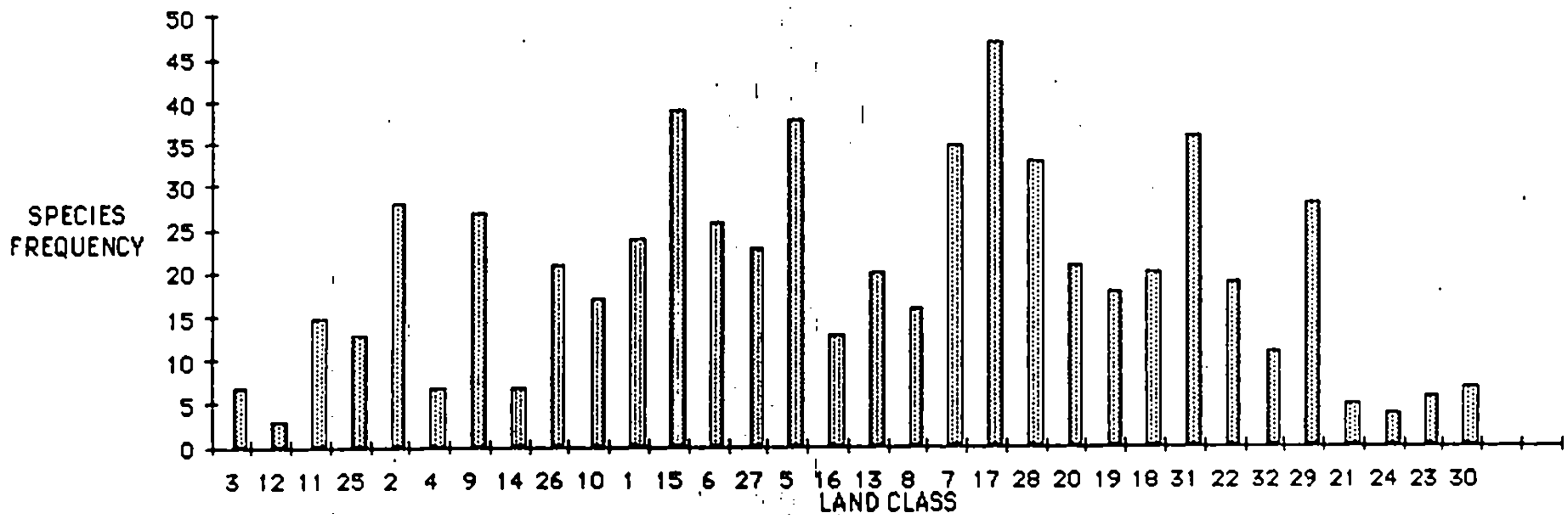

AGRICULTURAL GRASSLAND - SECONDARY GRASSLAND COLONISERS
SPECIES FREQUENCY
120
100
80
60
40
20
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS



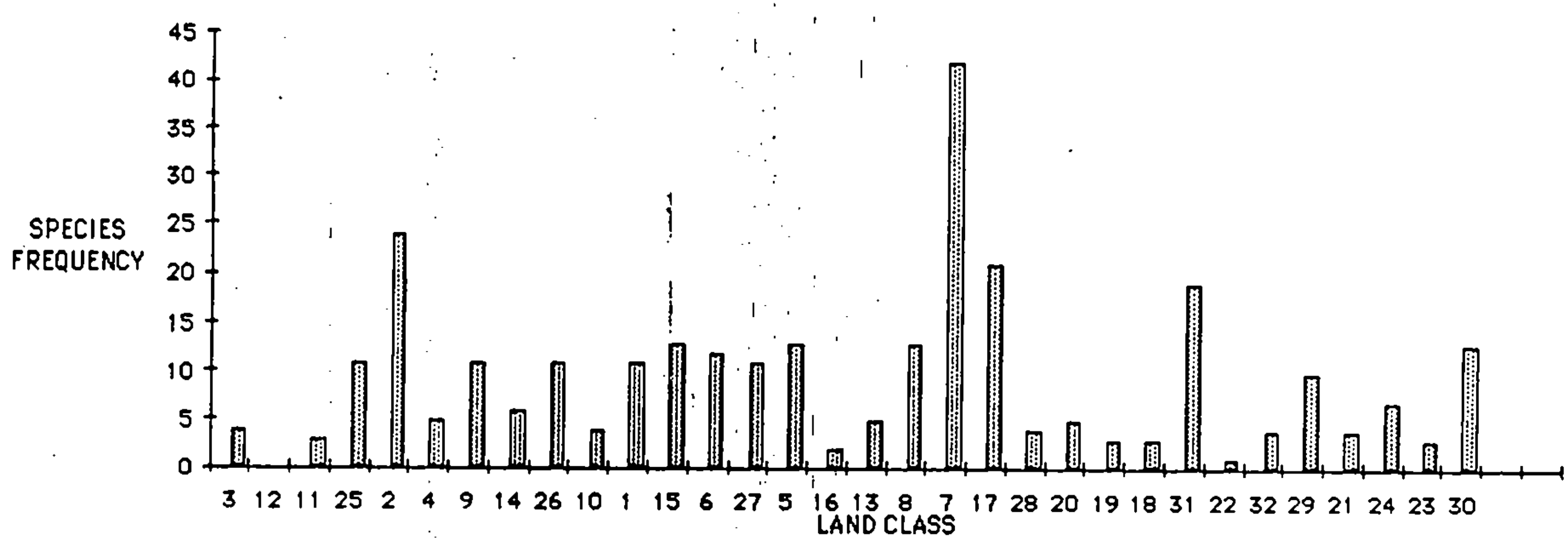
AGRICULTURAL GRASSLAND - INTERMEDIATE GRASSLAND
NEUTRAL
SPECIES FREQUENCY
45
40
35
30
25
20
15
10
5
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS


AGRICULTURAL GRASSLAND - MEADOW / HAYFIELD
NEUTRAL
SPECIES FREQUENCY
45
40
35
30
25
20
15
10
5
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS

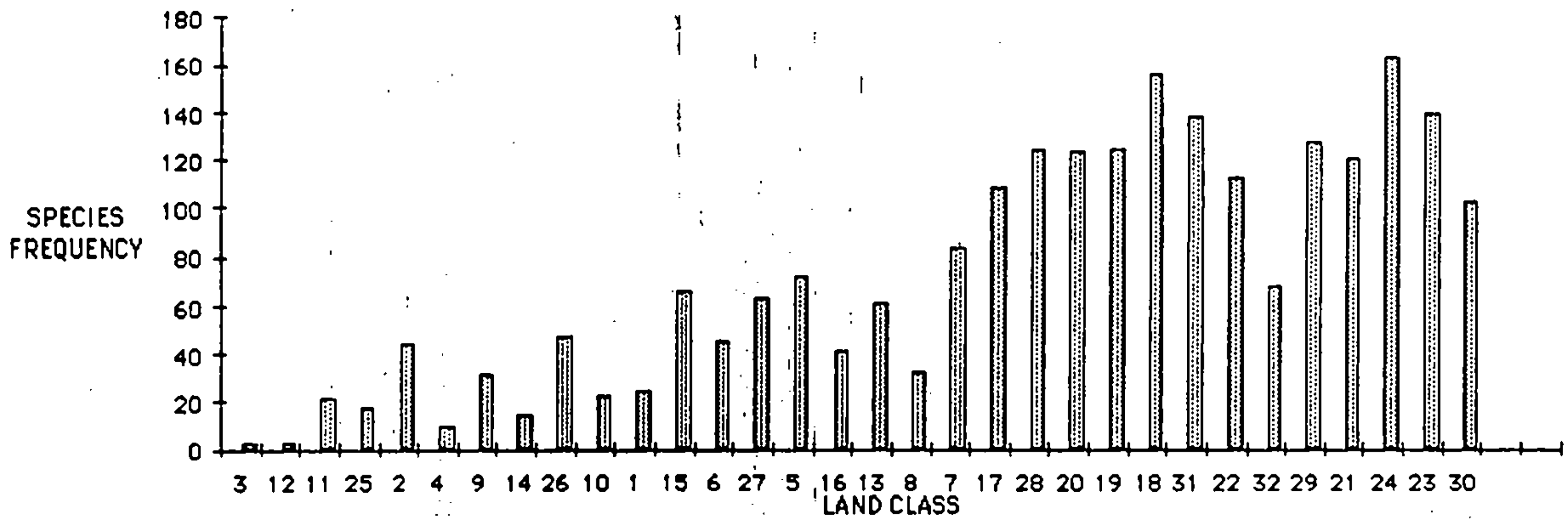
AGRICULTURAL GRASSLAND - OLD GRASSLAND
NEUTRAL

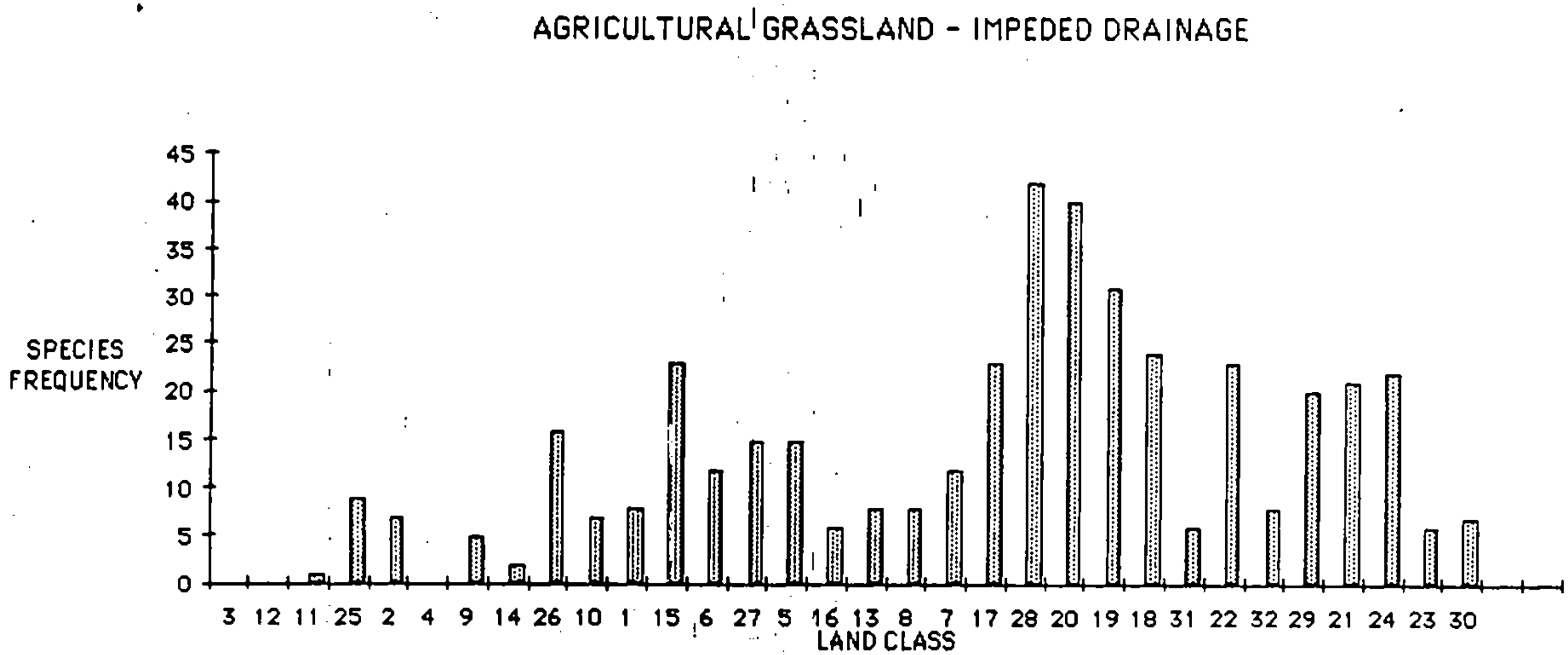


AGRICULTURAL GRASSLAND - CALCAREOUS GRASSLAND

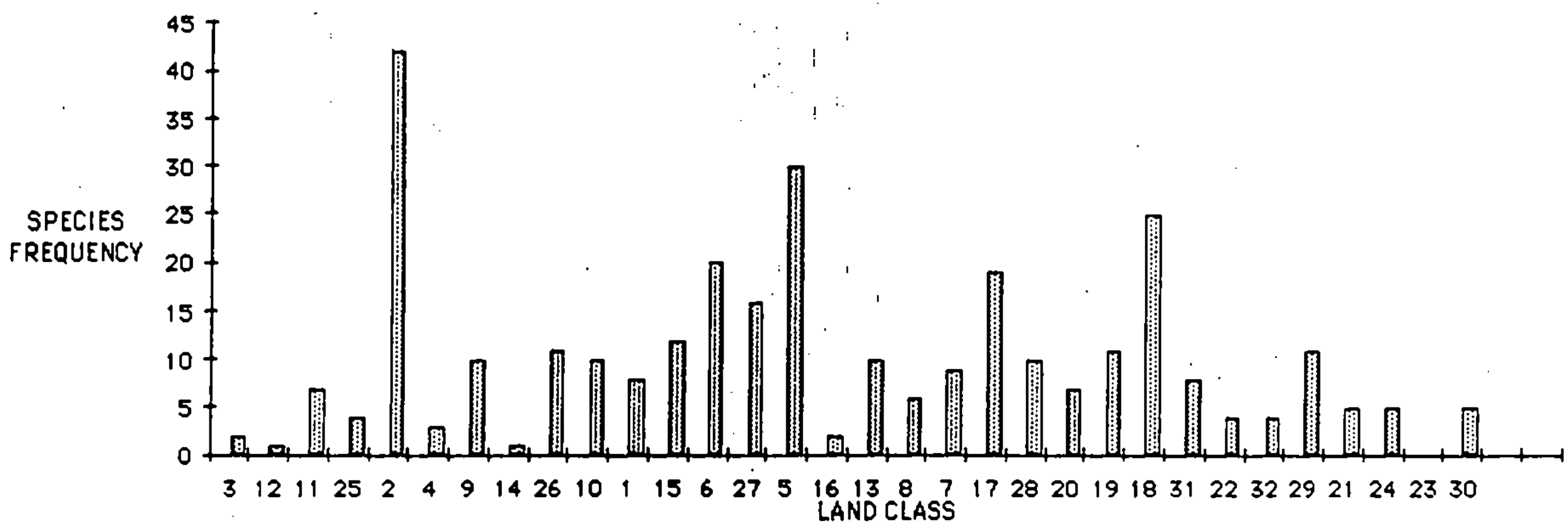


AGRICULTURAL GRASSLAND - ACIDIC GRASSLAND

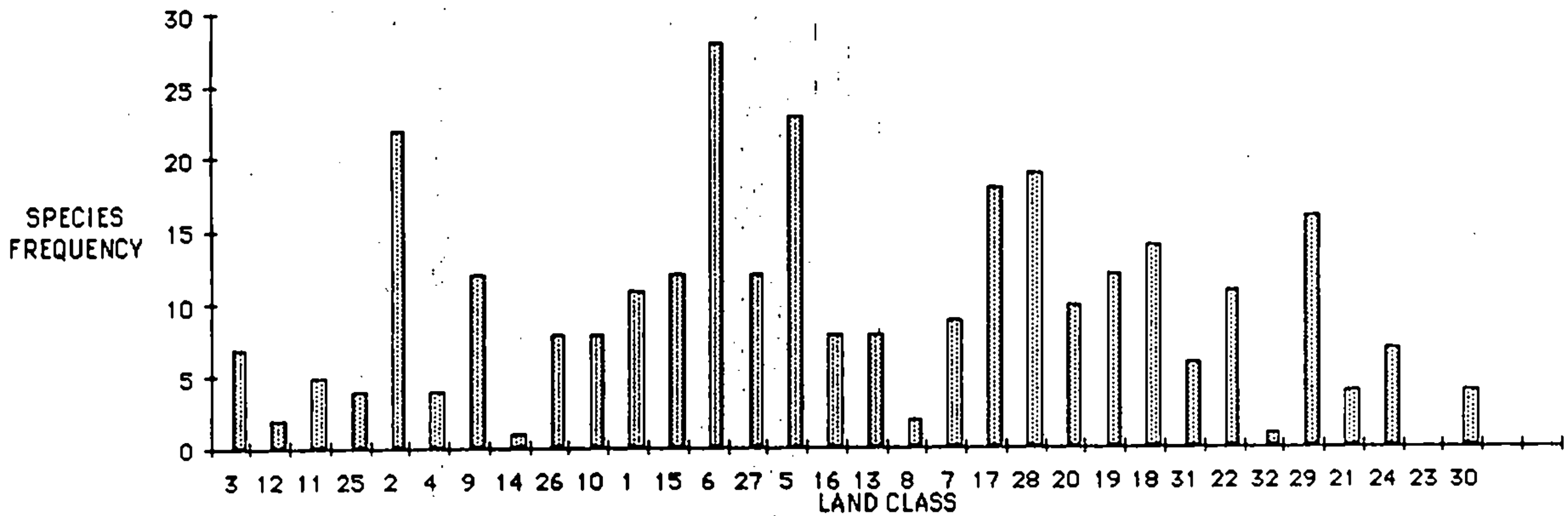



AGRICULTURAL GRASSLAND - IMPEDED DRAINAGE
SPECIES FREQUENCY
45
40
35
30
25
20
15
10
5
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS

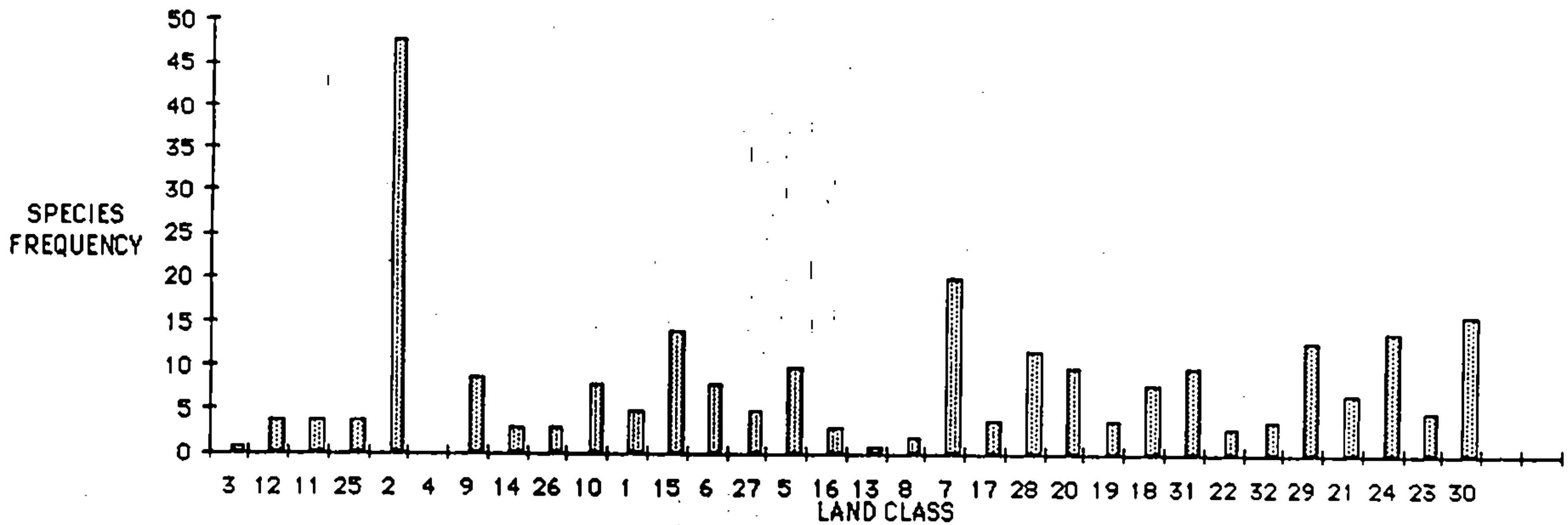
AGRICULTURAL GRASSLAND - SCRUB / LOW LEVEL MANAGEMENT



AGRICULTURAL GRASSLAND - ACIDIC WOODLAND



AGRICULTURAL GRASSLAND - CALCAREOUS WOODLAND



DISCRIMINANT FUNCTION ANALYSIS

LAND CLASS	FREQUENCY OF RECLASSIFIED SQUARES	LAND CLASSES OF RECLASSIFIED SQUARES									
1	10	2	4	5	5	5	6				
2	16	1	1	5	11						
3	14	2	2	4							
4	9	3	3	3	3	5					
5	19	1	2	15							
6	12	5	5	5	7	17					
7	7	2	2	5	6	8	8	30	30	30	
8	7	2	2	3	5	6	7	7			
9	16	10	10	10	11	11	11	11			
10	11	9	9	9	9	9	15	20	27		
11	14	9	9	9	12	12					
12	13	11									
13	12	10	16	16	16	14	30				
14	8	7	8	9	9	13	26	29	29		
15	14	1	10	10	10						
16	13	13	13	13	14	14	15				
17	13	6	6	15							
18	8	15	16	17	17	19	23				
19	9	18	20	20	20	20	22	26	27		
20	14	13	17	18	19	19	19	24			
21	13	19	20	22	28	31					
22	11	21	24	28							
23	12	28									
24	12	21	21								
25	14	21	26	26	27	27	27				
26	10	15	25	25	25	25	27	30			
27	9	10	14	16	25	25	25	25	26		
28	9	13	16	16	20	20	21	31			
29	10	28	21	30	30	30	30	32			
30	24										
31	17	32	32	32							
32	6	21	29	29	30	31	31	31	31	31	31
TOTAL	384	44% RECLASSIFIED									

THE APPLICATION OF THE DISCRIMINANT FUNCTION AS A MEANS OF AUTOMATING THE CLASSIFICATION PROCEDURE

The current procedure has been to use the seven variables (snow line, sunshine hours, minimum January temperature, distance to west coast, distance to north coast, maximum altitude and minimum altitude). The 12 sample squares from each land class have been used as the means for fitting individual members to the group means.

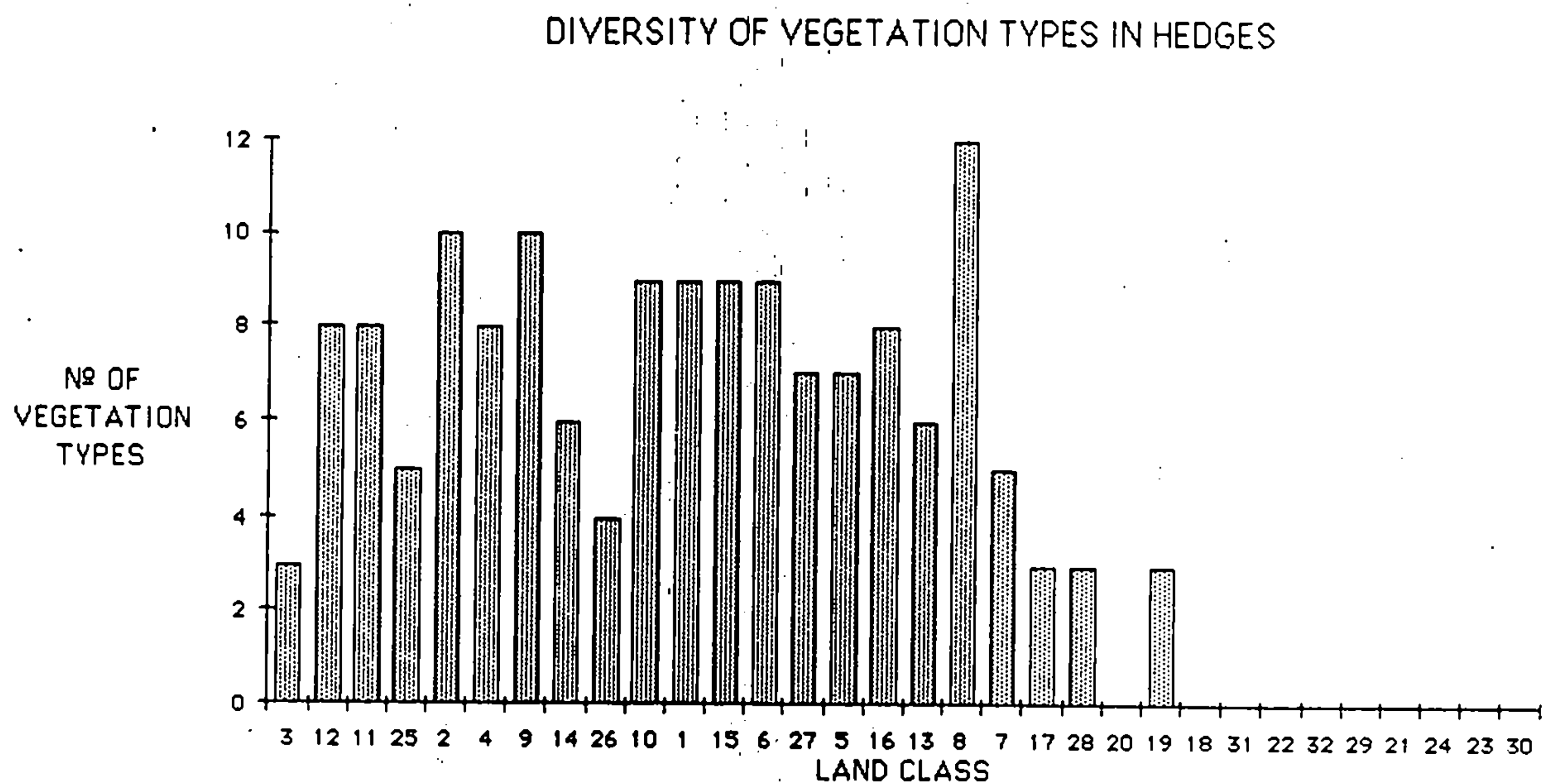
The test set of 384 squares revealed a misclassification rate of 44% which reduced to 26% if adjacent land classes are taken into account. However this oversimplifies the situation since if the position of the classes is taken in multivariate space then the misclassification rate is much lower. Indeed the allocationof marginal members of each class could be improved by the smoothing process with the discriminant function. Further studies are required to investigate the influence of this classification procedure on the errors from prediction.

An-example of the application of this procedure has been the classification of 500 squares for the RSPB for the setting up of a monitoring scheme for moorland birds in the north of Britain. The rapid classification of these squares enabled site selection to proceed efficiently.

		QUADRATS				
	LAND CLASS	CROPS	PERM GRASS	UPLAND GRASS	MOOR & BOG	TOTALS
CULTIVATED LOWLAND	3	10	4			14
	12	12				12
	11	10	4			14
	25	15	3			18
	2	16	6	2		24
	4	13	2			15
	9	13	4	1		18
	14	16	3			19
	26	14	4	3	1	21
PASTURAL LOWLAND	10	11	4	2	2	19
	1	14	5		1	20
	15	10	7	1		23
	6	19	4	1		25
	27	15	3	2		20
	5	12	7	4		23
	16	17	3	2	3	25
	13	17	5	1	2	25
	8	17	5	1		23
	7	12	5	3	2	22
MARGINAL UPLAND	17	6	6	5	1	18
	28	7	4	5	3	19
	20	8	3	6	2	19
	19	8	2	7	4	22
	18	5	2	6	6	19
	31	6	4	5	7	22
	22	6	2	6	7	21
	32	5		3	7	15
	29	4	2	4	7	17
UPLAND	21	1	1	5	9	16
	24	1		3	10	14
	23	3		3	10	13
	30	1		3	8	12
Nº OF TYPES	31	12	14	14	14	

LINEAR FEATURES - VEGETATION TYPE DIVERSITY

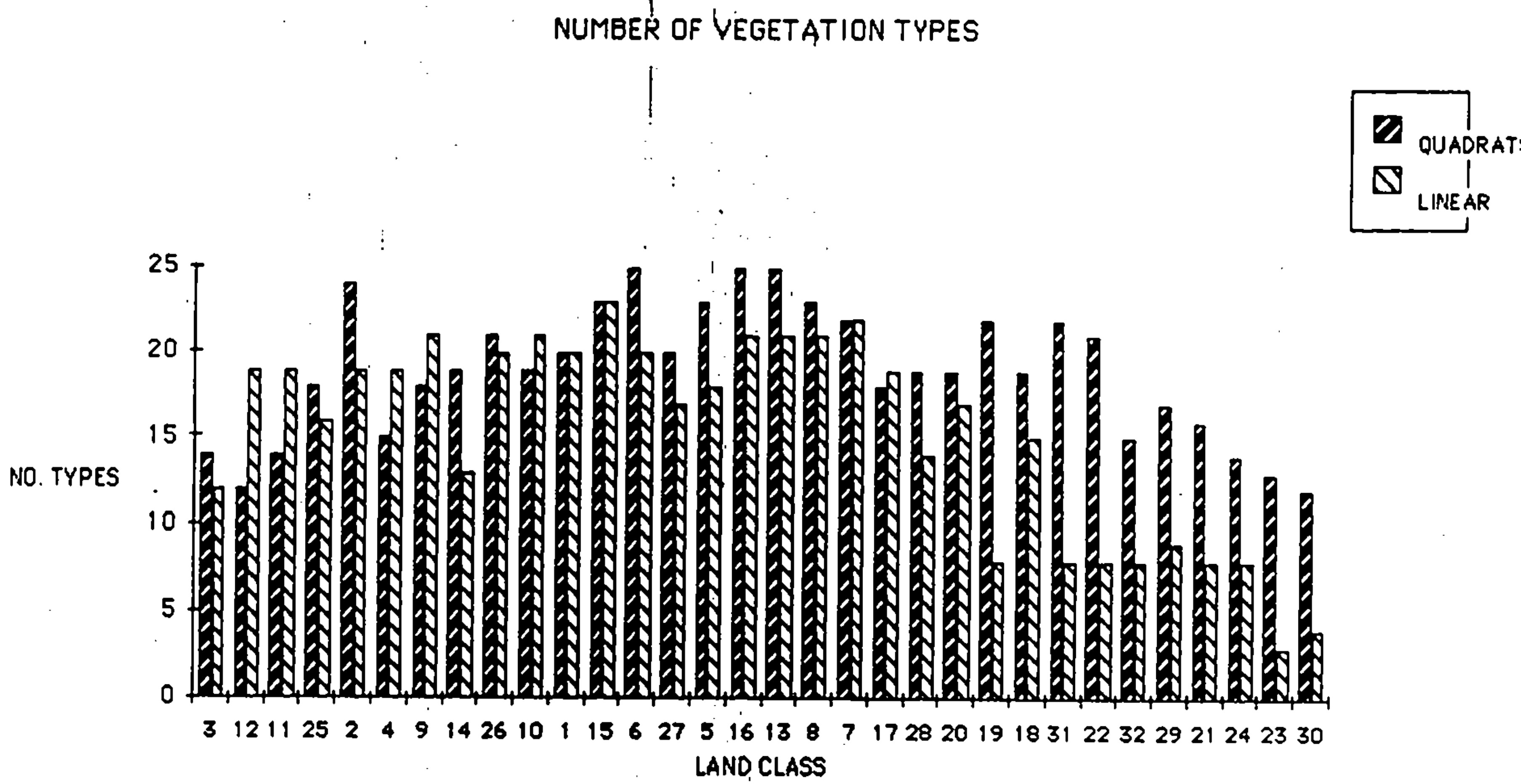
Hedges :	variability relatively consistent in lowlands, and falls off rapidly in uplands.
Verges:	variability consistent until land class 19, then falls off sharply.
Streams :	variability lowest in the intensively managed lowlands, otherwise consistent.


DIVERSITY OF VEGETATION TYPES IN HEDGES
Nº OF VEGETATION TYPES
0
2
4
6
8
10
12
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS

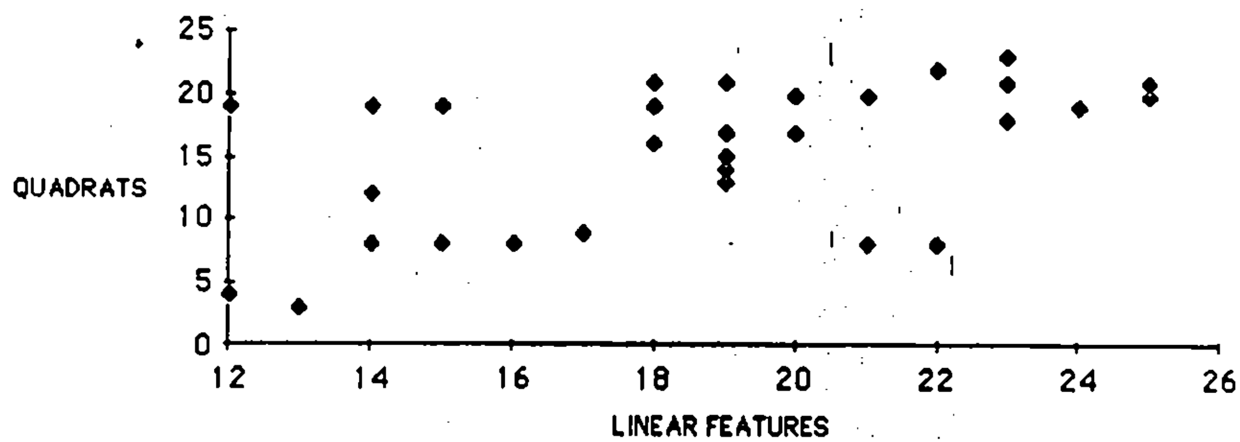
	LAND CLASS	LINEAR			
		HEDGES	VERGES	STREAMS	TOTALS
CULTIVATED LOWLAND	3	3	6	3	12
	12	8	7	4	19
	11	8	7	4	19
	25	5	6	5	16
	2	10	7	2	19
	4	8	5	4	19
	9	10	7	4	21
	14	6	4	3	13
	26	4	7	9	20
PASTURAL LOWLAND	10	9	6	6	21
	1	9	7	4	20
	15	9	7	7	23
	6	9	5	6	20
	27	7	5	3	17
	5	7	7	4	18
	16	8	7	7	21
	13	6	9	4	21
	8	12	9	6	21
	7	5	7	3	22
MARGINAL UPLAND	17	3	7	7	19
	28	3	3	8	14
	20		6	8	17
	19	3	4	4	15
	18		5	7	8
	31		3	5	8
	22		2	6	8
	32		2	4	8
	29		3	6	9
UPLAND	21		2	6	8
	24		2	5	8
	23			4	3
	30		1	3	4
Nº OF TYPES	31	15	13	16	

NUMBER OF VEGETATION TYPES :

the quadrat and linear features vary independently.


NUMBER OF VEGETATION TYPES
QUADRAT:
LINEAR
NO. TYPES
0
5
10
15
20
25
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS

NUMBER OF VEGETATION TYPES

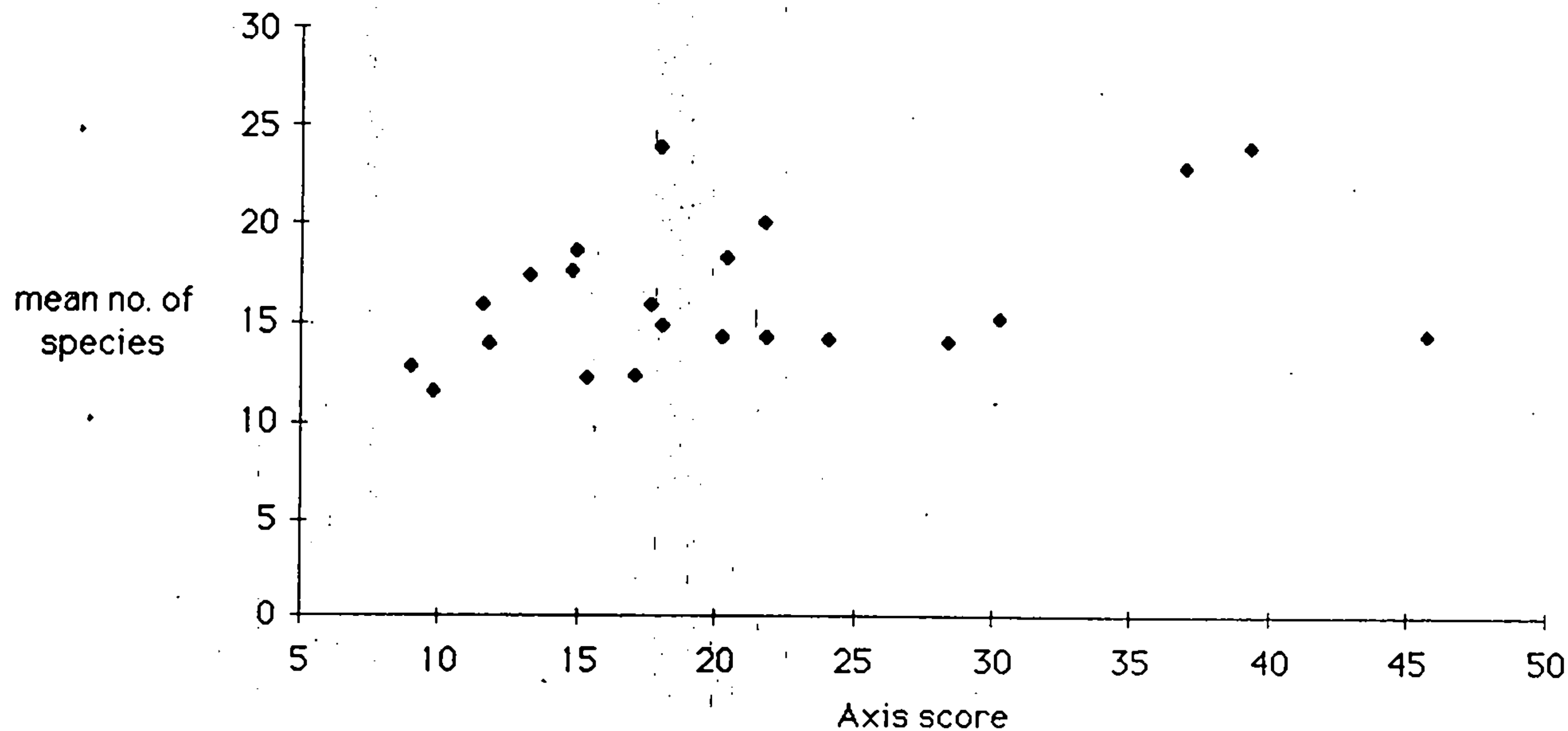


HEDGES - mean number of species per 10m

Numbers increase in upland land classes with a significant relationship with the environmental axis score of the land classes.

Land class 6 is exceptional - the hedge banks of the west country being very rich.

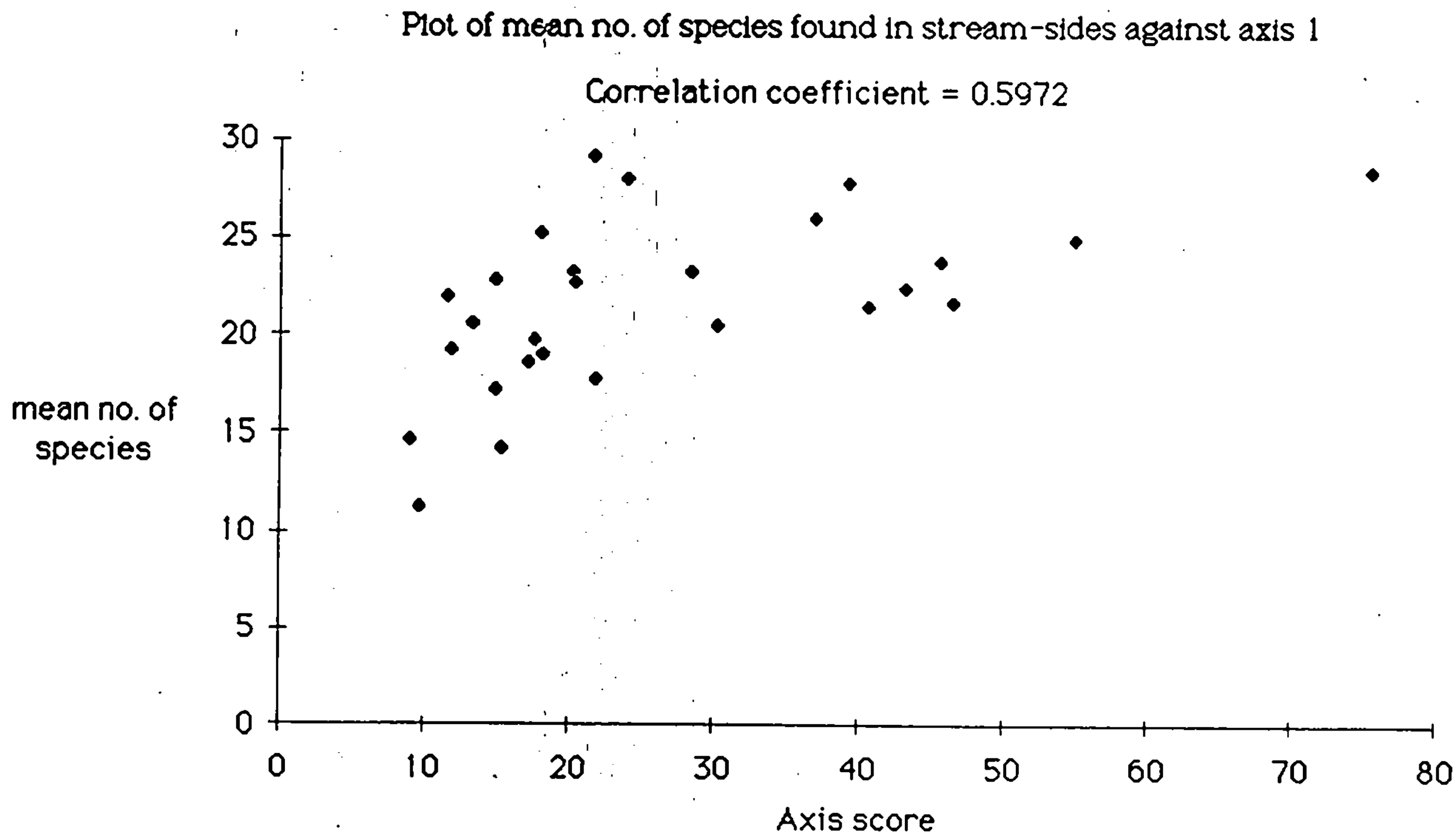
Plot of mean no. of species found in hedges against axis 1
- an expression of lowland - upland gradient
Correlation coefficient = 0.4432

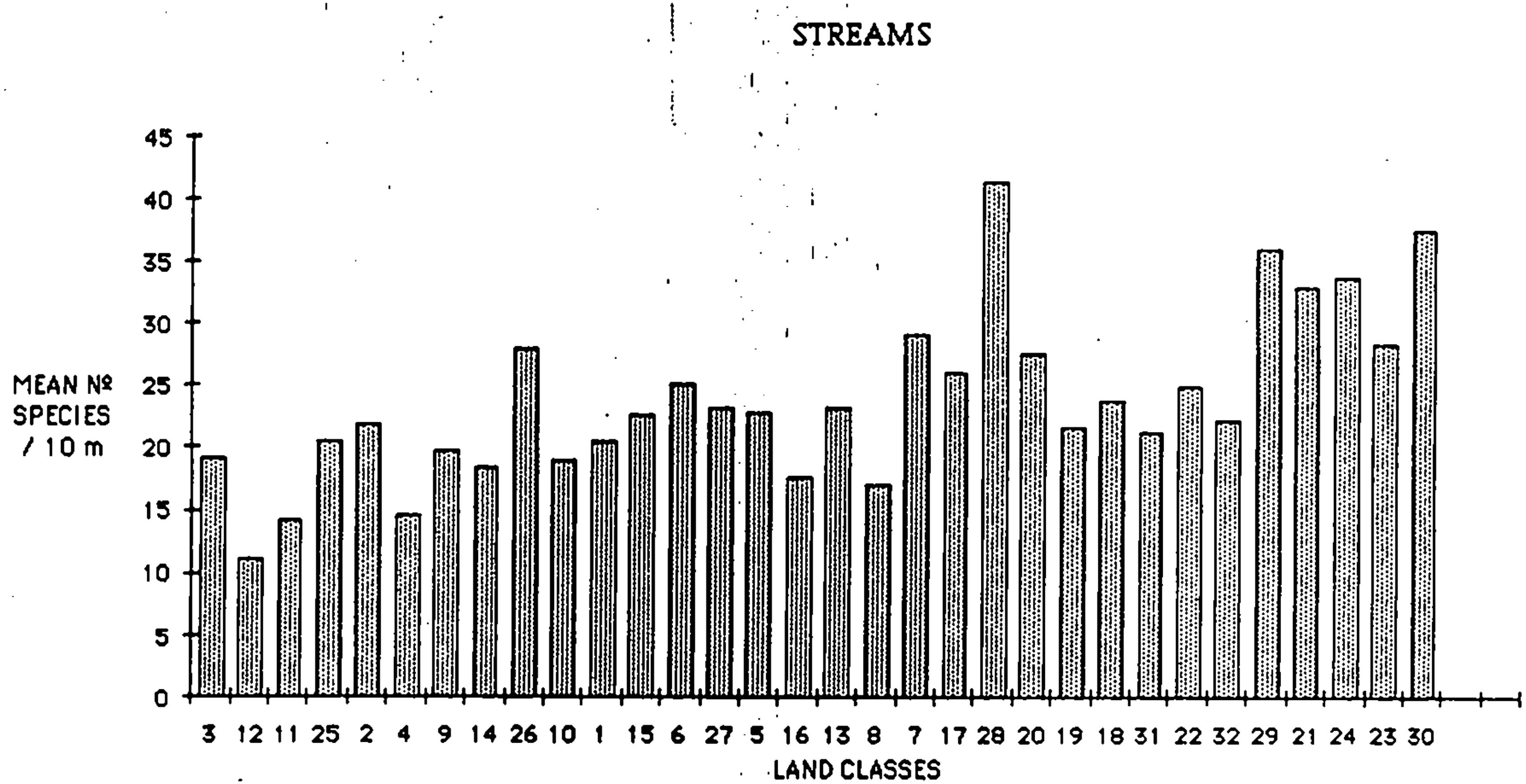


STREAMS - mean number of species per 10m

Numbers increase in upland land clases with a significant relationship with the environmental axis score of the land classes.

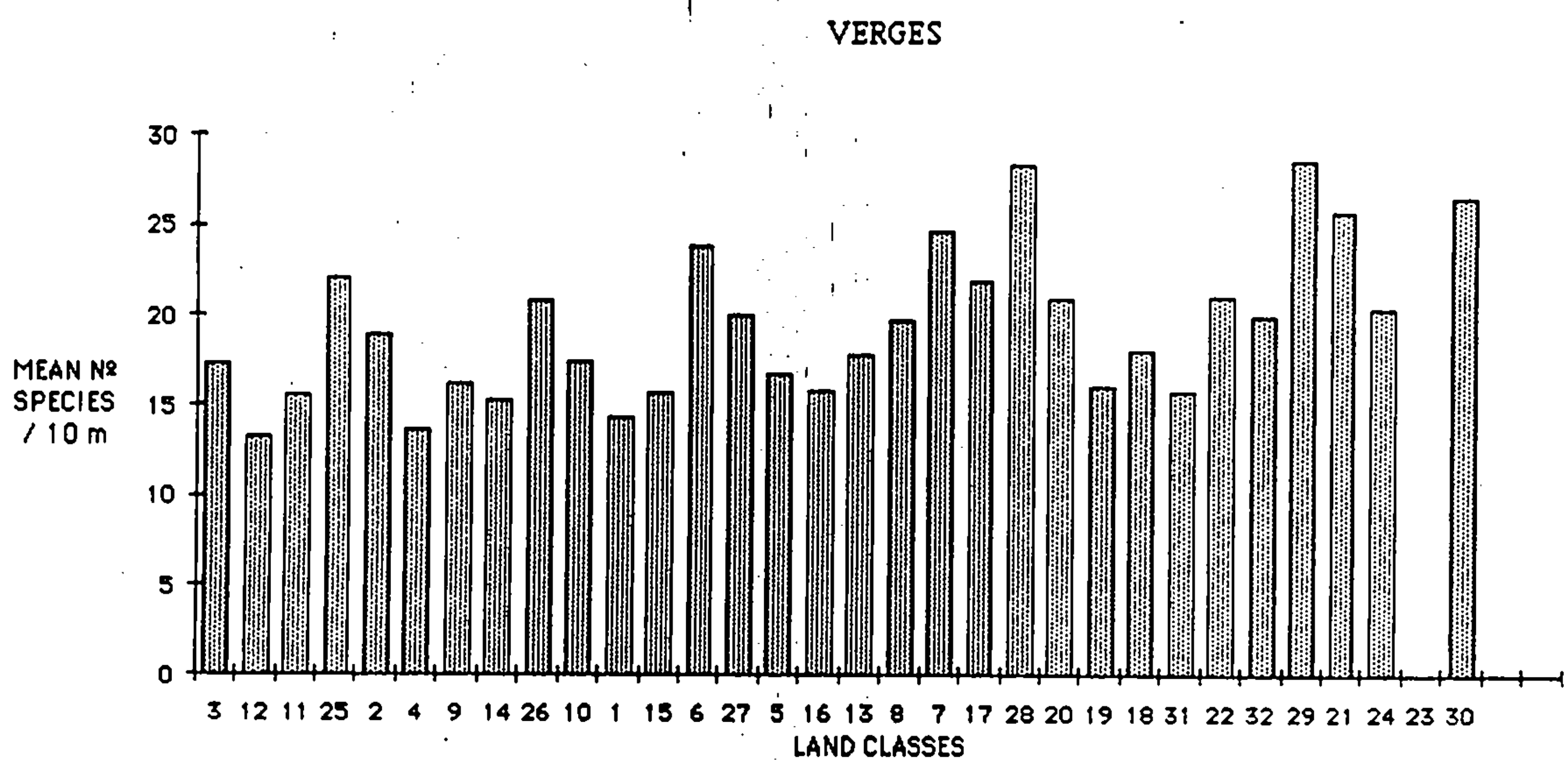
The lowlands are relatively consistent in comparison with the uplands.

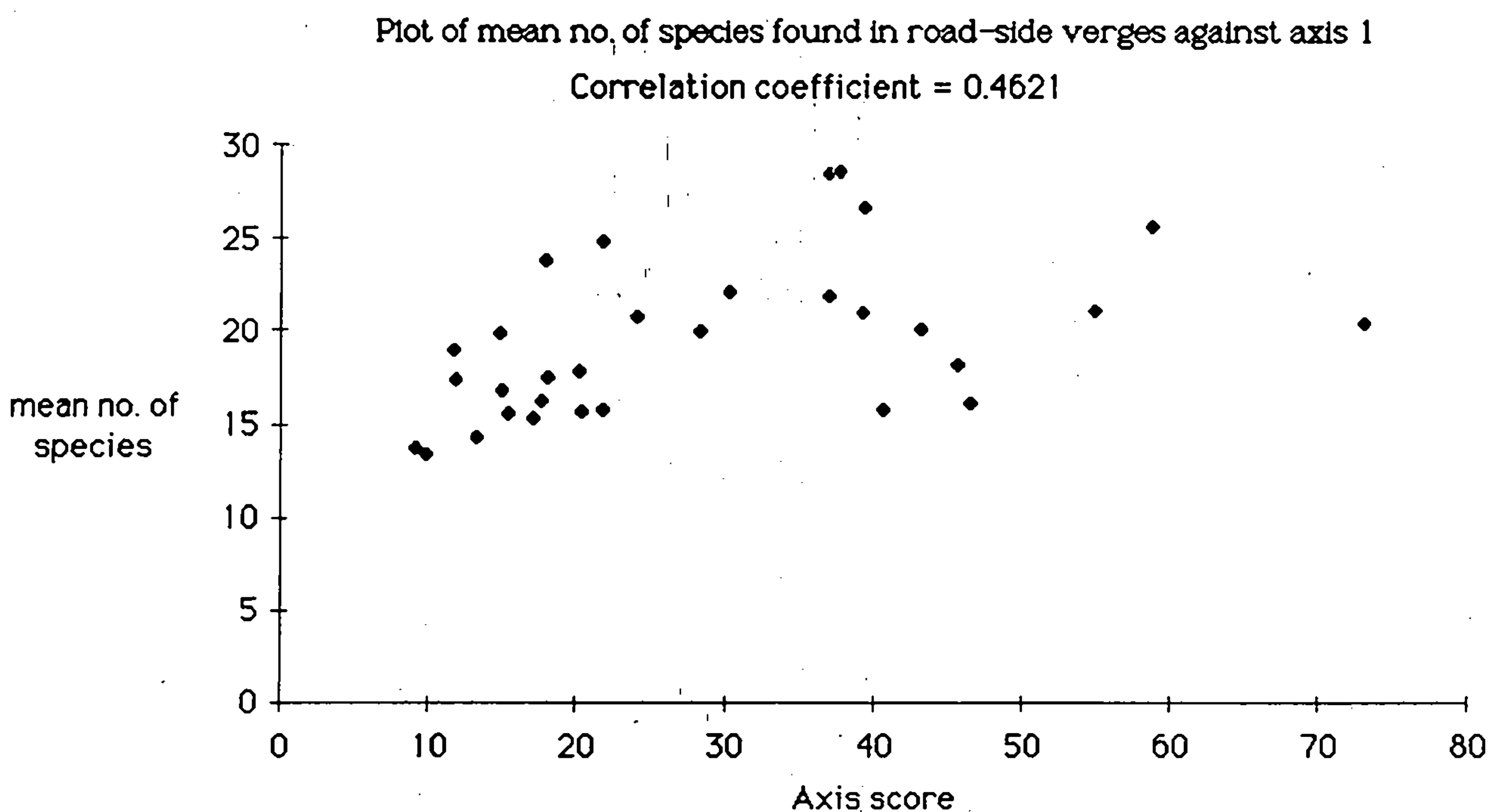

Plot of mean no. of species found in stream-sides against axis 1
Correlation coefficient = 0.5972
mean no. of species
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
Axis score


STREAMS
MEAN Nº SPECIES / 10 m
45
40
35
30
25
20
15
10
5
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASSES

VERGES - mean number of species per 10m

Numbers increase in upland classes although there is considerable variability, with the Scottish lowland classes standing out as having more species, presumably due to lower levels of management.

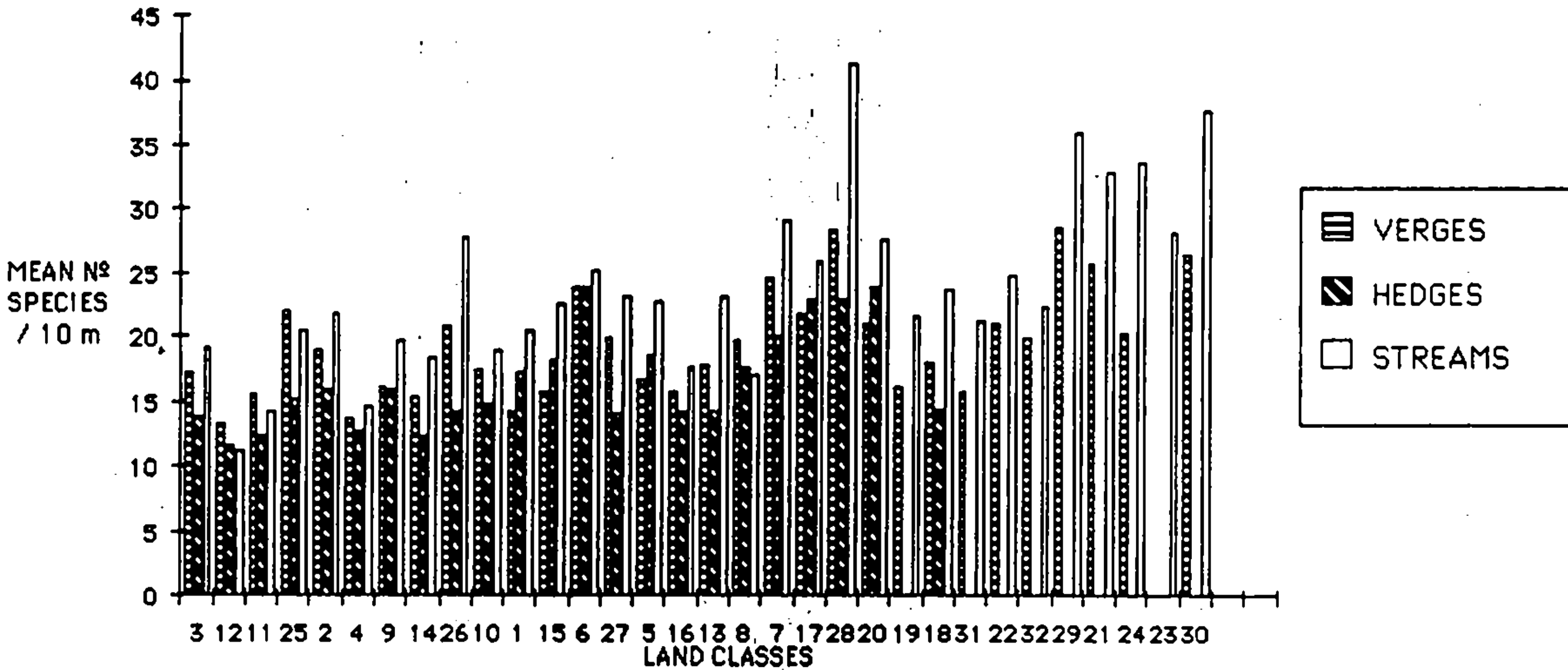

VERGES
MEAN Nº SPECIES / 10 m
30
25
20
15
10
5
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASSES


Plot of mean no. of species found in road-side verges against axis 1
Correlation coefficient = 0.4621
mean no. of species
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Axis score

LINEAR FEATURES - mean number of species

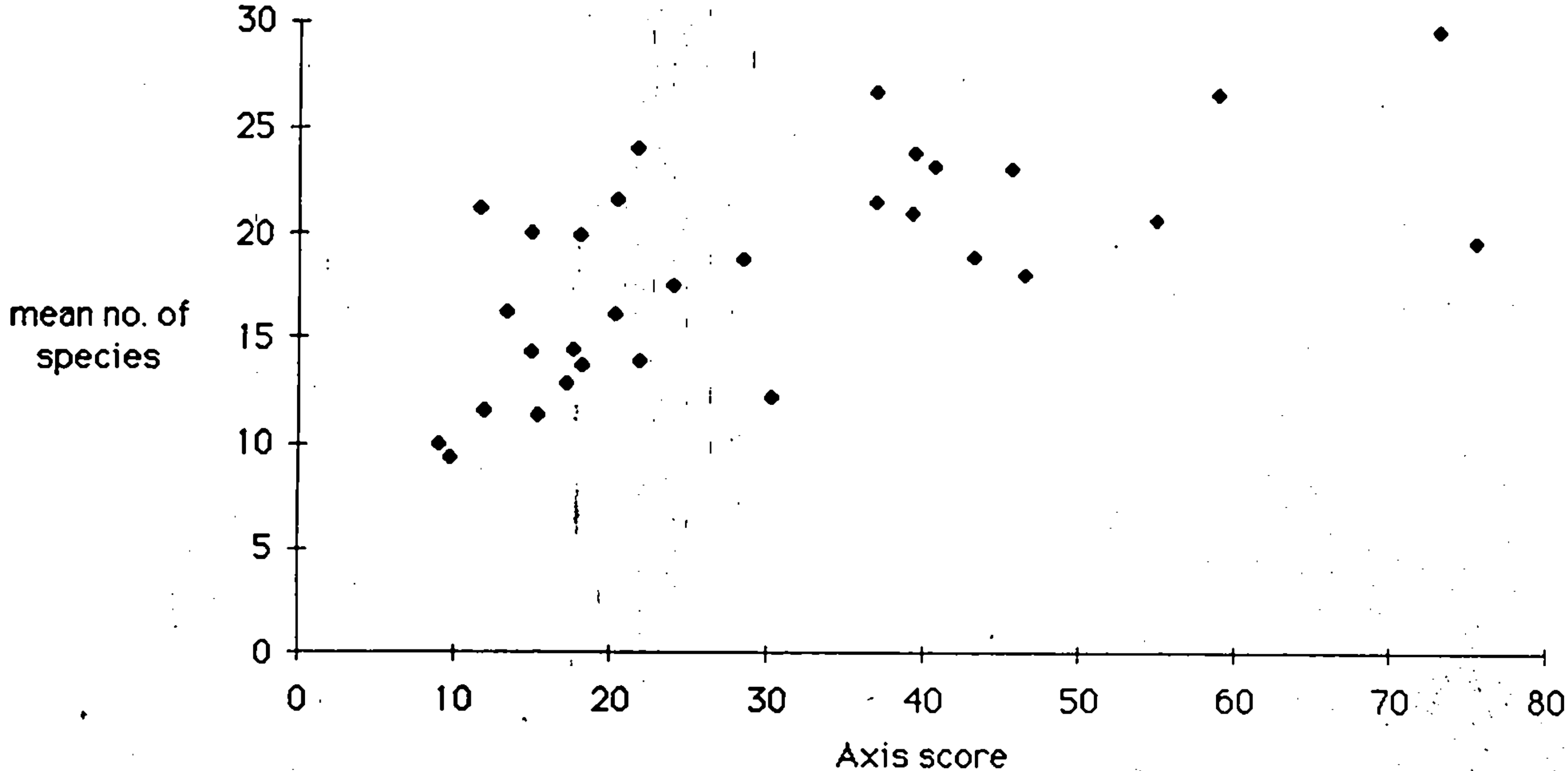
The combined data show the overall trend from the lowland classes to the upland classes; with the combined correlation being higher.

LINEAR FEATURES - MEAN NUMBER OF SPECIES



Plot of mean no. of species found in quadrats against axis 1

Correlation coefficient = 0.6290



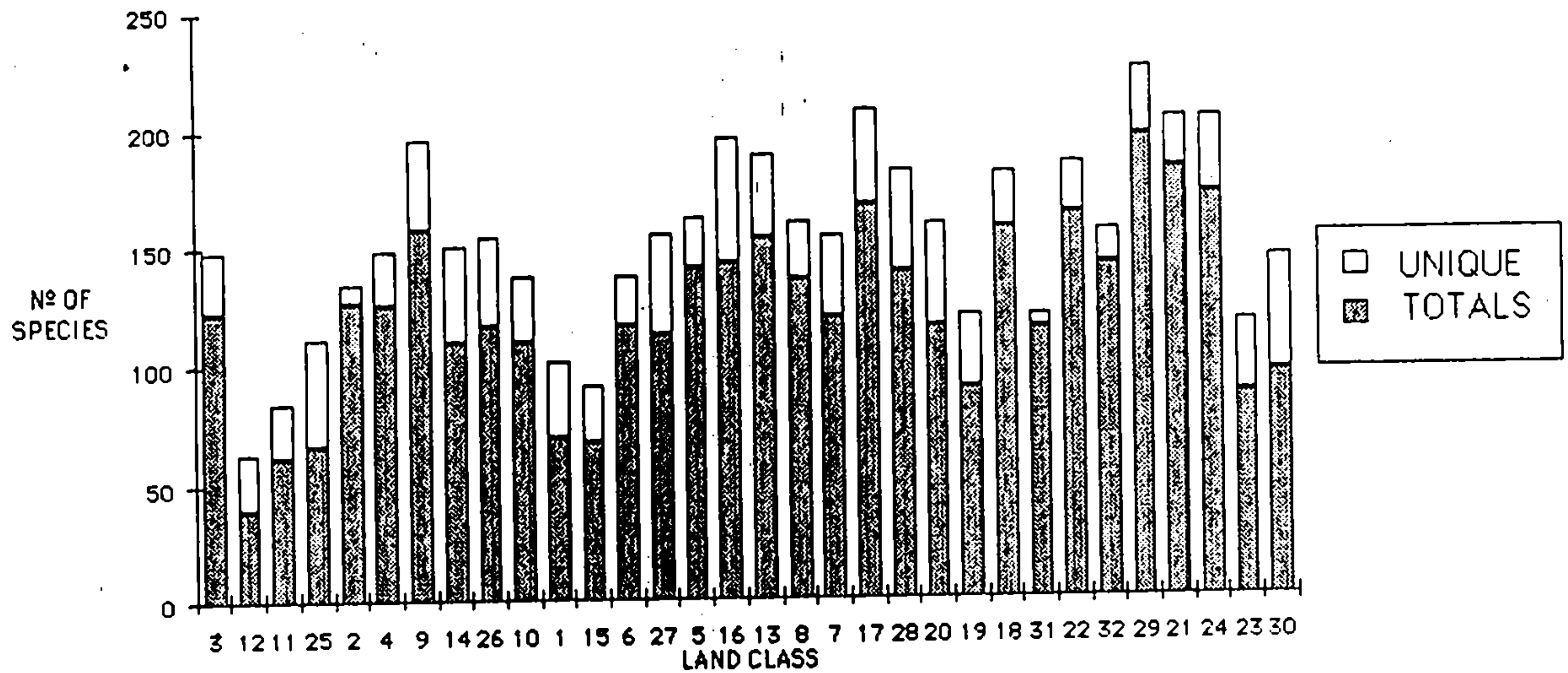
UNIQUE SPECIES

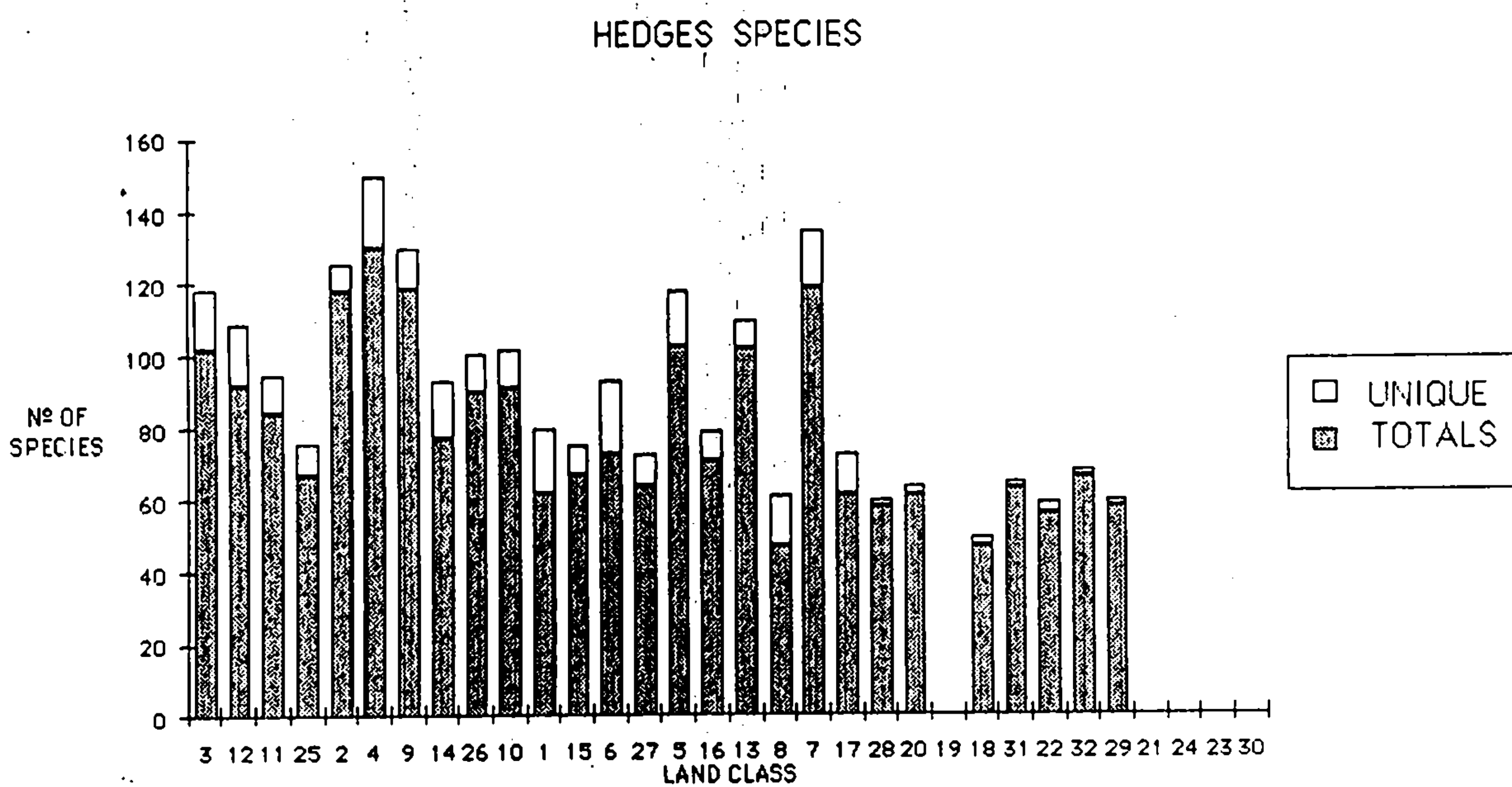
The species unique to the four data sets were extracted. It is important to consider that only $10m^2$ were recorded in the linear features, as opposed to $200m^2$ for the quadrats. Even so the streamsides have a comparable number of unique species to the quadrats, with verges and hedges being similar at much lower levels. The quadrats show consistent figures through the range of land classes. By contrast the hedges fall off rapidly in the uplands, because grazing removes the difference in habitat from the surrounding area. Verges show a very consistent pattern at a relatively low level. Streams likewise are consistent but at a higher level.

The above figures indicate the potential for the management of habitats outside the agricultural area, ie. the maintenance of a bank of species in the countryside. It also emphasises that the indirect effects of land use change can have a major inpact on the botanical capital, eg. eutrophication of rivers, particularly shown in the differenct between land class 25, a Scottish lowland land class with perhaps lower nutrient levels and the highest number of unique stream species, as opposed to land class 3 with a low number of species and high level of eutrophication.

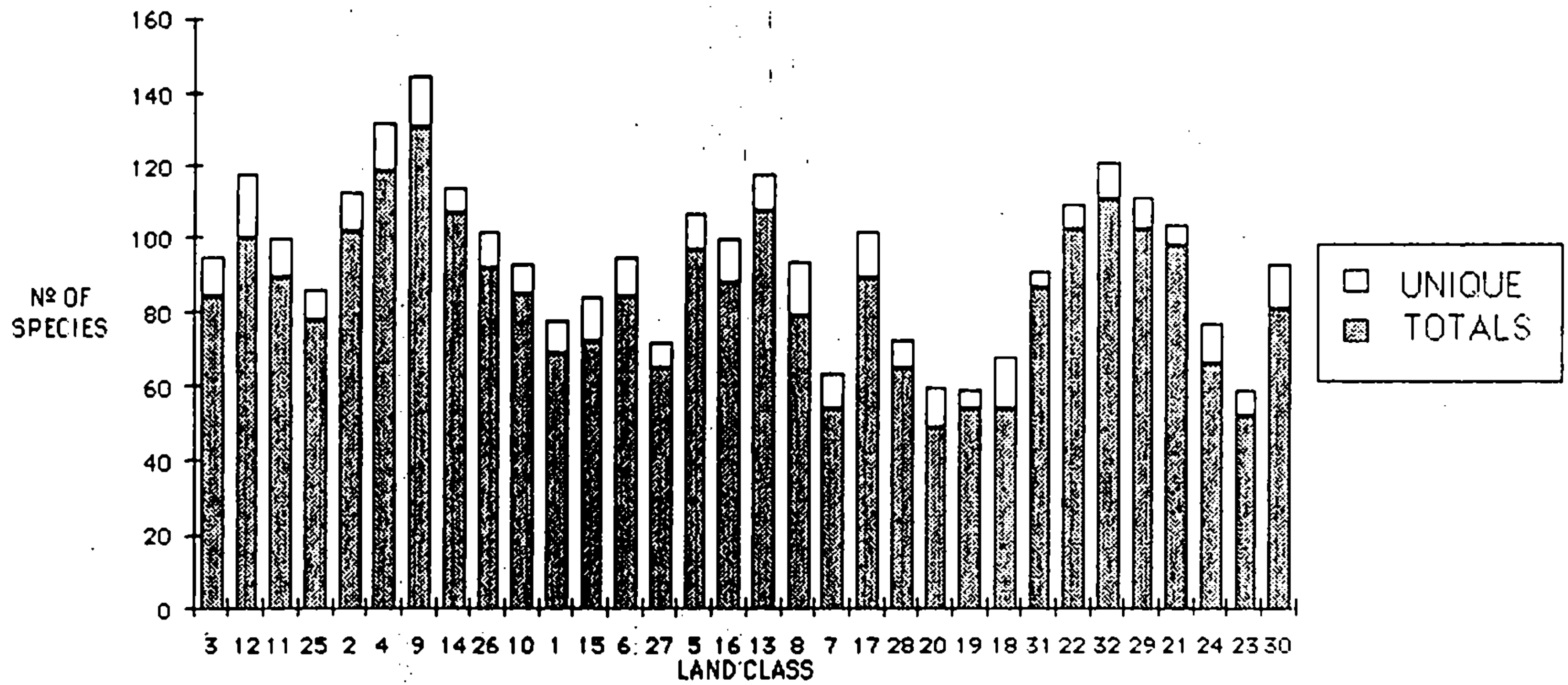
More detailed analysis of these data will be carried out to examine the character of the individual species in order to examine the response to change.

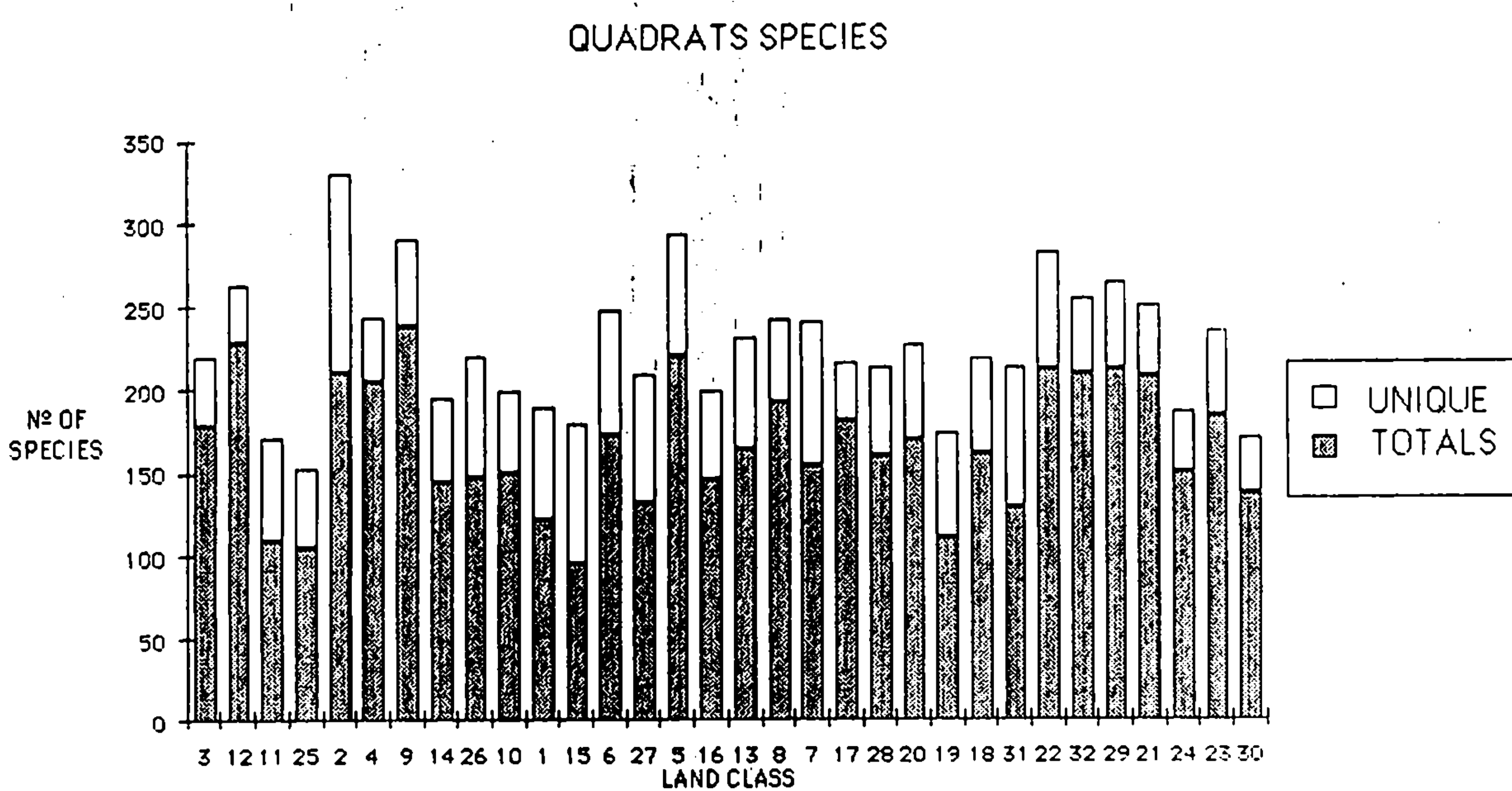
STREAMS SPECIES




HEDGES SPECIES
Nº OF SPECIES
160
140
120
100
80
60
40
20
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS
UNIQUE
TOTALS

VERGES SPECIES




QUADRATS SPECIES
№ OF SPECIES
350
300
250
200
150
100
50
0
3 12 11 25 2 4 9 14 26 10 1 15 6 27 5 16 13 8 7 17 28 20 19 18 31 22 32 29 21 24 23 30
LAND CLASS
UNIQUE
TOTALS

SPECIES UNIQUE TO STREAMS

Four examples of species unique to streams to show that the variability is contributed mainly by species from wet habitats not found elsewhere. The fewer species from hedges and verges indicate that many more of these species are found elsewhere in the nearby landscape.

SPECIES UNIQUE TO STREAMS
IN LAND CLASS 25

Agrimonia eupatoria
Alnus glutinosa
Anemone nemorosa
Athyrium filix-femina
Atrichum undulatum
Caltha palustris
Cardamine hirsuta/flexuosa
Dryopteris dilatata/carthusiana
Dryopteris filix-mas
Endymion non-scriptus
Epilobium hirsutum
Epilobium palustre
Epilobium spp.
Galium cruciata
Glyceria fluitans
Iris pseudocorus
Juncus conglomeratus
Lemna minor
Lysimachia nemorum
Mimulus guttatus
Mnium undulatum
Montia sibirica
Rorippa nasturtium-aquaticum
Ononis repens
Oxalis acetosella
Phalaris arundinacea
Ranunculus ficaria
Ribes sylvestre
Stachys sylvatica
Stellaria alsine
Stellaria holostea
Valeriana officinalis
Veronica anagallis-aquatica
Veronica beccabunga
Vicia hirsuta
Viola palustris
Marchantia spp.
Acrocladium cuspidatum
Pellia spp.
Rumex hydrolapathum
Tanacetum vulgare
Myosotis palustris
Salix spp.
Senecio aquaticus

SPECIES UNIQUE TO STREAMS
IN LAND CLASS 6

Angelica sylvestris
Apium graveolens
Apium nodiflorum
Bromus ramosus
Caltha palustris
Festuca arundinacea
Galium boreale
Iris pseudocorus
Malus domestica
Rorippa nasturtium-aquaticum
Phalaris arundinacea
Typha latifolia
Valeriana officinalis
Veronica beccabunga
Viola odorata
Barbarea vulgaris
Glyceria plicata
Mimulus luteus
Polygonum amphibium
Allium ursinum
Pulicaria dysenterica

SPECIES UNIQUE TO STREAMS
IN LAND CLASS 19

Ajuga reptans
Athyrium filix-femina
Callitriche spp.
Caltha palustris
Cardamine hirsuta/flexuosa
Carex pulicaris/pulchella
Equisetum arvense
Equisetum spp.
Galium aparine
Galium boreale
Galium cruciata
Galium palustre
Galium uliginosum
Heracleum sphondylium
Hypericum tetrapterum
Juncus bulbosus
Lychnis flos-cuculi
Myosotis spp.
Pedicularis sylvatica
Potentilla anserina
Potentilla sterilis
Pseudotsuga spp.
Ranunculus ficaria
Sphagnum spp.
Stellaria graminea
Stellaria holostea
Thelypteris oreopteris
Valeriana officinalis
Veronica beccabunga
Cardamine amara
Montia perfoliata

SPECIES UNIQUE TO STREAMS
IN LAND CLASS 24

Achillea ptarmica
Alnus glutinosa
Angelica sylvestris
Atrichum undulatum
Caltha palustris
Cardamine hirsuta/flexuosa
Cardamine pratensis
Centaurea nigra
Digitalis purpurea
Galium palustre
Geum urbanum
Lonicera periclymenum
Parnassia palustris
Polypodium vulgare
Polystichum setiferum/aculeatum
Pseudotsuga spp.
Ranunculus ficaria
Sanicula europaea
Scutellaria galericulata
Thelypteris dryopteris
Tussilago farfara
Peltigera canina
Acrocladium cuspidatum
Geum rivale
Helictotrichon pratense
Breutelia chrysocoma
Salix atrocinerea
Allium ursinum
Festuca altissima
Thalictrum alpinum
Cornus suecica

SPECIES UNIQUE TO VERGES IN LAND CLASS 1

Arctium spp.
Crepis capillaris
Euphorbia agg.
Ligustrum vulgare
Picris echioides
Potentilla anserina
Stellaria holostea
Hypericum androsaemum
Populus nigra

SPECIES UNIQUE TO VERGES IN LAND CLASS 2

Aegopodium podagraria
Artemisia vulgaris
Centaurea scabiosa
Crepis spp.
Knautia arvensis
Ligustrum vulgare
Potentilla anserina
Vicia cracca
Vicia sativa
Centaurea nemoralis
Silene alba

SPECIES UNIQUE TO VERGES IN LAND CLASS 3

Agrimonia eupatoria
Geum urbanum
Medicago sativa
Rubus caesius
Tragopogon pratensis
Tussilago farfara
Vicia sativa
Viola hirta
Carex hirta
Aethusa cynapium
Melica uniflora

SPECIES UNIQUE TO VERGES IN LAND CLASS 4

Agrimonia eupatoria
Artemisia vulgaris
Bromus mollis
Deschampsia cespitosa
Geum urbanum
Hieracium spp.
Lathyrus pratensis
Lotus uliginosus
Malva sylvestris
Silene vulgaris
Stellaria holostea
Tussilago farfara
Linaria vulgaris

SPECIES UNIQUE TO HEDGES IN LAND CLASS 1

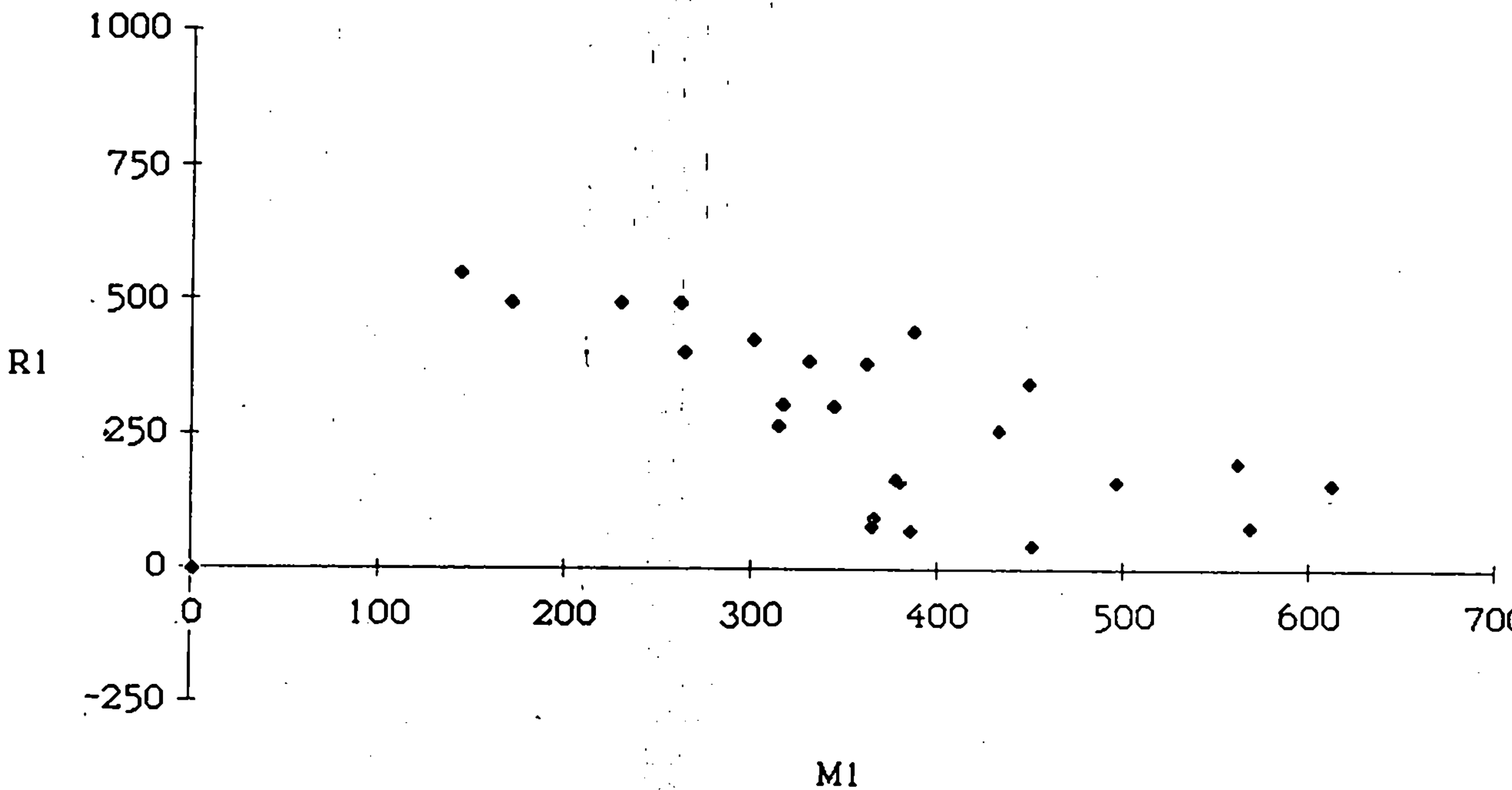
Betonica officinalis
Digitalis purpurea
Galium saxatile
Lonicera periclymenum
Pseudotsuga spp.
Ranunculus ficaria
Silene vulgaris
Stellaria neglecta
Tamus communis
Ulex europaeus
Ulmus glabra
Vaccinium myrtillus
Vicia cracca
Vicia sativa
Viola riviniana
Ulmus procera
Jasione montana
Aesculus hippocastanum

RELATIONSHIPS BETWEEN ANALYSES

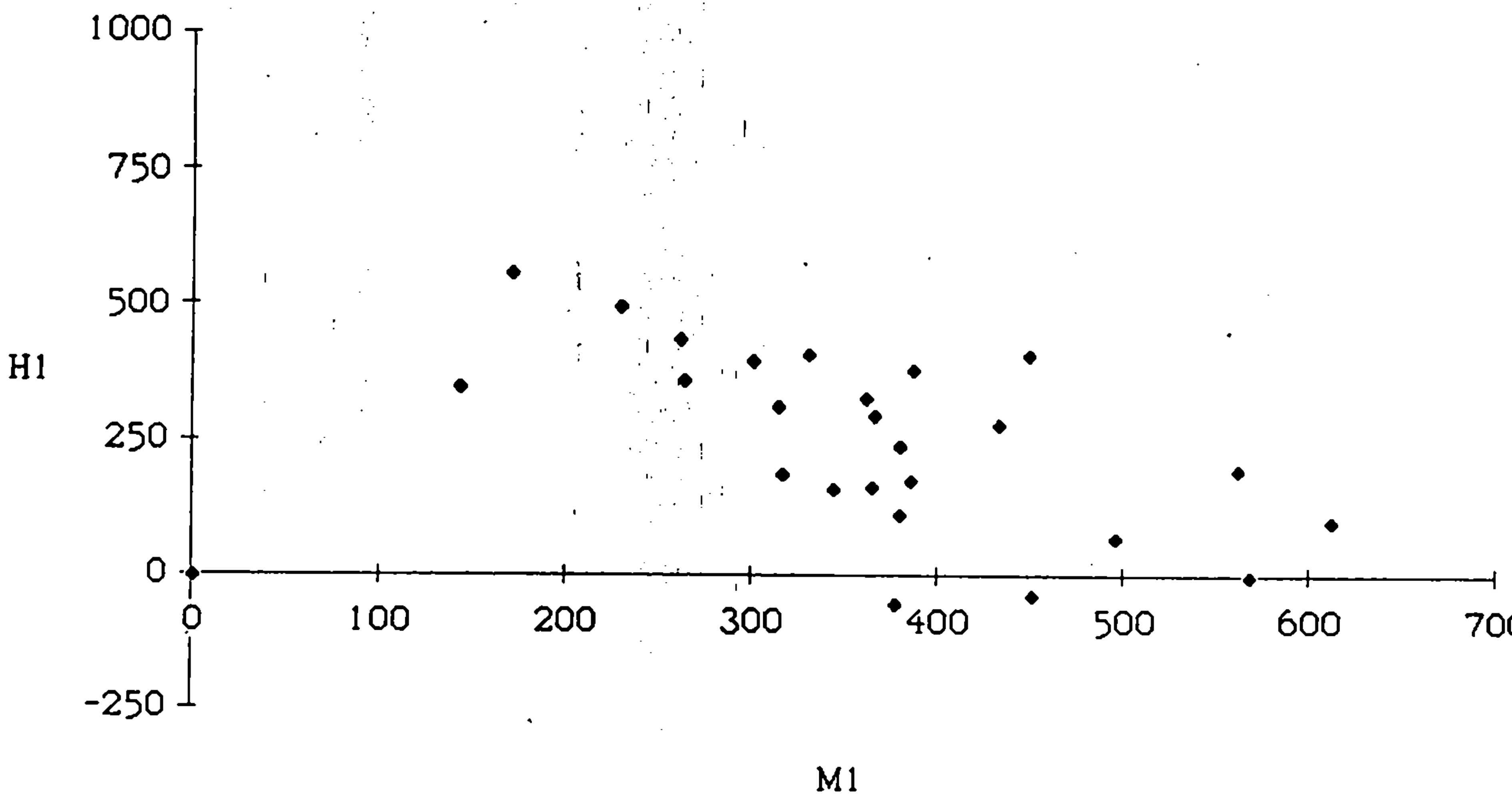
The following graphs show that species within the different habitats behave in a comparable way but the information from small sub-samples can reflect ecological amplitude efficiently. However the secondary gradients reflected by the second axis are not same, showing the dominance of the upland to lowland gradient.

The graphs also demonstrate the potential for cross correlation between data sets, which will be followed up subsequently.

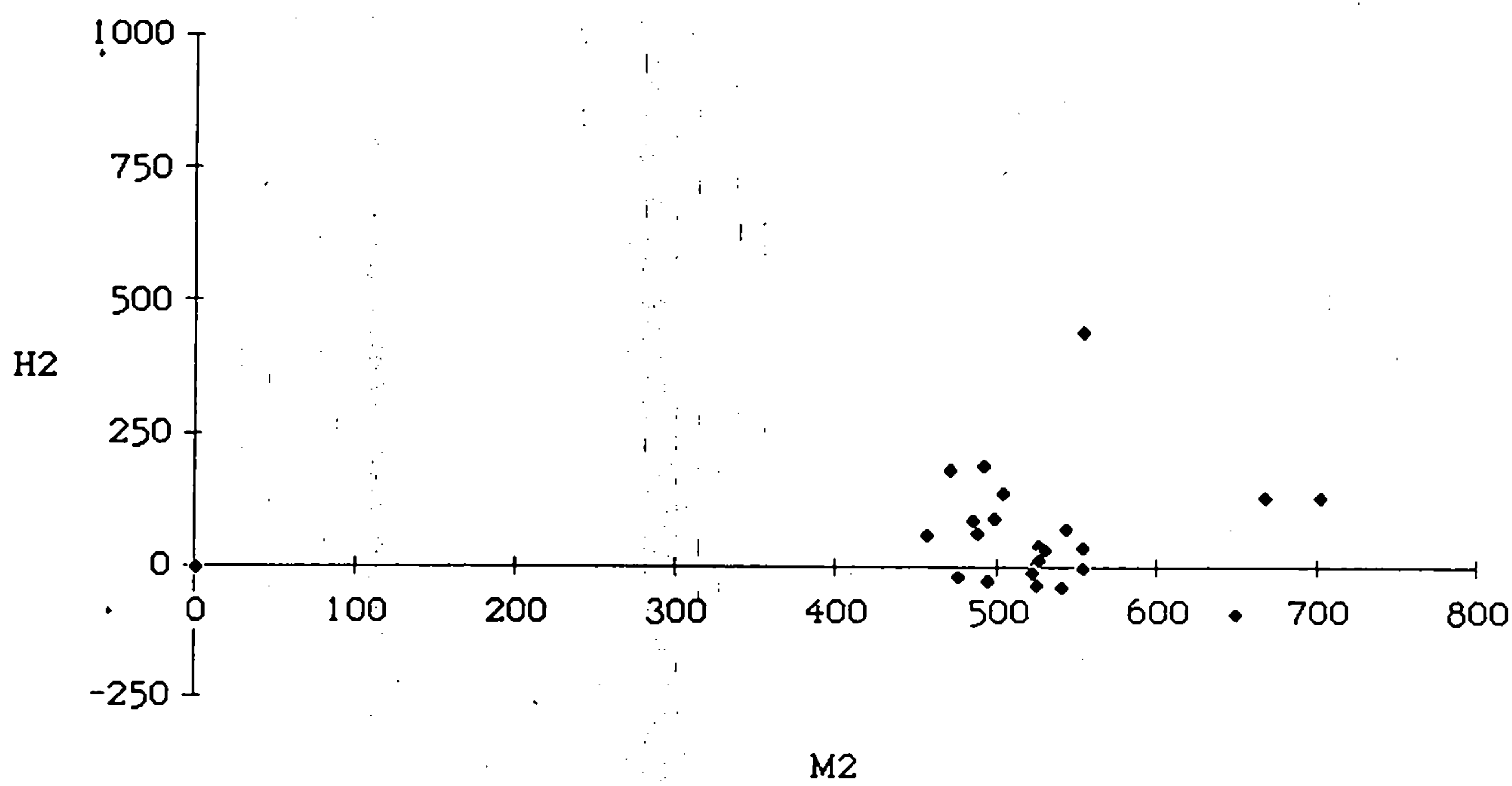
Plot of decorana scores for quadrats (M1) and roads (R1)



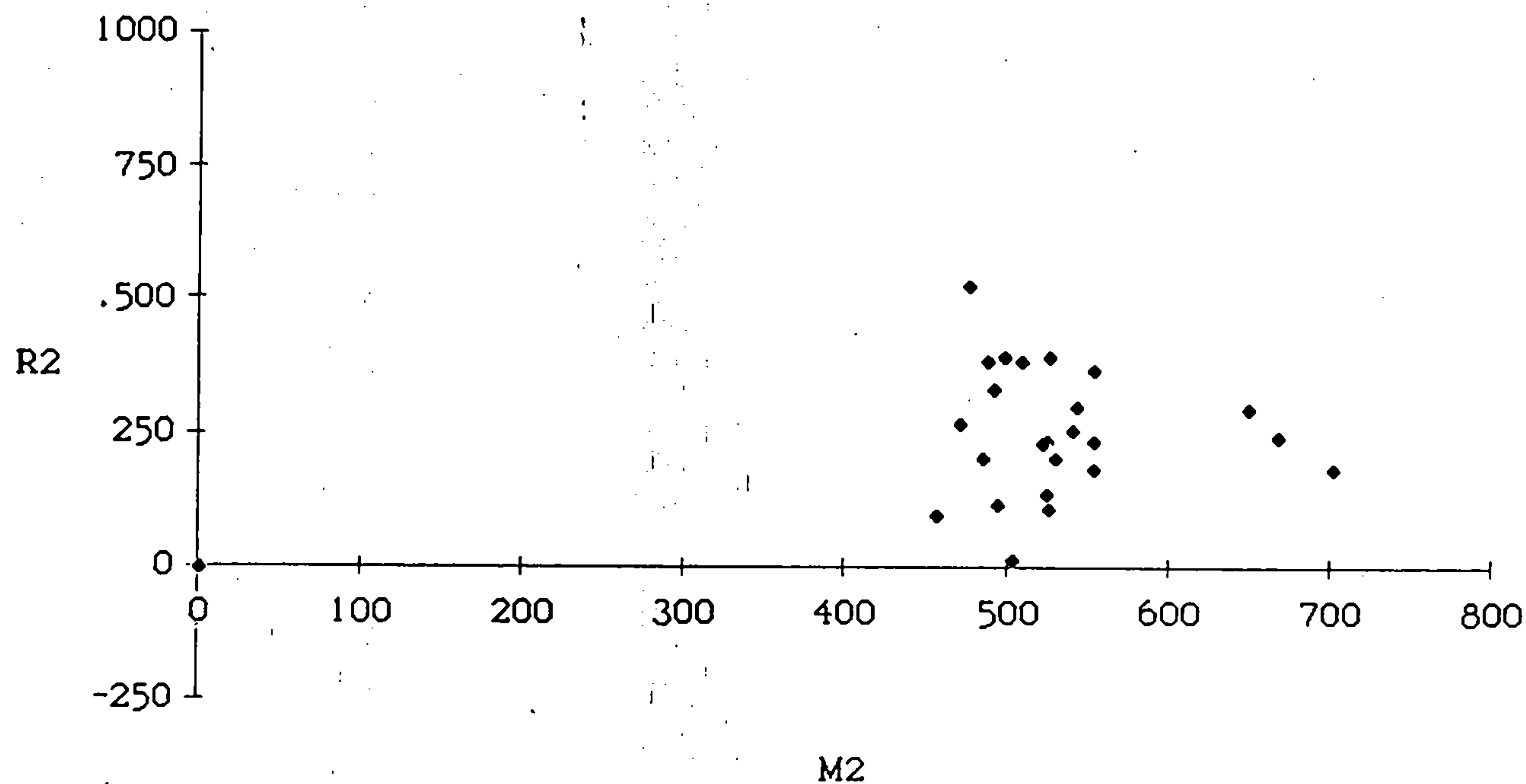
Plot of decorana scores for quadrats (M1) and hedges (H1)



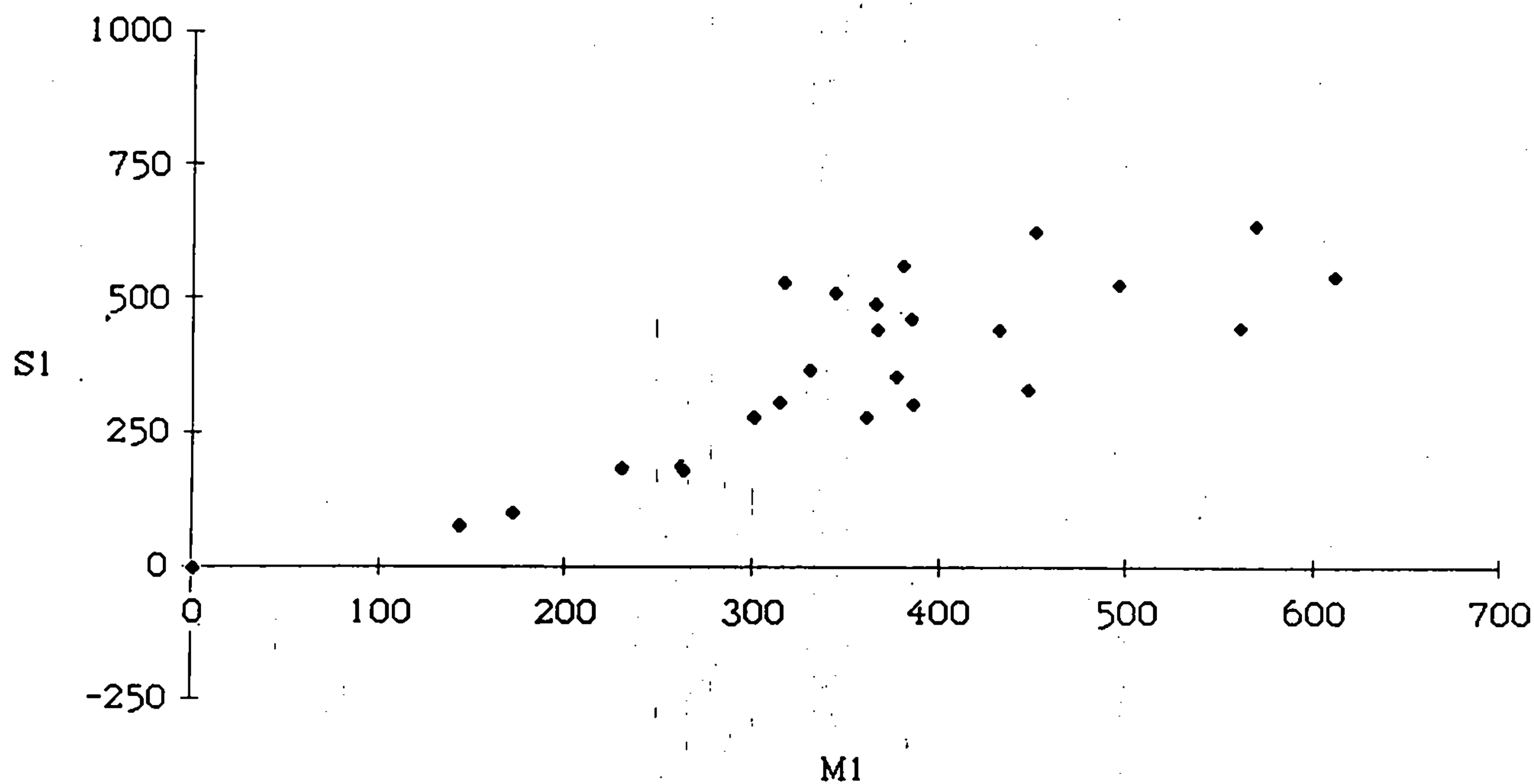
Plot of decorana scores for quadrats (M2) and hedges (H2)



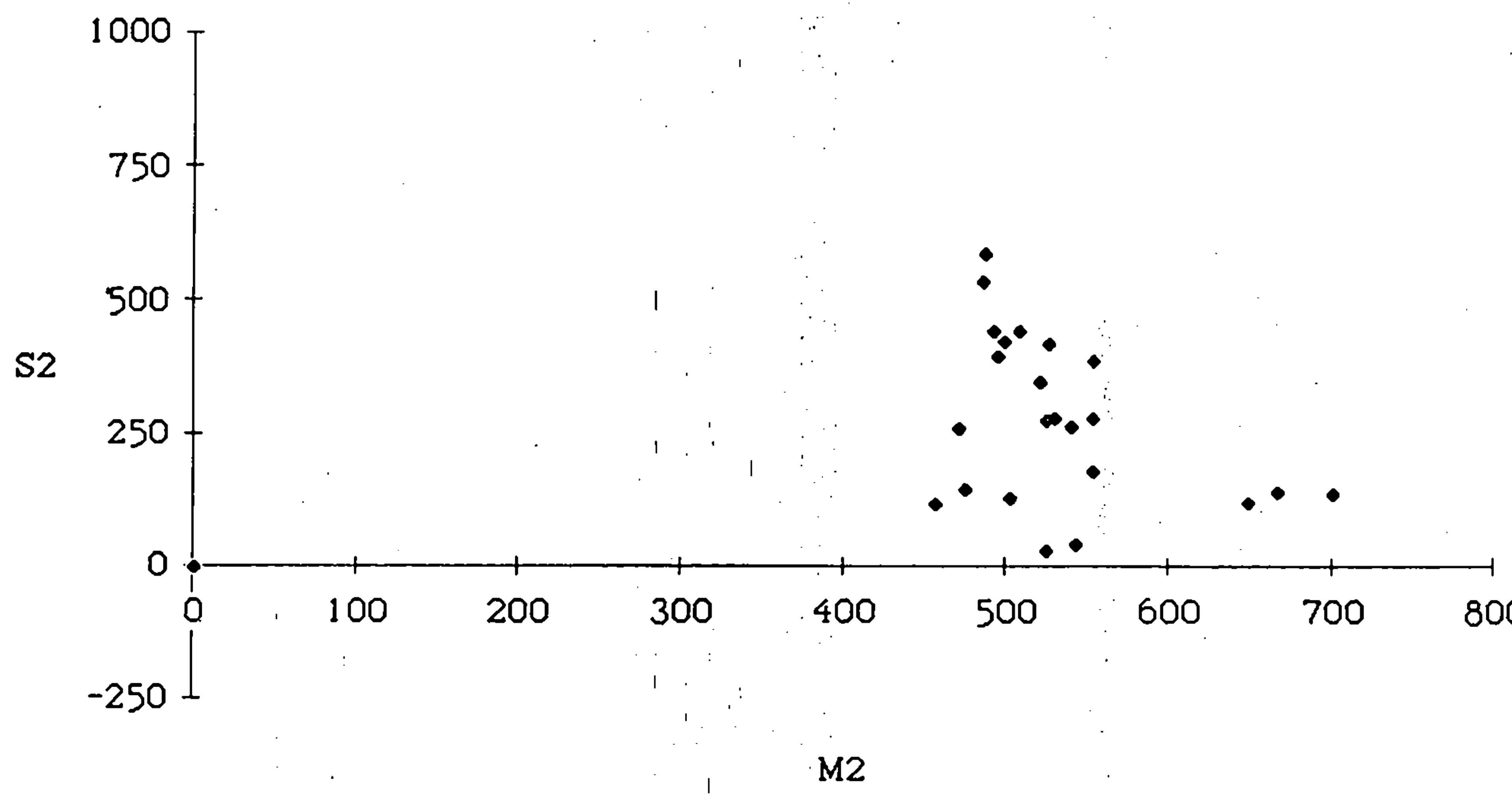
Plot of decorana scores for quadrats (M2) and roads (R2)



Plot of decorana scores for quadrats (M1) and streams (S1)



Plot of decorana scores for quadrats (M2) and streams (S2)



FAUNAL ANALYSES

FOXES

The potential of using habitat variables to predict the relative abundance of foxes, Vulpes vulpes, was investigated using hunt statistics as indices of fox population density. The mean number of foxes moved for all known hunt visits was employed as an index of fox density in two adjacent Hunt countries in Buckinghamshire - Bicester and Heythrop.

Using developed techniques of land stratification as a basis (see Bunce et al.1981), additional habitat features, thought to be of potential importance to foxes, were gathered from maps and other sources to supplement this data. Subsequent numerical analysis of the data employed methods of ordination and regression.

Initial simple linear multiple regression calculations of surveyed fox density (mean number of foxes moved), on the habitat characteristics recorded, revealed altitude variables to be of the greatest significance in explaining the observed variation in animal density. However, examination of the correlation matrix of the entire data set, revealed a high degree of intercorrelation between the altitude variables and other recorded habitat characteristics (as one might expect) of potentially greater importance to foxes. Thus, subsequent analyses were performed including and then excluding this altitude information,-in order to assess the relative importance of this data, and to 'expose' formerly hidden, and possibly more important predictor variables.

Excluding altitude data, stepwise multiple regression analyses to select the most-significant explanatory variables to account for the variation in fox density, extracted 21 habitat variables to be included in the regression equation, explaining a total of 47.8% of the variation. On inclusion of the altitude data, 21 variables were again selected, this time accounting for 59.1% of the observed variation in animal density.

Running the data (including altitude information) through DECORANA to reduce the heterogeneity within attribute scores and weight the means, and regressing the resulting four axes with the fox parameters, revealed the most significant correlation with axis 1. (The axes generated by Detrended Correspondence Analysis are conglomerates of the original habitat attributes calculated orthogonally). When regressed with the mean number of foxes moved for both Hunt countries, axis 1 explained 20.5% of the variation in fox density. Overall, all four axes explained only 24.4% of the variation in animal density (mean numbers of foxes moved). On exclusion of the altitude information, axis 1 explained only 0.4% of the variation, axis 4 this time emerging as important to the extent of explaining 9.2% of the variation in fox density. Significant correlations with this axis revealed the potential importance of the agricultural profile and urban fringe habitats.

When the altitude information is retained, and axis 2 is plotted against axis 1, the two different Hunt areas appear as converging sausages, indicating a fundamental difference in terms of altitude and ruggedness, and to a lesser extent, agricultural profile. When the area of overlap is examined on a map, the km sqs common to both hunts appear to occur chiefly in the river valleys. Further, more detailed, survey work could be focussed on these areas of similar habitat for both hunts. In a further examination of this 'phenomenon', the different Hunt countries were each assigned a dummy variable, and regressed against the DECORANA axes including and excluding altitude information respectively. Employing all four axes in the regression resulted in a decrease of 22.3% in the percentage variation explained on omission of altitude data (ie. from 48.7% to 26.4%). Most of this being carried on axis 1 (as anticipated), which is highly correlated with altitude variables. Including altitude data, Axis 1 accounts for 45.8% of the variation between the two hunt areas; this figure drops to 10.5% on their subsequent exclusion.

Stepwise regressions performed for each individual Hunt country produced a similar trend in predictive ability of the habitat variables with and without altitude information included in the analysis. However, as might be expected on account of the percentage variance explained by hunt area alone (63%) in a bivariate linear regression, the habitat attributes selected as significant predictors of fox density, were different in the case of each hunt (this was also borne out by the DECORANA and TWINSPAN analyses). The stepwise regression for Bicester (including altitude data) selected 14 variables - explaining 55.9% of the variation in fox density. However, exclusion of the significant altitude data for the surrounding squares reduced the variation in fox density accounted for by the significant variables, from approximately 25% to less than 10%. Unlike the Heythrop analysis,the variables selected as significant did not change on exclusion of the selected altitude variables . Similarly, for the Heythrop Hunt, the variance explained by the significant predictor variables selected in the stepwise regression analysis, was very low when the altitude information was excluded, and not sufficient in either case to satisfy the a priori criteria for prediction of fox densities proposed by Harris and Rayner (1986).

In total, the 20 variables selected in the stepwise regression for Heythrop accounted for 69% of the variation in fox density when the altitude information was included. When omitted, this figure dropped to 59.2%. In this case, it is interesting to note (though almost certainly not of any predictive significance in this particular analysis) that on omission of selected altitude variables, the list of significant variables changed to include agricultural aspects of the environment and, notably the number of 5-20 ha woodlands in the central square emerged as significant ($P<0.05$). It would appear that most of the predictive power of this woodland variable, in particular, is held in common with a number of the altitude variables.

As woodlands are often found on the steeply sloping plateau escarpments in the Heythrop Hunt area, where agricultural practices are either impossible or economically inviable, the strong positive relationship between the two is to be expected. This conclusion is also bourne out in the DECORANA analyses, repeated with and without the inclusion of altitude variables. Where the highly significant correlations - observed when axis 1 is used as the dependent variable and all habitat variables as independent variables - are with the woodland characteristics when the selected altitude variables are omitted. This is notably the case when woodland area and number are considered (particularly deciduous woodland) and the area of scrub.

In a further analysis to extract the 'best' six, followed by the 'best' 12 habitat variables, for the two different hunt areas, the presence of park land, the area of open space, water and root crops, the hilliness of the surrounding squares (as indicated by the number of contours in the 8 surrounding squares) and the maximum altitude were found to be the best predictors in order of decreasing importance and accounting in total for 51.6% of the variation in the mean number of foxes moved and therefore fox density, for the Heythrop hunt.

In the case of the Bicester hunt, 50.7% of the variation was explained by the 'best' 6 habitat variables selected; these being (in order of decreasing importance) the presence of parkland in the central square, the area of woodland in the central square, the mean minimum altitude in the 8 surrounding squares, the height of the centre of the central square, the area of agricultural land class 1 (this being the "most versatile and high yielding" of the 5 classes , representing a "relatively-scarce resource and constituting only 17% of the agricultural land in England and Wales"), and finally the slope of the land.

Examination of the subsequent variables extracted in this analysis indicates that the area of the different agricultural land classes and the number and size of woodlands, may be important. However, to what extent these factors might play a significant role would require further fieldwork to ascertain. The configuration and/or interface length between woodland and farmland may well be important in determining the size of fox home-ranges, for example (Macdonald et.al., 1981).

Running the habitat data for both hunts through a TWINSPAN analysis provided the basis for the assessment of the contribution of linear features to heterogeneity within the landscape of the two hunt areas. Examination of the correlation analysis of TWINSPAN groups with all habitat variables and the mean number of foxes moved, reveals a significant positive linear correlation with TWINSPAN group 3 (0.4277,df-48,P<0.01),for the Heythrop hunt. The most significant correlations (P<0.001) with fox density are with the woodland variables in the central and surrounding squares; particularly the number of 5ha woodlands and the area of scrub. It is possible that a certain combination of one or more of these features is of particular importance in explaining the variation in fox abundance, and may merit further fieldwork to elucidate.

Running the same correlation analysis for the Bicester hunt, reveals no significant correlations between TWINSPAN group and any of the fox parameters. Combining the data for both hunts and examining the correlation matrix, reveals significant correlations between the mean number of foxes moved and TWINSPAN groups 2 (0.2251, df-94, P<0.05), 4 (-0.3668, P<0.001) and 6 (0.3592, P<0.001). In the case of TWINSPAN group 2, the most significant negative correlations with the habitat variables contained therein were found to be with altitude and woodland variables; the only significant positive correlation was found to be with the presence of water in the central square (0.3776, P<0.001). Strong positive correlations within group 4 (with which fox density was strongly negatively correlated) were found with all the altitude variables: maximum altitude of central square , minimum altitude of central square, height of centre of central square, mean max.-altitude of surrounding squares, mean min.alt.of surrounding squares, hilliness of surrounding squares, height of nearest hill; in each case P<0.001. This can probably be explained simply in terms of areas favoured and those avoided by the hunts; the horses/huntsmen finding the steeper areas difficult to negotiate. In the case of TWINSPAN group 6, strong negative correlations were observed with altitude variables, and positive correlations with the area of town and the area of agricultural land class 1 - the urban fox population may be being put up in these areas.

In the combined data analysis for both hunts, TWINSPAN group 6 was the only one of the three TWINSPAN groups common to both hunts to show significant correlations with the mean numbers of foxes moved (0.3526, P<0.001). The TWINSPAN analysis characterised group 6 primarily on the area of cereal present (0-5; the lowest category recorded) and the minimum altitude of the central square (between 0 and 90 metres).

Inspite of the fact that relatively little of the observed variation in fox density could be explained by the habitat features recorded for both Hunt countries, significant correlations were identified, and there is certainly scope for further work to look more closely at these particular features in the context of discoveries made here. However, one should exercise caution when interpreting apparently significant correlation coefficients emerging from a relatively large sample such as this, insofar as significant correlations can be generated with a relatively small proportion of the total variation being explained, leading to a distorted (and potentially inaccurate) picture of the nature of any relationships. Those aspects identified as meriting further detailed analysis include the particular agricultural profile in the fox homerange together with further detailed surveys focussing on the configuration of surrounding woodland, length of woodland edge, connecting corridors of natural vegetation (eg. hedgerows and hedgebanks) within otherwise predominantly intensively farmed landscapes.

Although there exist a number of possible sources of bias inherent in using hunt statistics as indices of fox density (not detailed here), I believe that there is scope for further, more detailed work concentrating on both hunt statistics and attempts at absolute estimates of fox density from direct observation (den counts, radio-tracking etc) for the same 'hunt area'. Future habitat characterisation should also encompass features such as hedgerows, woodland edge length, urban/farmland interface etc.; determination of some kind of index of food availability in different habitats would be of value. It has been evident from this study that a greater volume of data is required for more 'environmentally homogeneous' areas, in order that more variation is to be explained by fewer habitat variables. Insufficient data exists from this study alone to explain the necessary variation in fox density in order to formulate a predictive model. Data from more environmentally comparable areas must be acquired. Areas of high and low fox densities could be the focus of more detailed field work, in an attempt to identify the critical 'controlling' factors. Marginal habitats may well be of importance; the degree to which this may be so, having been formerly obscured by methods so far adopted where 'gross' features of the habitat have been recorded, rather than the importance of their juxtaposition (ie. two different suitable habitats providing, for example, simultaneous food supply - where the agricultural profile may be of particular importance - and cover - provided, for example, by woodland and hedgerows.) Hunting pressure will almost certainly vary, both between, and within landclasses. This, in turn, will affect the behaviour of the fox and how it 'uses' its environment in different areas. Thus, although food availability may be the principal underlying factor controlling fox density, the habitat mosaic (particularly in view of the cosmopolitan nature of this species) may be playing an increasingly important secondary role, and this may be most pertinent in urban/intensively farmed landscapes, where disturbance by man is a critical influential factor. Identifying what may be a very complex relationship is the task that lies ahead.

It may be possible to predict fox densities more accurately at certain times of the year only, when particular prey species, whose relative abundance can be accurately predicted from habitat characteristics, are being almost exclusively and consistently taken. It is likely to be at harsher times of the year when the importance of such features of the habitat (as mirrored by the prey abundance) are highlighted; and perhaps more so where fox densities are comparatively low. Here, I am referring to low densities within the same land class, and thus on a more local scale, in an attempt to relate specific habitat attributes with the variation in animal density. These areas could perhaps be studied in greater detail, together with high fox density areas, in an attempt to focus upon any differences in habitat characteristics which could be used ultimately to predict fox density or relative abundance.

BADGERS

Employing similar numerical methods to analyse density estimates for badgers, Meles meles, in Bicester and East Sussex in relation to the habitat data recorded both in the field and (for the most part) from maps, revealed some potentially valuable predictors; though their actual value can only be realised through further detailed field work.

Main sett density was used as an index of badger population density as it is widely held that the number of social groups is related to main sett density in a given area. The relationship usually being one main sett (and more rarely 'a few') per social group. Aspects of the ecology of the badger still remain an enigma; one of them being the numbers of animals constituting a 'social group'. Food availability, and particularly the dispersion of this resource, is already recognised as being of primary importance; but the importance of other habitat variables, and their relationship with regard to the primary criterion of 'choice', has yet to be elucidated.

Examination of the regression analyses for Bicester, to extract the best explanatory variables, selects the mean number of contours - and therefore 'hilliness' of the landscape - and the area of allotment ($P<0.01$ and 0.05 respectively), to be the only habitat variables significantly correlated with badger density. On subsequent extraction of habitat variables in the regression equation, aspect, mean number of woodlands in surrounding sqs, the mean minimum altitude of the surrounding sqs were selected, but were not shown to be significant.

Similarly, for badger density in the central square, the mean minimum altitude was selected as being highly significant ($P<0.001$) together with the area of extractive industry ($P<0.001$). The area of root crops and farm land in agricultural land class 4 (poorest etc...) were found to be significant at the 1% level; and the area of allotment at the 5% level. Increasing the number of habitat variables to be selected from 6 to 10, introduces the number of small woodlands (between 1 and 5 ha) to be highly significant ($P<0.001$), and the area of orchard with grass to be significant at the 1% level.

As anticipated, a similar trend is observed with the stepwise regression analysis. For badger presence/absence in the central square, 18 habitat variables were selected for the final equation, accounting for 45.8% of the variation. The hilliness of the landscape and the area of woodland were the only significant variables ($P<0.01$ and 0.05 respectively). For badger density in the central square, 15 variables were selected for the final regression equation, accounting for 58.4% of the variation. The most significant contributors being area of extractive industry ($P<0.001$), and the number of small woodlands ($P<0.05$).

In the stepwise analysis, with mean badger density in the surrounding squares as the dependent variable, agricultural land class 5 was selected as a significant contributor ($P<0.01$) out of the 23 variables selected to explain 67.8% of the variance in the final regression equation. Other significant variables at the 1% level include the hilliness of the surrounding landscape, distance to the nearest hill and length of footpath. At the 5% significance level, the mean maximum altitude of the surrounding sqs., the presence of minor roads and the area of rootcrops were selected for inclusion in the regression equation.

There are indications that the agricultural land use details, and the area of small woodlands, may be important. Specific information regarding the configuration of such features, the extent of the farmland/woodland interface and the interspersion of connecting natural features within the particular agricultural landscape being considered, (which could act as corridors for wildlife, for example), needs to be acquired. A survey of hedgerows and their parameters in areas of high and low badger densities, would be of interest in E.Sussex. Such information cannot be collected from OS maps.

In an initial analysis of the East Sussex data, linear correlation coefficients were calculated using the six dependent badger parameters and all independent habitat variables recorded in the survey (n=31). Each habitat variable was then regressed individually against all six badger parameters (ie.number of main-setts, no. outlying setts, no. of main sett holes, no. of outlying sett holes, total setts, total holes). As expected from the correlation analysis, a few variables only made a small contribution to the variation in badger density.

Scattergrams regressing badger parameters against all the different habitat variables, exhibit a random dispersion of points, lacking any systematic pattern. The habitat variables, not surprisingly, explaining an almost negligible (and certainly statistically insignificant) proportion of the observed variation in badger density - whether one is considering the number of setts or the number of holes for both sett categories - main and outlying.

In order to try and single out the significant factors involved in the predictive equation for badger density in E.Sussex, and to reduce the intra-sample heterogeneity (observed in the scattergrams), the environmental data was put through a DECORANA programme. The resulting four axes generated by detrended correspondence analysis are conglomerates of the original habitat attributes calculated orthogonally.

However, a regression analysis of the habitat variables against the badger parameters, revealed the highest percentage variance explained to be no more than 10% (for total number of setts versus all four axes summed).
A stepwise regression procedure was employed to ascertain the relative contribution of the most important predictor variables in the regression equation.

The best stepwise regression 'model' utilising 11 of the variables accounted in total for only 15.6% of the variation in main sett density and therefore badger density; 13.9%, 9.9%, 6.9%, 17.0% and 15.5% of the variation in number of main sett holes, number of outlying setts, number of outlying sett holes, number of total setts and number of total sett holes respectively. However, the variation explained is too low to attempt the formulation of a predictive model.

Examination of the correlation matrix of TWINSPAN groups with badger parameters revealed badger density to be significantly correlated with TWINSPAN group 4 only ($P<0.05$). Sett density is therefore greatest where the altitude is between 0 and 90 metres, and where the topography is relatively hilly. This is consistent with the findings of previous studies on badger ecology, regarding the highest density areas for these mammals. However, the percentage variance explained is so small, that the habitat features characterising TWINSPAN group 4, could not be used reliably in any predictive model for determining the relative abundance of badgers in areas where the land class only is known.

Mean badger density (+/- st.dev.) was found to be 0.86 setts per km sq. for TWINSPAN group 4. This corresponds with hilly areas at relatively low altitudes. This compares with the lowest sett density recorded of 0.06 main setts per km sq for TWINSPAN group 1. This group is characterised primarily by flat landscape (Pevensey Marshes and other coastal areas).

The regression analyses using the 6 dependent badger parameters and fitting the different TWINSPAN groups, reveals that this group is highly significant in the regression equation for main sett density ($P<0.001$); emphasizing the importance of these topographical features. TWINSPAN group 7 is also revealed as significant in the regression equation ($P<0.01$). These km sqs are characterised by between 1 and 3 small deciduous/mixed woodlands, very few isolated buildings and a north-easterly aspect. However, only 7.4% of the variation is explained overall.

Outlying setts were significantly correlated ($P<0.001$) with TWINSPAN groups 4 and 6. The km sqs falling into this category being characterised by the presence of 4 or more deciduous woodlands.

TWINSPAN groups 5 and 3 were also revealed as significant at the 5% level. These groups correspond to:

TWINSPAN group 5: areas of soil type corresponding to Hastings Beds at relatively low altitudes, with one or more ponds/lakes/reservoirs present and a stream(s);

TWINSPAN group 3: areas dissected by stream(s), numerous isolated buildings and a few deciduous woodlands.

However, overall, only 4.3% of the variance is explained. Regression analyses with the other badger parameters mirror these findings. From examination of the stepwise regression, and consistent with the findings of the Bicester badger survey,, the hilliness of the landscape is revealed as significantly important in the regression equation ($P<0.05$). However, overall only 15.6% of the variance in badger density is explained in the final equation using 11 of the variables.

These findings are mirrored with all other badger parameters in the stepwise regression analyses, and when run through analyses to select the best explanatory variables.

The following table gives the mean number of main setts per land class for the 8 land classes identified in East Sussex.

LANDCLASS	MEAN FIGURES		
	MAIN SETTS	ST.DEV.	ST.ERR.
1	0.39	0.81	0.09
2	0.29	0.89	0.13
3	0.40	0.65	0.13
4	0.07	0.26	0.07
5	0.54	0.66	0.18
6	1.20	1.30	0.58
7	0.43	0.79	0.30
8	0.29	0.76	0.29

On subjective examination of the means for main sett density in the eight land classes stratifying East Sussex, land class 4 is seen to have the lowest density. As anticipated, this landscape has few features to recommend it from a badger's point of view; being predominantly flat, intensively farmed with virtually no natural vegetation and otherwise largely built-up. This contrasts well with the highest observed badger density of 1.20 main setts per km2 (+/- SD 1.30 - rather large !)for land class 6 (approximately 17 times greater than that observed for land class 4), and is consistent with other studies of badgers and their preferred habitat. This land class is characterised topographically by its complexity; with many broad even slopes, predominantly at medium/low altitudes (consistent with the TWINSPAN regression analysis, insofar as badger density was found to be significantly correlated to group 4; characterised by undulating landscape at low altitudes). The landscape is intricate with small fields enclosed by hedges on banks with small woodlands. The land use is chiefly fertile pastures with some barley.

The second highest observed badger density - 0.54 main setts per km2 - was recorded for land class 5 (almost eight times greater than that observed for land class 4)and is consistent with other studies of badgers and their preferred habitat. This land class is characterised topographically by uniform-gentle slopes at low altitude (consistent with the TWINSPAN regression analysis); the landscape comprises varied lowlands with many natural features, and limited but varied vegetation; the land use is chiefly mixed farmland with a predominance of good grass. Land class 7 also contained a comparatively high badger density (0.43 main-sett-per km2). This class is described as coastal, with varied morphology and vegetation. The topography is usually coastal cliffs cut into tablelands and these are often backed by lowland farmland, comprising mainly pasture with some arable and good grass. The importance of the grassland element in this study may well have been underestimated, or obscured; either through the method of data collection or through some relationship (other than a linear one) with sett density.

Though requiring refinement, the results of these analyses emphasize the need for further fieldwork to incorporate finer scale environmental details within the broader categories identified here as being of importance, eg. hilliness of the landscape at relatively low altitudes. It would be useful to survey in detail those areas where high badger densities are consistently recorded and, with regard to this particular locality, resurvey certain areas. Broad features of the environment important to badgers have been identified. However, the subtleties of these require extraction in order to provide us with an accurate (within defined limits) predictive model.

Food availability at all times of the year appears to be of primary importance (Neal, 1977); other important determining factors include the nature of the soil (ie. if it is liable to water-logging and difficult to dig, then it will not be attractive to badgers), the proximity (if located in the 'open') and degree of cover (ie.woodland, hedgerow etc), and the extent to which the potential domain is likely to suffer from disturbance by man. A more thorough assessment of related habitat characteristics would be of value. Some way of assessing food availability, and the nature of its dispersion, and incorporating this into any particular predictive equation, would also merit further research. Areas of high and low badger density in relation to habitat features could be focussed upon, in order to try and identify the critical 'controlling' factors.

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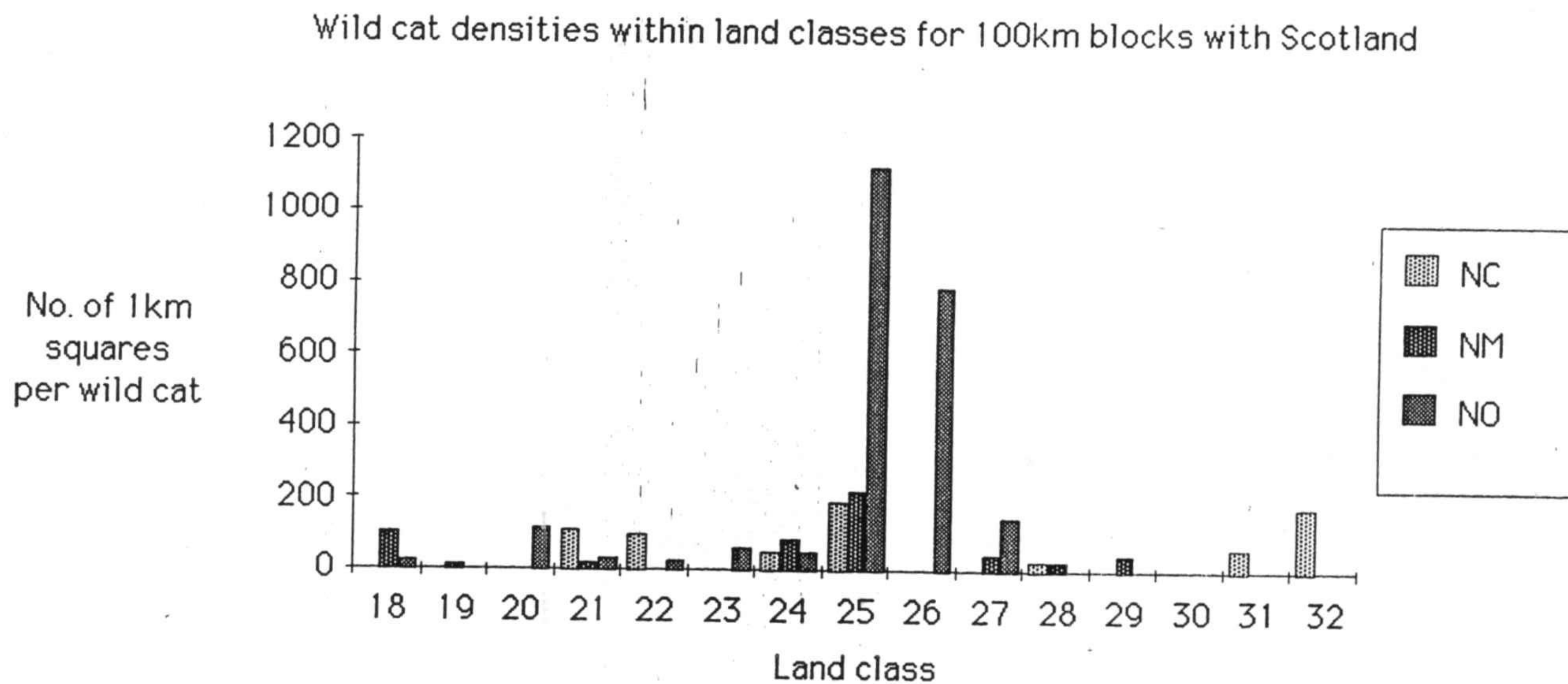
Wildcats

Nigel Easterbee of NCC has been using the land classification to examine the factors underlying wildcat distribution in Northern Scotland. Major differences appear between land classes within 100km^2 blocks. Work is continuing and the results will be coordinated into the expert system, in order to show the effects of land use change on wild cat populations.

The attached figure shows the frequency of occurance of wildcats in the land classes in 3 of the 100km^2 blocks.


Wild cat densities within land classes for 100km blocks with Scotland
No. of 1km squares per wild cat
1200
1000
800
600
400
200
0
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Land class
NC
NM
NO

FOX AND BADGER DENSITIES AND THEIR PREDICTION FROM HABITAT FEATURES USING HUNT STATISTICS AND SETT DENSITY RESPECTIVELY AS INDICES.

INTRODUCTION

The ability to formulate a predictive model capable of estimating fox and badger densities from environmental features, would be of enormous value. Such an application is particularly pertinant in the context of wildlife management and control on a large scale, where accumulation of the necessary data directly would be difficult, time-consuming and expensive. Many species, and in this case particularly foxes, are difficult to study in the field. In the event of a rabies outbreak, for example, the availability of such a predictive model would enable immediate action to be focussed upon those areas identified as likely hot spots for the spread of the disease. The behaviour of the rabies epizootic is thought to be influenced by fox population densities, which in turn are thought to be influenced by food availability, and therefore habitat characteristics. Similarly, previous studies of badger ecology indicate that population abundance is largely determined by habitat type. Though widely distributed, and adapted to a whole spectrum of habitat types, badger and fox densities are very variable. Their distribution being largely determined by the satisfaction of certain ecological requirements in their environment. Thus, for both of these mammals, it should be possible to quantify the relationships between animal density and habitat characteristics through detailed local studies, and thus allow the development of a predictive model which could be used to estimate animal densities in unsurveyed areas by recording the important habitat characteristics therein. The importance from a management aspect with regard to badgers,particularly concerns the spread of bovine tuberculosis, and the potential of any predictive model to identify such disease areas. It is believed that high levels of bovine tuberculosis infection are correlated with high badger density. The predictive ability of any model based upon habitat characteristics will depend ultimately on the nature of the relationship, its consistency in terms of density predictions either on a local scale or (hopefully) nationally, and its resilience in the face of unpredictable fluctuations, whether of direct or indirect origin, in the environment.

Information on inverterbrates for the land use database

The surveys undertaken by ITE to collect information for the land use database has been dominated by vegetation and land use types. It is desirable to include information on other taxa and even from other fields (such as geology and socio-economics). At present studies are under way to make good the information gap, for example by investigating the distribution of mammals and birds within land classes and looking at factors such as recreational potential and human populations. However there does remain one large gap - the invertebrates.

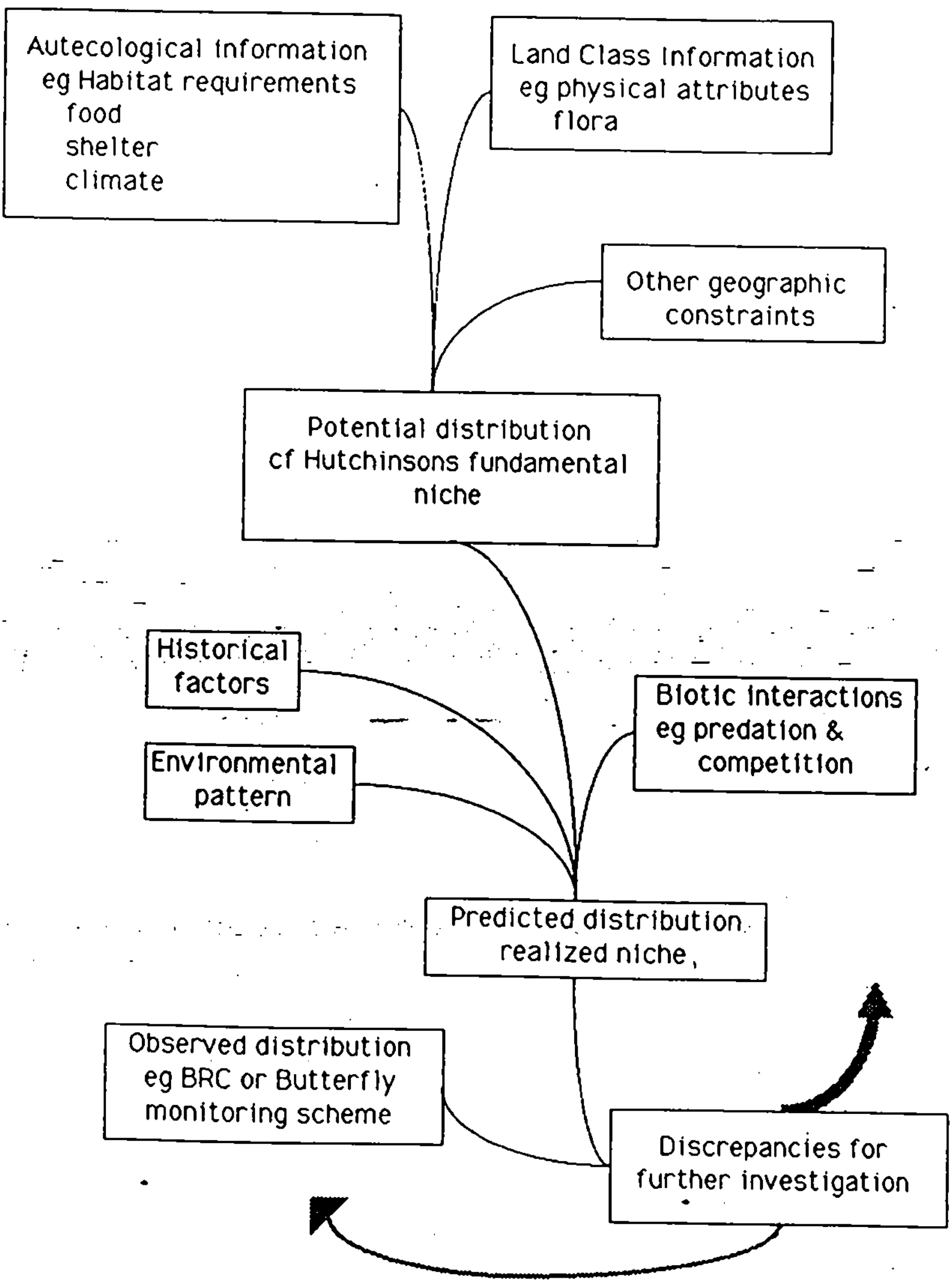
There are a number of reasons for the paucity of information regarding invertebrates, some of which are listed below :-

1. Number of species. There are well over 20 000 species of insects recorded in GB, an order of magnitude more than the higher plants.
2. Difficulty in identification. Adequate keys are not available for many families and key attributes may require considerable skill to determine.
3. Poor distribution of experts. The distribution of experts including keen amateur naturalists tends to leave some areas of GB unstudied. Distribution maps may only show the distribution of entomologists.
4. Dificulties in making observations. Insects can be highly mobile and exhibit a wide range of behavioural patterns. No single survey technique can claim to give an overall picture of the invertebrate fauna of an area.
5. Temporal distribution. Many insects have complex life cycles which may include dormant periods and forms which are impossible to identify with any confidence.
6. Weather. Unlike plants insects respond immediately to changes in weather. Surveys cannot be made on a single visit basis and so become much more expensive.

Even accepting all these problems there is a wealth of information regarding insects and other invertebrates. Some datasets recording the distribution of insects, such as those collected by Rothamsted Experimental Station, may be incorporated directly into the land use database (see the section by Ian Woiwod in this report). Other distributional information may be useful for validation of predictions.

A far more exciting approach is the potential use of autecological information such as that in ITEs herbivory database* linked through the land classification along with appropriate additional information and theory to produce predicted distributions (Figure 1). Such predictions can then be validated either by comparison with datasets such as the BRC, or by field survey.

Figure 1. The interpretation of autecological data through the ITE Merlewood Land Classification



At present the Joint Committee for the Conservation of British Insects is investigating how entomological survey can be better coordinated. The three areas which they have identified are :-

1. Enlisting the help and facilitating the work of voluntary organizations and individuals.
2. The development of widely acceptable methods of recording which could replace traditional attempts to produce total species inventories.
3. Acting as a clearing house for specimen identification, data storage and handling, and the circulation of information.

One of the obvious pitfalls of involving voluntary assistance can be seen in the professional Rothamsted work, where light traps were not set in four of the land classes. By examining the distribution of the human population around the land classes it is clear that the least populated areas receive the least sampling (land classes 23, 24, 30 and 32 in Figure 2) although ecologically they may be the most important. However the collection and collation of entomological information without such assistance would be prohibitively expensive.

Finally there is the question of the form of presentation of invertebrate information. To give a policy advisor a list of latin (or even English) species names would no doubt be counter productive. Some care will have to be taken in producing succinct species descriptors which encapsulate the functional role of species, their abundance and conservation value and their susceptibilty to disturbance.

Moths and land classes

A preliminary study

Ian Woiwod
Rothamsted Experimental Station

The sites used by Rothamsted Experimental Station for regular moth trapping have been allocated to their respective land classes. An α diversity index (Whittaker (1972)) measuring the number of species and frequency of their occurance within a community has been determined for all species caught in the traps. Figure 1 shows the mean diversity plotted against land class ranked by its first axis score from a decorana analysis. A trend can be seen showing in general fewer recordings in the land classes with higher decorana scores. When the first axis score is plotted against the mean diversity index the trend is more obvious (although not significant at th 5% level) with a correlation coefficient of -0.2912. Unfortunately the trap distribution did not include land classes 23, 24, 30 and 32, where moth diversity may be expected to be low.

As well as an initial investigation into the relationship of the moths as a sub-order the distribution of individual species has also been looked at. The species used are all widespread throughout GB although they may be restricted to certain habitats.

The individual moth species are listed below :-

1. Cerapteryx gramnis L. (Noctuidae) The Antler Moth. This species may be found in extremely high numbers such that is is a sporadic pest of upland pasture. The larval food plants are grasses and rushes, especially Molinia caerulea. Three plots of its frequency are presented, two showing logarithmic means the other a geometric mean to give some feel for the variability. Figure 3 shows the log. mean catch against land class from which a clear relationship can be seen between the occurance of the moth and the higher land classes. The other plots (Figures 4 and 5) show the mean number of moths trapped in each trap. An interesting feature of the latter two plots are the results for land classes 17 to 22, where the moth is always present and in high numbers. A fourther plot of the log. mean no of captures and the proportion of a land class having a vegetation cover including M. caerulea shows a clear relationship.

2. Graphiphora angur Fab. (Noctuidae) The Double Dart. Although widespread this species usually is only found in small numbers. The younger larvae feed on a variety of low growing plants but mature larvae move into trees and bushes such as hawthorn, sloe and birch. G. angur has been recorded as a pest of soft fruit in Scotland and the northern bias in the species distribution can be seen in the frequency of occurance in the more northerly land classes.

3. Plusia gamma L. (Noctuidae) The Silver Y. This is a migrant species which cannot usually over-winter in Britain, however two generations a year can develop from the spring migrants. The distribution is biased to the south and east as can be detected from the frequencies in different land classes. P. gamma is another species displaying a catholic taste in larval food plants, feeding on peas (Pisium), clover (Trifolium), collards (Brassica) and a variety of other wild and cultivated species.

4. Agrotis exclamationis L. (Noctuidae) The Heart and Dart. This species shows a more marked north - south trend in its frequency by land class. This may be partially explained through its univoltine life cycle and preference for agricultural weeds and root crops as its larval food.

5. Callimorpha jacobaeae L. (Arctiidae) The Cinnabar Moth. The southerly distribution of this moth is very obvious from the frequency in land classes. It is most common in land class 11 which is puzzling since it is known that higher populations occur in areas with well drained soils; land class 11 includes fens and gley soils!

6. Lithina chlorosata Scop. (Geometridae) The Brown Silver-line. A bracken feeding species, abundant everywhere. The plot of the log. mean no. of captures and area of bracken in the land classes is also shown, but no clear relationship can be seen.

7. Lygris populata L. (Geometridae) The Northern Spinach. The host plant for this species is Vaccinium myrtillus which is more common in the higher land classes.

8. Lygris pyraliata Schiff. (Geometridae) The Barred Straw. A common species feeding on species of Galium commonly found in hedgerows.

References

Whittaker R H (1972) Evolution and measurement of species diversity. Taxon. 21, 213-251.

Figure 2

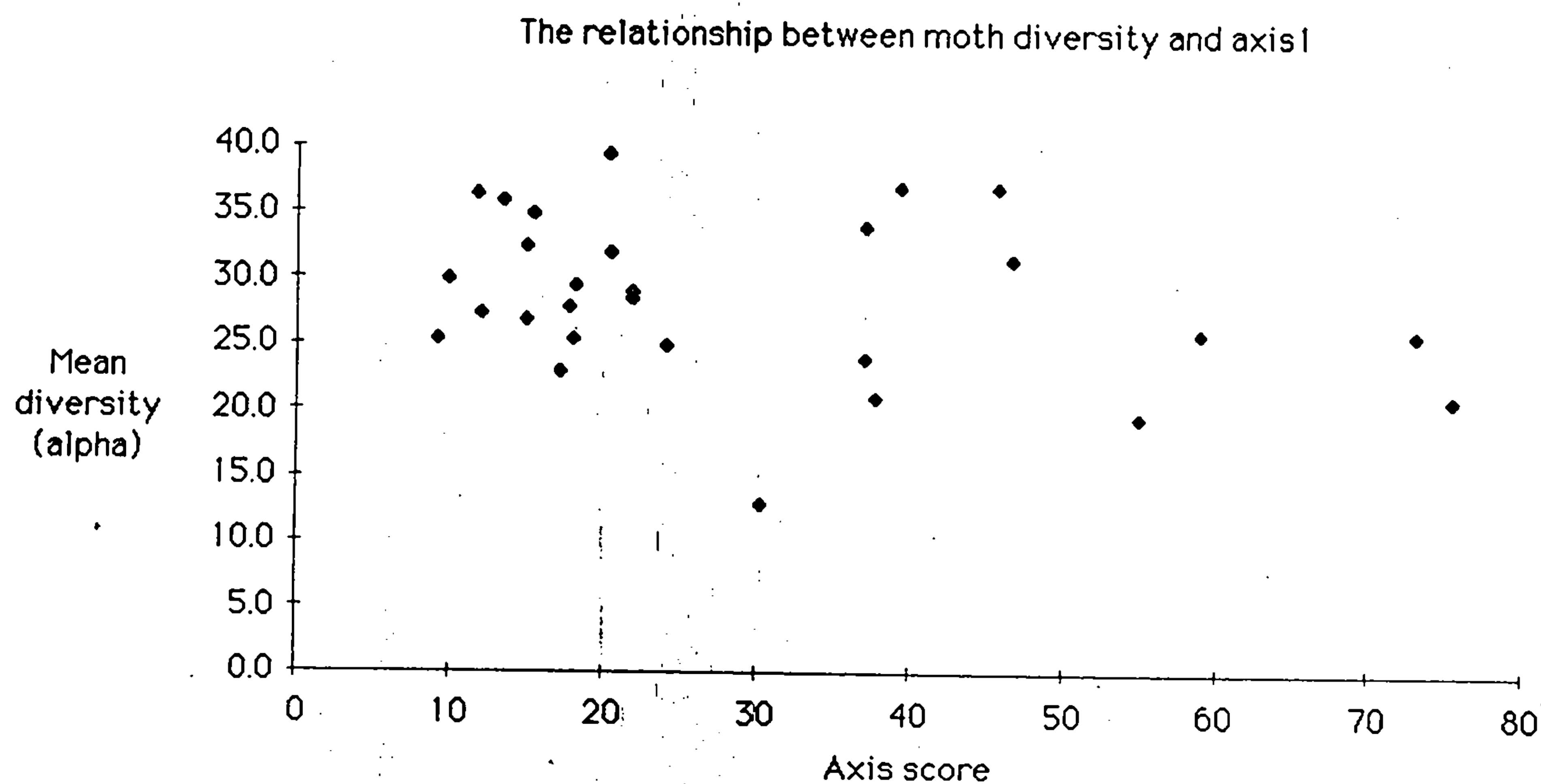
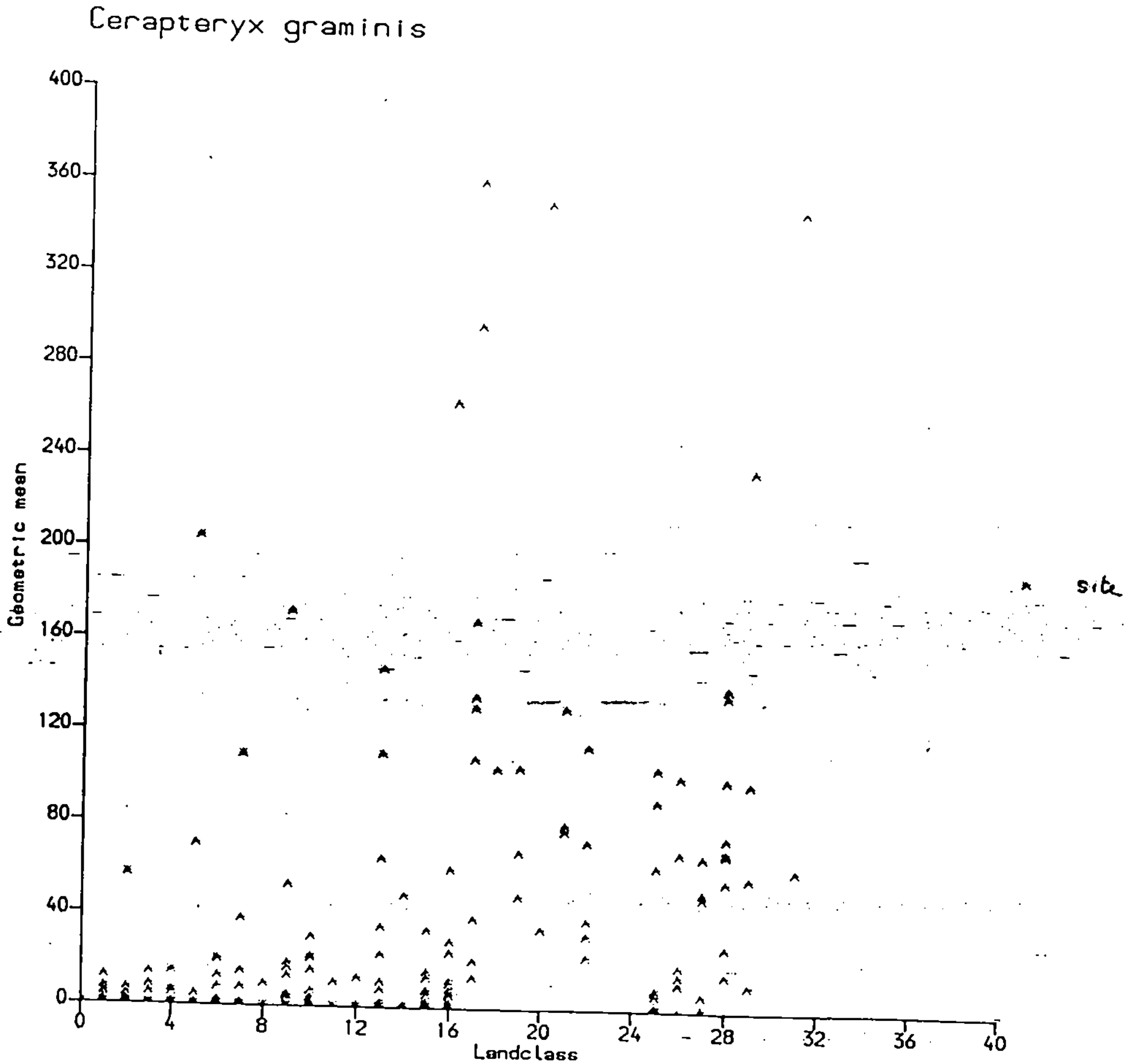

The relationship between moth diversity and axis1
Mean diversity (alpha)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
10
20
30
40
50
60
70
80
Axis score

Figure 3



Cerapteryx graminis
Geometric mean
400
360
320
280
240
200
160
120
80
40
0
Landclass
0
4
8
12
16
20
24
28
32
36
40
site

Figure 5

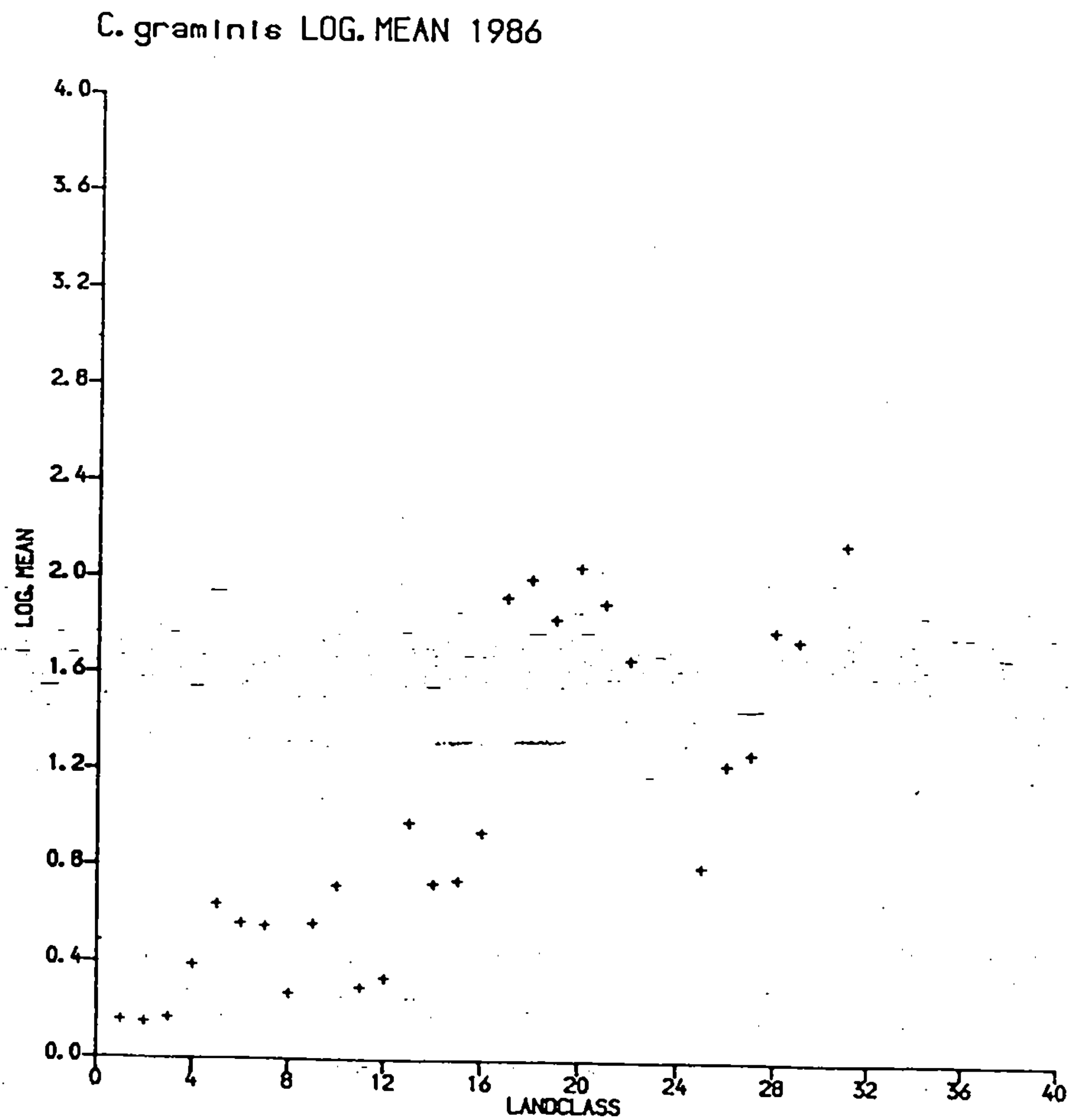

C. graminis LOG. MEAN 1986
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
LOG. MEAN
0
4
8
12
16
20
24
28
32
36
40
LANDCLASS

Figure 7

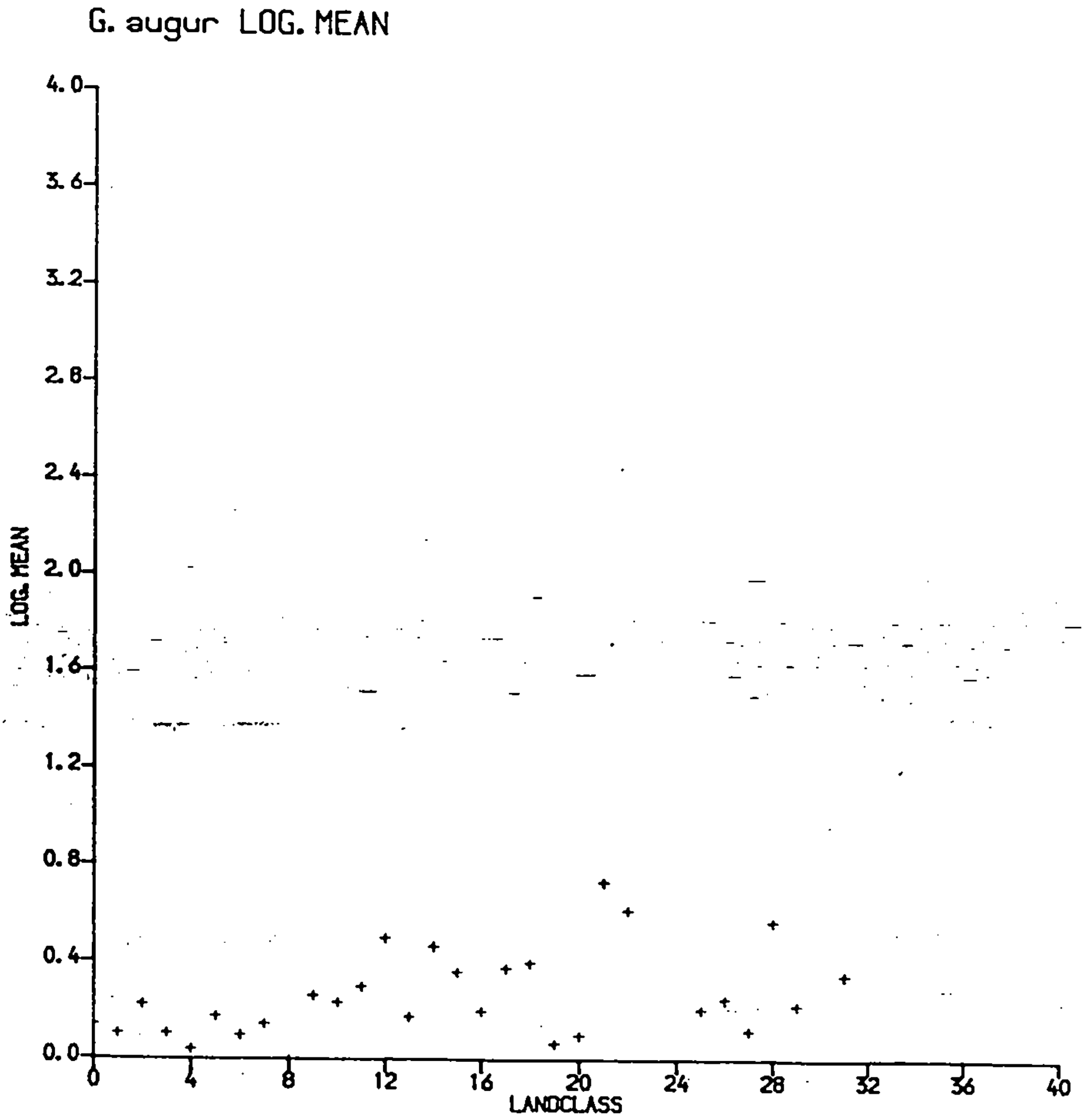

G. augur LOG. MEAN
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
LOG. MEAN
0
4
8
12
16
20
24
28
32
36
40
LANDCLASS

Figure 9

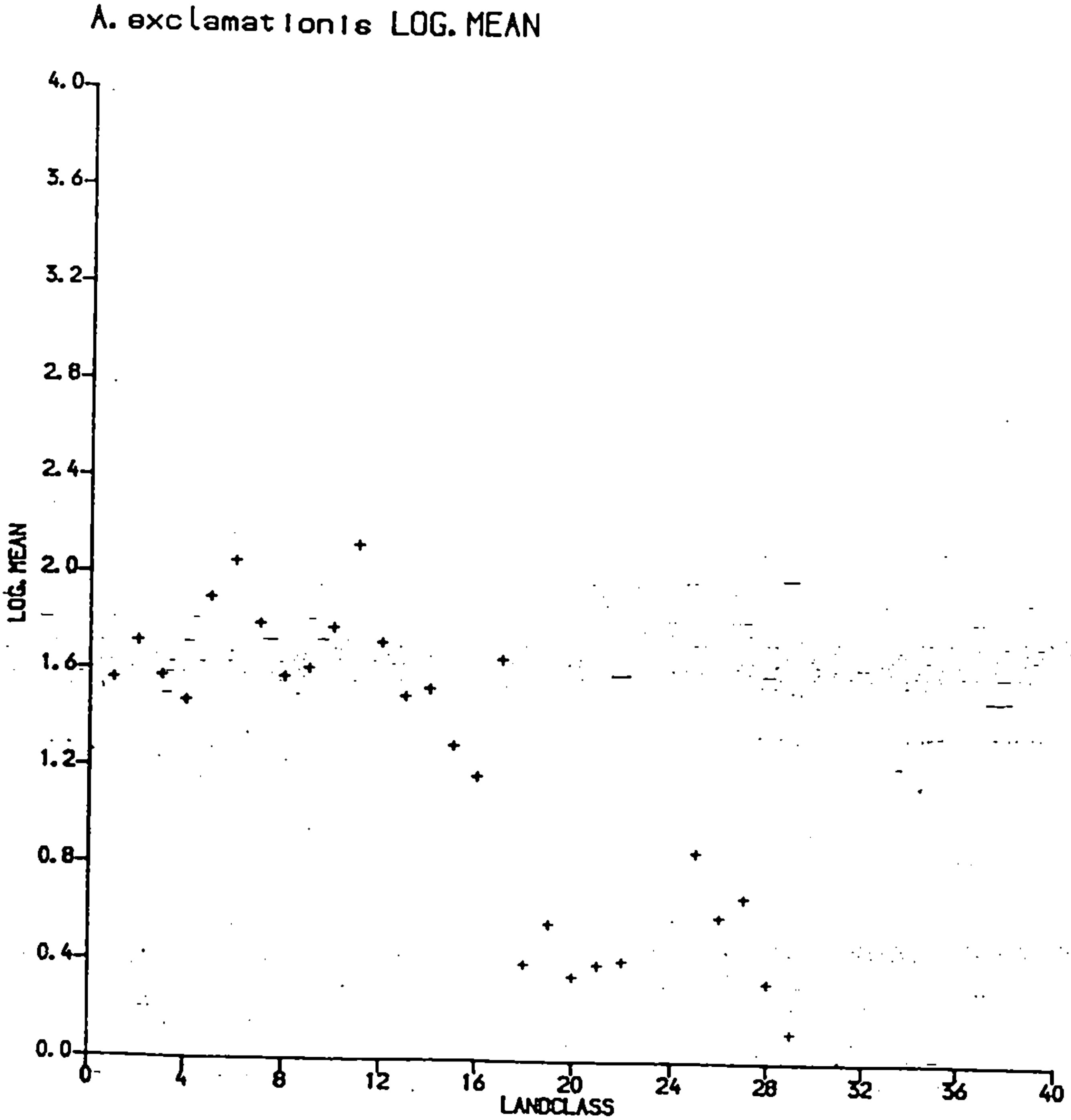

A. exclamationis LOG. MEAN
LOG. MEAN
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0
4
8
12
16
20
24
28
32
36
40
LANDCLASS

Figure 10

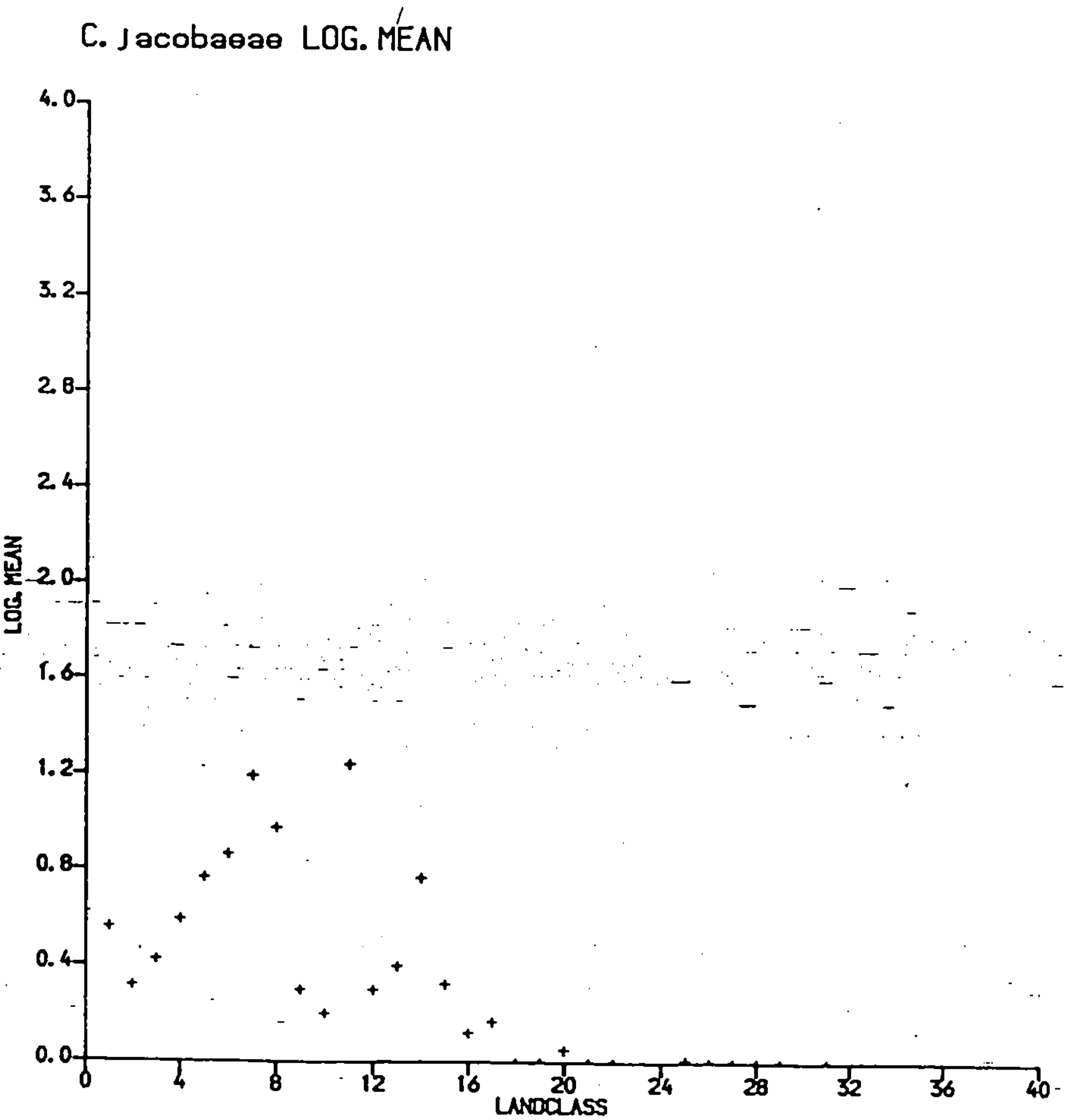

C. Jacobaeae LOG. MEAN
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
LOG. MEAN
0
4
8
12
16
20
24
28
32
36
40
LANDCLASS

Figure 11

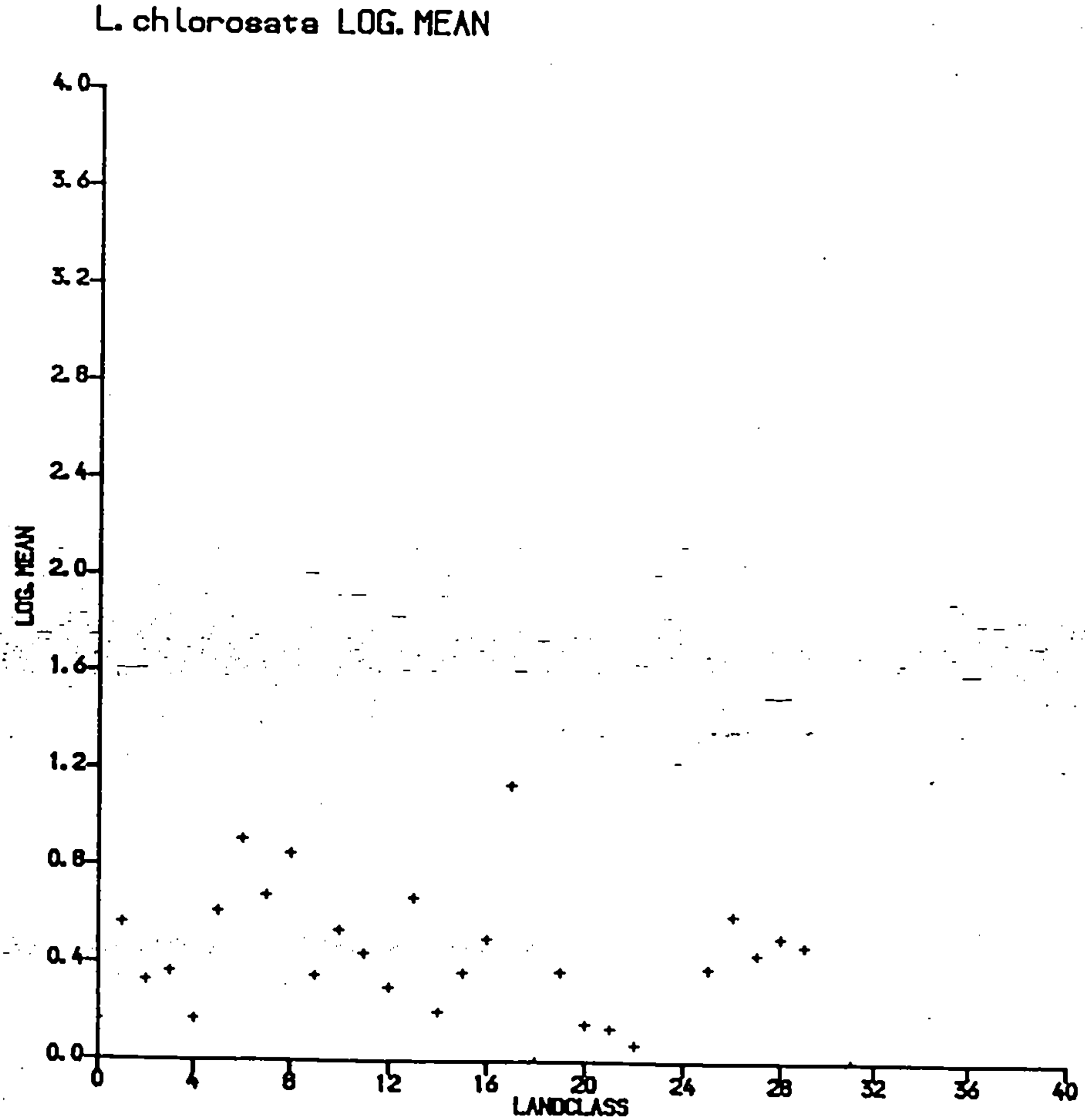

L. chlorosata LOG. MEAN
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
LOG. MEAN
0
4
8
12
16
20
24
28
32
36
40
LANDCLASS

Figure 12

The relationship between the capture of the Brown Silver-line (Lithinia chlorosata) and its food plants Pteridium aqualinum

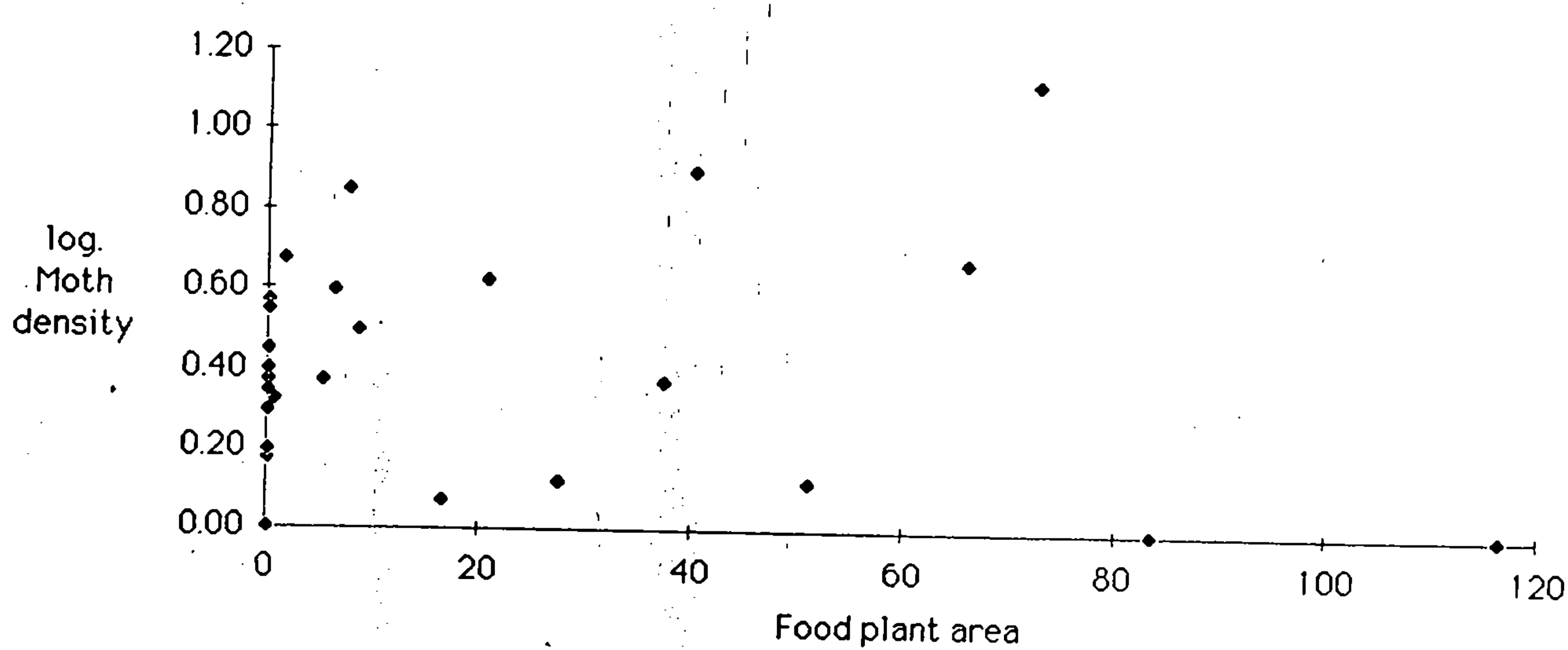
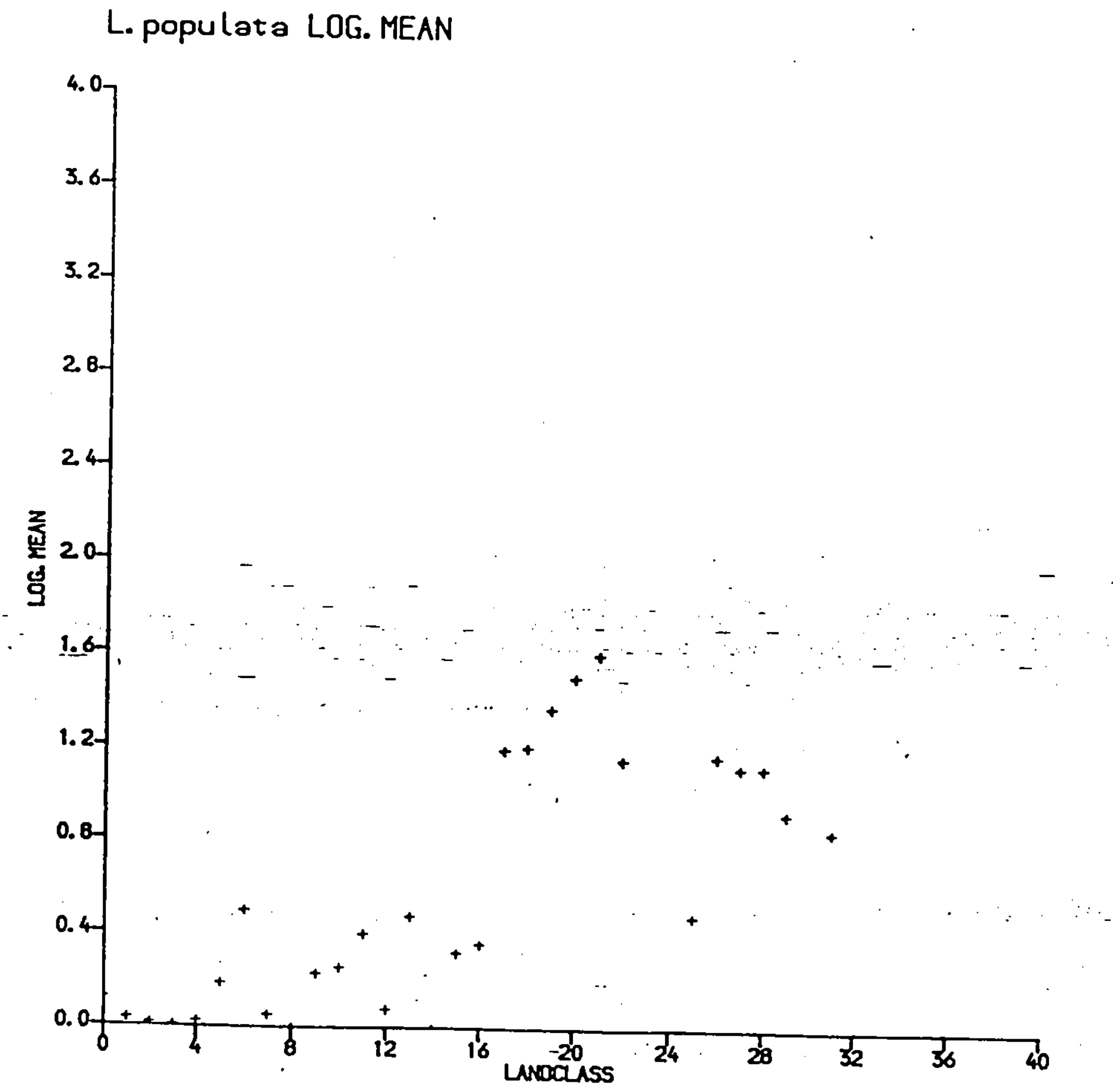
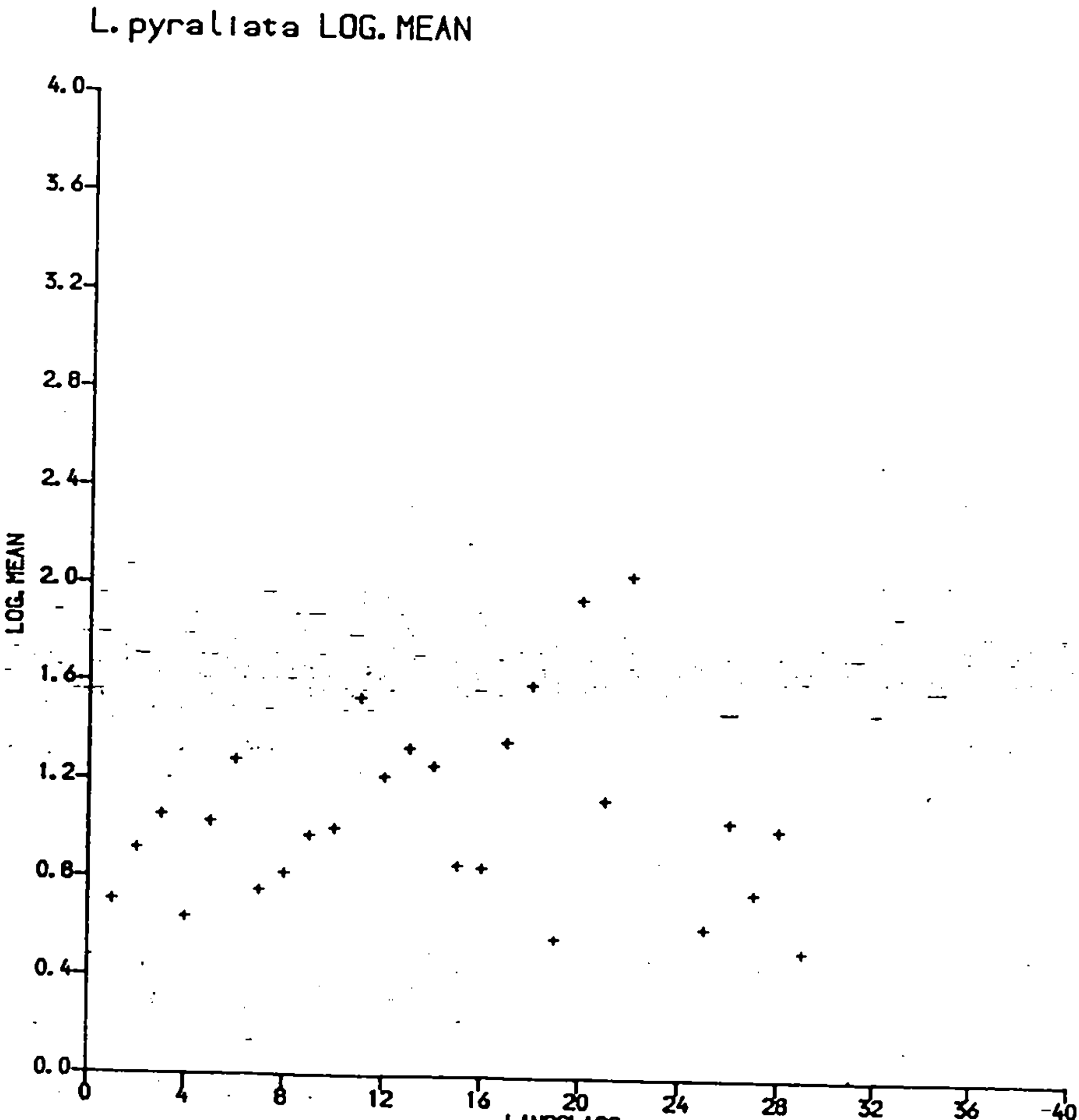


Figure 13



L. populata LOG. MEAN
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
LOG. MEAN
0
4
8
12
16
20
24
28
32
36
40
LANDCLASS

Figure 15

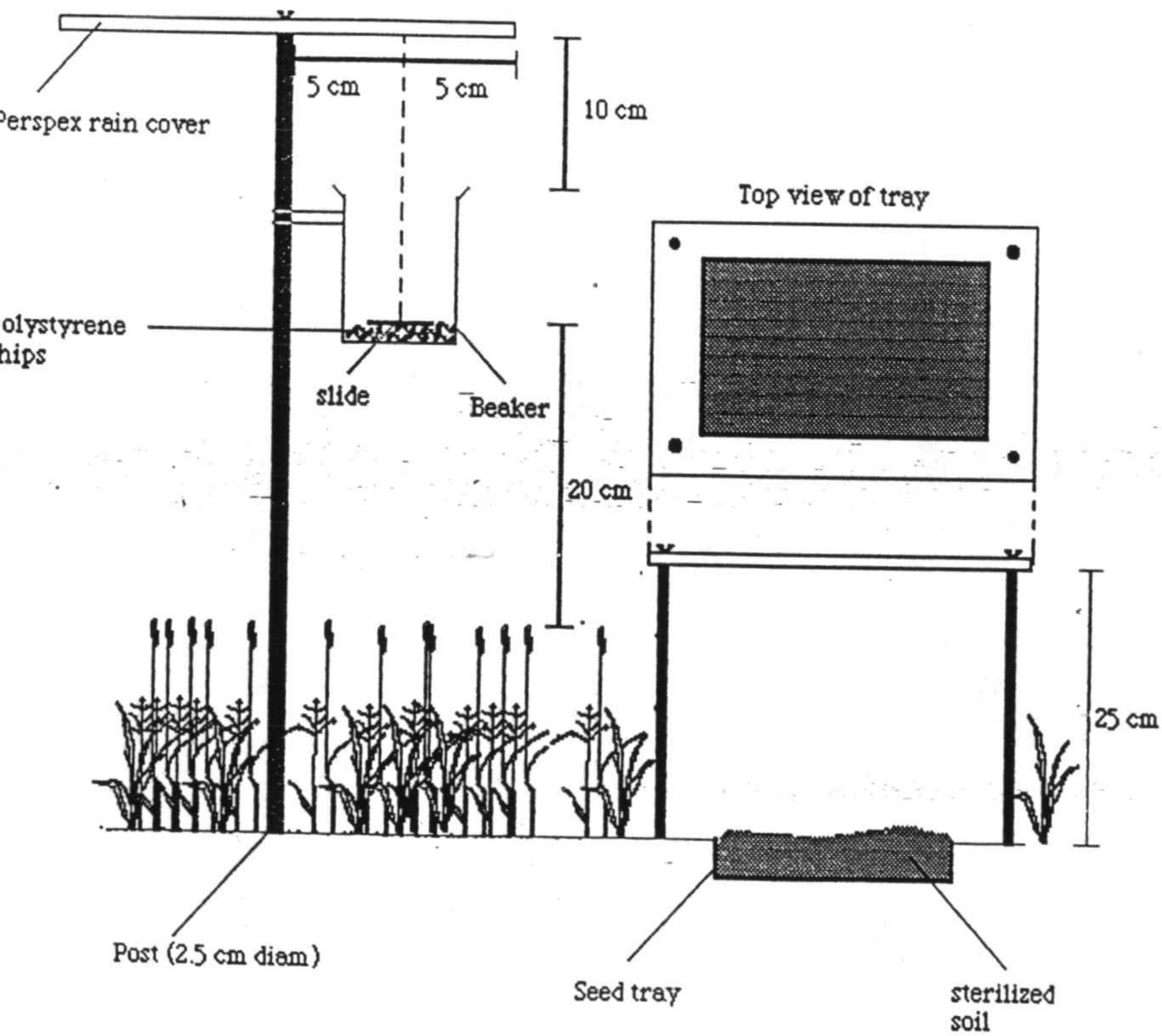

L. pyraliata LOG. MEAN
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
LOG. MEAN
0
4
8
12
16
20
24
28
32
36
40
LANDCLASS

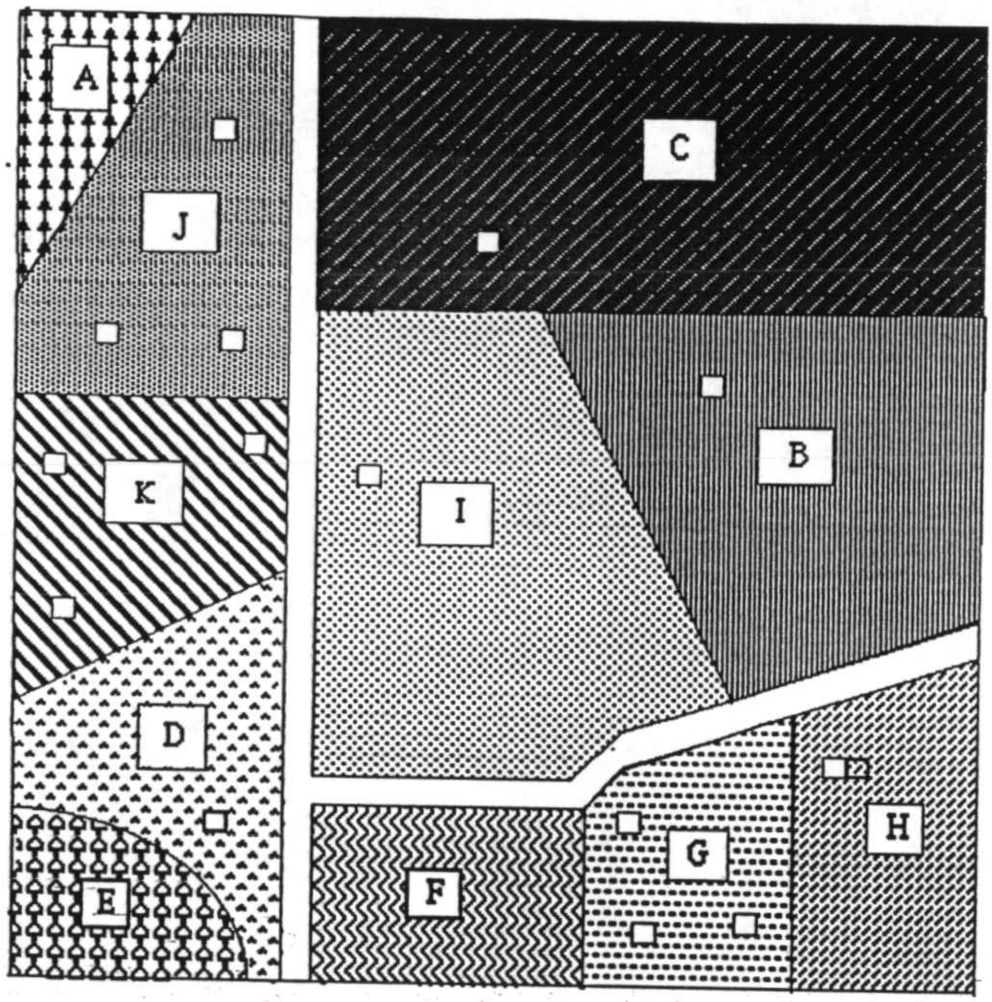
SEED BANK SURVEY

SEED BANK AND DISPERSAL SURVEY

A series of squares within land classes surveyed in 1987, has been identified, to contain as many land cover categories as possible. The categories are Arable, Ley, Permanent Grass, Upland Grassland, Grass Moor, Moorland, Hedgerow, Streamside and Verges. Within a category soil samples are being collected from the top 10 cm and brought to Merlewood. The soil samples will then be grown on at Merlewood and seedlings identified as they come through. Within each square traps will be placed at two locations for spores and seeds.

Trap design for capturing airborne spores and seeds

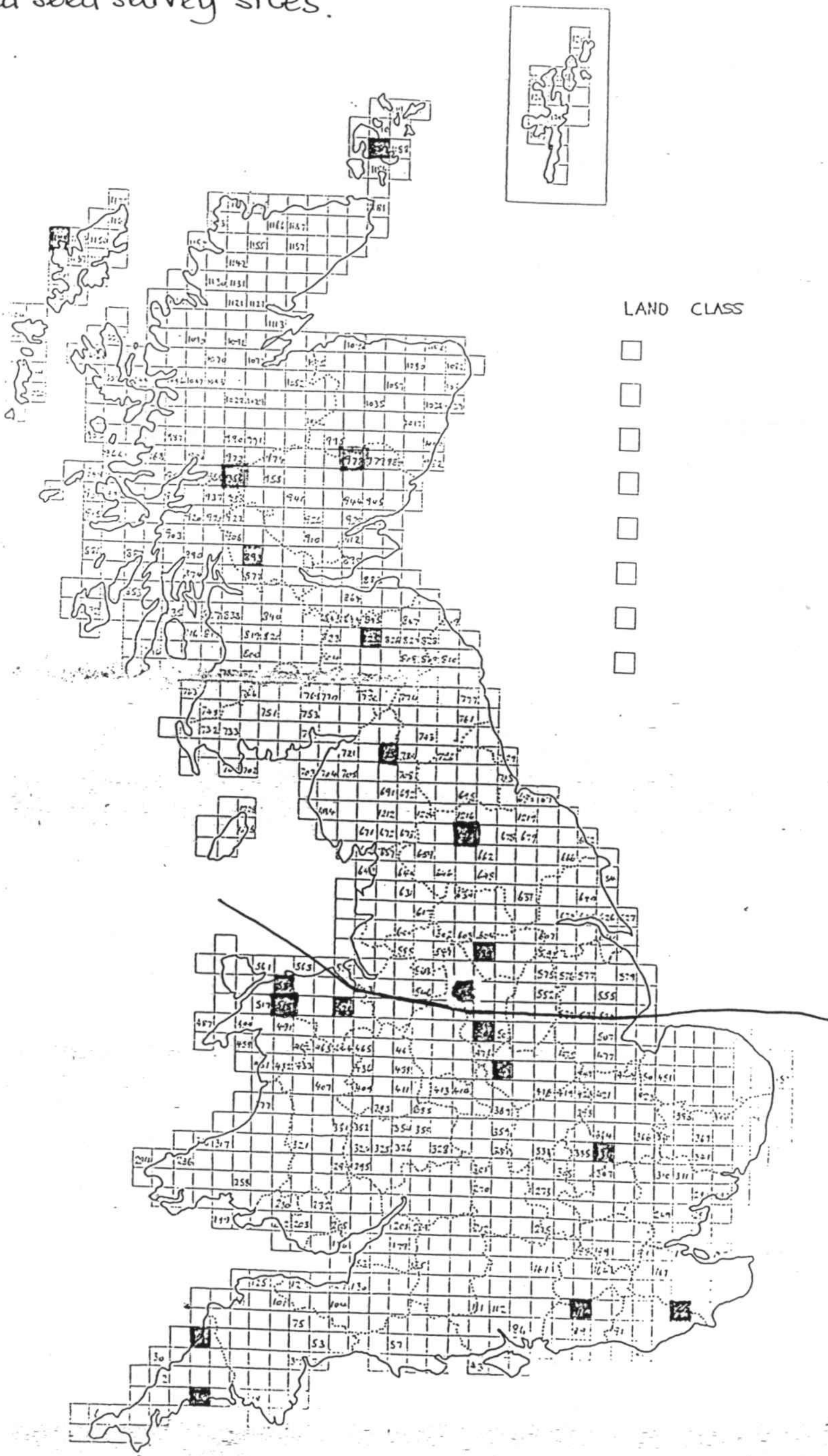




A = Coniferous woodland
B = Barley
C = Wheat
D = Permanent pasture, Lolium perenne dominant.
E = Broadleaf woodland
F = Ploughed
G = Ley, Lolium multiflorum/ Trifolium repens
H = Permanent pasture, Lolium perenne, Dactylis glomerata
Holcus lanatus.
I = Oilseed rape
J = Upland grassland
K = Grass moorland

□ = Site where 3 soil samples removed

37 Buried seed survey sites.



38 SPRING SEED SURVEY. SAMPLE SQUARES (X).

…RE	GRID REF	LOCATION	CROPS.	LEY	P. PAST	UP. G	GM	DSM	HEDGE	ROAD	STREAM	
[illegible]	507127/509128	BILLINGSHURST	1	1	1				1	1	1	
	582127/580128	NEWENDEN.	1	1	1				1	1	1	
…	222052/222054	LOOE	1	1	1	1			1	1	1	
…7	222097/224095	WEEK St MARY	1	1	1				1	1	1	
…43	447307/448305	THORTON	1	1	1				1	1		
…21	327352/325851	MINERA		1	1				1	1	1	
…6	522247/523249	POTTON	1		1				1	1	1	
…1	432334/432339	DERBY	1	1	1				1	1	1	
…18	282 532			1	1	1			1	1	1	
…46	[illegible]	THORNTON STENARD	1	1	1				1	1	1	
…9	282367/280365	LLANRWST	1	1	1				1	1	1	
…8	417367/415869	BAKEWELL		1	1				1	1		
…23	357547/359547	CROGLIN	1	1	1				1	1	1	
…25	342637/340638	CLOVENFORDS.	1	1	1				1	1	1	
…56	237 759	LAIDON, PERTHSHIRE				1	1	1			1	
…48	325 774.	SHANK OF DREISH TAYSIDE.					1	1			1	
…9	432397/430397	CHAPELTOWN	1	1	1				1	1	1	
…13	252697/250697	GARTMORE	1	1	1				1	1		
…8	104937/103935	AIRD UIG	1		1	1	1	1	1	1	1	
…57	3421012/3421010	KIRKWALL	1	1	1			1	1	1	1	
[illegible]			15	16	18	4	3	4	18	18	17	113.

DISCRIMINANT FUNCTION

THE APPLICATION OF THE DISCRIMINANT FUNCTION AS A MEANS OF AUTOMATING THE CLASSIFICATION PROCEDURE

The current procedure has been to use the seven variables (snow line, sunshine hours, minimum January temperature, distance to west coast, distance to north coast, maximum altitude and minimum altitude). The 12 sample squares from each land class have been used as the means for fitting individual members to the group means.

The test set of 384 squares revealed a misclassification rate of 44% which reduced to 26% if adjacent land classes are taken into account. However this oversimplifies the situation since if the position of the classes is taken in multivariate space then the misclassification rate is much lower. Indeed the allocationof marginal members of each class could be improved by the smoothing process with the discriminant function. Further studies are required to investigate the influence of this classification procedure on the errors from prediction.

An example of the application of this procedure has been the classification of 500 squares for the RSPB for the setting up of a monitoring scheme for moorland birds in the north of Britain. The rapid classification of these squares enabled site selection to proceed efficiently.

DISCRIMINANT FUNCTION ANALYSIS

LAND CLASS	FREQUENCY OF RECLASSIFIED SQUARES	LAND CLASSES OF RECLASSIFIED SQUARES									
1	10	2	4	5	5	5	6				
2	16	1	1	5	11						
3	14	2	2	4							
4	9	3	3	3	3	5					
5	19	1	2	15							
6	12	5	5	5	7	17					
7	7	2	2	5	6	8	8	30	30	30	
8	7	2	2	3	5	6	7	7			
9	16	10	10	10	11	11	11	11			
10	11	9	9	9	9	9	15	20	27		
11	14	9	9	9	12	12					
12	13	11									
13	12	10	16	16	16	14	30				
14	8	7	8	9	9	13	26	29	29		
15	14	1	10	10	10						
16	13	13	13	13	14	14	15				
17	13	6	6	15							
18	8	15	16	17	17	19	23				
19	9	18	20	20	20	20	22	26	27		
20	14	13	17	18	19	19	19	24			
21	13	19	20	22	28	31					
22	11	21	24	28							
23	12	28									
24	12	21	21								
25	14	21	26	26	27	27	27				
26	10	15	25	25	25	25	27	30			
27	9	10	14	16	25	25	25	25	26		
28	9	13	16	16	20	20	21	31			
29	10	28	21	30	30	30	30	32			
30	24										
31	17	32	32	32							
32	6	21	29	29	30	31	31	31	31	31	31
TOTAL	384	44% RECLASSIFIED									

EXPERT SYSTEMS PROJECT

Expert Systems in the ECOLUC project

Background

Over the past fifteen months or so the Imperial College contribution to the ECOLUC project has conmprisedsome 70 or so man-days in the area of expert and knowlcdge-based systens (KBS).

In many books and papers on the design and inplementation of KBS, a number of factors have been identifed as important to the successful design and implementation of knowledge-based systems:

the potential end-user is identifiable and preferably is available to help define the problems to be tackled; the identification of the problems in turn must be matched with the location of suitable experts who must be available to provide expertise in the production of problem solutions; the mode of use of the system needs to be reasonably well identified with the help of potential users as well as experts in the application area and the design and implemention of expert and knowledge-based systems.

Early KBS Work on ECOLUC

At the beginning of the KBS work on ECOLUC, ITE with sone help fron Imperial College, made considerable effort to identify potential users. In addition, some small systems were rapidly prototyped to indicate a range of features and applications that a KBS might provide and cover.

More recent activity

Although some work at the local level has continued (e.g. Wildflower Meadows), much of the remaining effort has been reorganised so as to be able to take advantage of national and regional databases (such as LUST). towards the end of 1987, the ITE land classification system was selected as a suitable "backbone" upon which to build particular expert and knowledge based systems. In addition, a workshop, organised by Peter Hammond and Geoff Norton (Department of Pure and Applied Biology, Imperial College), was planned so that existing KBS work could be demonstrated and discussed. More importantly, it was anticipated that the workshop would be a suitable forum for identifying more clearly the intended uses for the KBS in ECOLUC.

Expert Systems

The majority of the Expert and Knowledge Based Systems will be presented as computer demonstrations at the Advisory Group meeting. The summaries below describe the progress on the Wildflower Meadow work carried out to date.

T03002f1 Ecological Consequences of Land Use Change EXPERT SYSTEMS

Wildflower areas on farms

A small trial system for advice on creation of wildflower areas on farms is due to be completed at the end of March. This is a rule-based system with no graphical input. Most of the ES has been written in a "shell" (programming environment) called EXSYS. A smaller part, mainly concerned with selection of suitable species, has been written in a programming language called PROLOG. Programming in EXSYS has been by Emma Prentis (Imperial College at Silwood Park). Mark Hill of ITE Monks Wood has done the PROLOG programming.

Both of these programs are true expert systems, in that they ask the user a series of questions about his problem and circumstances, and come up with recommendations about what he should do. Their main purpose has been as training, to develop our programming capability and to compare methods. They are stand-alone systems, designed to run on IBM PC's and compatibles, under the MSDOS operating system. They cannot be transferred to other operating systems.

Ecological effects of afforestation

This expert system is still at a preliminary stage. It has been developed using a computer program called BRAINSTORM, which also runs under the MSDOS operating system. It allows the enquirer to explore the kinds of and consequences of afforestation wherever it may occur in Britain. The system is arranged in a hierarchical structure, allowing the user to explore knock on effects as they cascade downwards from major decisions.

In its present form, its major limitations are that it is not quantitative, and that it is not quite (but very nearly) user friendly enough to be consulted by a user who has not been instructed in the use of BRAINSTORM.

M O Hill
ITE Monks Wood
14 March 1988

Future work

If there is to be any beneficial and satisfactory outcome to the KBS component of ECOLUC (satisfactory, in particular to DOE), then it seems to me that the following should be carried out in the very near future:

(i) at least two potential "high level" decision makers, of the kind that DOE have in mind, are identified and take part in discussions with ITE staff and Imperial College KBS experts;

(ii) durng these interviews, at least three areas are selected as those where the decision makers would like adittional ecological/environmental assistance and also where ITE ecologists are confident there is identifiable and useful ecological expertise;

(iii) at least one sample problem for each of the three areas is supplied by the decision makers as illustrative of the problems they are required to tackle (with obvious protection regarding individual or commercial confidence);

(iv) each problem is analysed with respect to the available environmental/ecological data and expertise so that a skeleton or sequence of problem solving steps is produced in an attempt to provide an initial description of a computerised solution.

It is quite feasible that interesting prototype and real KBS can be (and are being) produced without the kind of co-operation from DOE that I have suggested-ITE and Imperial College staff are suitably experieneed and expert so to, do. However, without more obvious involvement from DOE, it seems unlikely that the end results will match the criteria applied by DOE in their assessment.

Dr. Peter Hammond
Logic Programming Group,
Department of Computing,
Imperial College

March 18th 1988

ECOLOGICAL CONSEQUENCES OF LAND USE CHANGE

"MEADOW" A PROTO-TYPE EXPERT SYSTEM FOR ADVICE ON THE ESTABLISHMENT AND MANAGEMENT OF DIVERSE GRASSLANDS IN THE RURAL ENVIRONMENT

Depending on information gathered regarding the looation of the farm (eg. Western or Eastern England), specific site characteristics and the objectives of the end user for the site, "Meadow", provides advice on the suitability, methods, management and consequences of establishing diverse grasslands on agricultural land.

SYSTEM DESIGN

When designing a system it needs to be known what information the system is trying to convey and how it will achieve this. This information will be determined by the requirements of the users, the ability of available expertise to meet these requirements and finally by the extent to which the expertise can be successfully represented through the medium of an expert system.

Consequently, the process of design has involved the following:

1. Determining the end user.
2. Collecting the available expertise.
3. Representing knowledge within the system.

With regard to this project the first two steps have been completed, while the third is still in progress.

END USERS

For "Meadow", potential end users of the system have been identified as:
1. Farming and Wildlife Advisory officers (FWAG)
2. Agricultural Development Advisory Service officers (ADAS)

Both of these groups are responsihle for giving ecological, conservational advice to farmers.

A number of FWAG and ADAS officers were visited at the start of the project to determine what information they would like to receive via an expert system.

AVAILABLE EXPERTISE

Knowledge on the methods of establishment and management of diverse grasslands has been gathered from a wide variety of sources, though the main input has been been from Terry Wells, and Mark Hill at ITE (Monkswood) and Alan Morton (Imperial College).

KNOWLEDGE REPRESENTATION

Having collected information from both users and experts it was then necessary to see to what extent available expertise could match user requirements within the constraints of an expert system. From this process it was deoided to design a system which gives general recommendations for the establishment of diverse grasslands at specific sites as well as detailed information on species that would be suitable for particular sites.

While there is no doubt that the FWAG or ADAS officers will be aware of some of the recommendations for establishment and management given by the system, it is felt this aspect of the system could be particularly useful, as a point of reference, for farmers attempting to estabiish diverse grasslands, and a quick and clear way for FWAG and ADAS officers to generate such recommendations.

The selection of suitabie species for a particular site has the potential to offer FWAG and ADAS officers access to expert knowledge that is otherwise hard and time consuming to obtain. There is much interest in this part of the system as species suited to a particuiar site will help to improve the success of diverse grasslands as well as offering potential to reduce costs (ie. fewer, but "the right" species are selected).

Due to time available and computing difficulties the two features of the system have been developed separately. The establishment and management recommendations within "Exsys" (an expert system shell), and the species selection via a "Prolog" programme and data base. Ultimately however it would be possible to combine the two parts of the system into one programme.

VARIABLES CONSIDERED BY THE TWO PARTS OF THE SYSTEM

EXSYS "MEADOW"

1. Farmers objectives for the site
2. Existing land use where diverse grassland is considered
3. Availability of the site (i.e. time)
4. Size of the site
5. Soil characteristics
6. Available forms of management for the grassland.

PROLOG "MEADOW"

1. Farm location
2. Soil characteristics
3. Data base of species and thier requirements.

So far a proto-type has been developed for both parts of the system and development wili continue till the end of the contract. However in an attempt to validate the proto-types and gain guidance for any future development oi the system a small workshop of end users and experts has been arranged for March the 28th at Silwood.

FWAG AND ADAS OFFICERS VISITED DURING THE COURSE OF THE PROJECT.
(* THOSE ATTENDING THE WORKSHOP ON MARCH 28TH)

FWAG:

1. Mr. M. Simmons	- Berkshire
2. Ms. M. Shapland	- Surrey
3. Mr. C. Smith	- Buckinghamshire
4. Ms. J. Greenall	- Oxfordshire
5. Ms. P. Bury	- Cambridgeshire

ADAS:

1. Ms. A. Terran	- Reading, Regional Planning Offioer
2. Mr. C. Dibb	- Reading, Regional agronomist
3. Mr. S. Peel	- Reading, Regional agronomist
4. Mr. M. Bucklgnd	- Oxfordshire
5. Mr. T. Owen	- South Downs ESA project officer

WORKSHOP ON EXPERT SYSTEMS FOR WILDFLOWER MEADOWS
SILWOOD PARK, 28 MARCH 1988

MEADOW AND FINDSEED

The workshop was chaired by Dr G A Norton; presentations were given by E Prentis and M O Hill.

Two systems were exhibited: MEADOW, written in the expert system shell EXSYS by Emma Prentis; and FINDSEED, written in the programming language PROLOG by Mark Hill. These two programs are different and complementary. MEADOW gives general advice on establishing wildflower meadows. FINDSEED produces a list of wildflower species suitable for the site, together with costs.

MEADOW and FINDSEED were demonstrated to the participants; suggestions for improvement were sought. Many useful comments were made. The participants saw good potential use for what had been done, and would like to see the work followed up. We made it clear, however, that this is not feasible unless further funding can be obtained.

Action points

Prentis to provide: Executive summary on workshop (2 sides); end-user copy of MEADOW; list of rules; copy of system in form that can be edited or listed

Hill to see if any follow-up possible; let interested users have copies of systems in their present form.

Suggestions made

1. The programs should be rigorously tested by users; recommendations for improvement to be incorporated after testing.

2. There is still some doubt about the identity of the end users. How ignorant are they? In their present form, the programs do not assume sufficient ignorance to be let loose on the general public. Even when in a final form, they should always refer the user to organizations such as FWAG and ADAS, who might prevent the worst of ignorant mistakes. County councils are a possible end user.

Other points arising

1. The research gap in knowledge is still great. More research needed, rather than people relying just on anecdotes. (C Smith).

2. Workshops for farmers could well use MEADOW and FINDSEED as a basis. It would be best to select a given site, and work on (e.g.) 15 terminals at a well equipped agricultural college. (L Jones-Walters).

3. The system should be shown to NCC; they might well show interest if the right people were reached. One is advised to concentrate on the regions rather than head office. (L Jones-Walters).

4. During the demonstration, 2 small bugs in FINDSEED became apparent (a corner of a diagram showing through after the print option is summoned up, difficulty with exiting from the program). Chris Smith objected to sowing Hypochoeris radicata on calcareous ground. Its reaction rating has been adjusted to 2. One should comment that Cynosurus has an attractive flower.

5. Red clover can be a problem with mixtures taken from the wild. Too aggressive.

6. What about the possibility of chain-harrowing to break soil, sweeping the barn and throwing back the chaff?

7. It would certainly be useful to have a list of names and addresses of nurserymen. ADAS is nowadays paid by suppliers to recommend them. Problem of who to include is vexatious. (Bartholemews of Chichester have an ESA mix.)

8. The difference between what expert systems might advise and what an expert might advise depends strongly on the human element. When an expert is confronted with a farmer wanting to sow wild flowers, he asks:
- will he apply management suggested?
- is he not really committed?
- is he disorganized?
- is he in financial difficulties?
- is he of an unstable temperament?

Recommendations are made on the basis of an assessment of the enquirer's character. The ES does not know much about this. Note that FWAG (?Durham) has produced 12 categories of people who come to them for advice.

APPENDIX

LIST OF PARTICIPANTS

IC	G A Norton E Prentis
ITE	M O Hill
FWAG	* Joy Greenall (Oxford) * Helen Shapland (Guildford) * Chris Smith (Stoke Manderville)
NCC	* Lawrence Jones-Walters (Newbury)
ADAS	* Steve Peel (Reading) Stewart Hodges Barbara Chadburn
Bracknell D.C.	Helen Tranter Alan Wilson

* to receive a distribution copy of MEADOW and FINDSEED if possible

LINK PROJECT

Link Projects

The main reports produced to date will be tabled at the Advisory Group meeting. Recent summaries received are included below.

ECOLOGICAL CONSEQUENCES OF LAND USE CHANGE

Part 1. Existing and potential recreational and tourist activities in the ITE squares

Objectives.

i) an identification of existing recreation and tourist activity taking place in the ITE squares
ii) an assessment of the potential recreation and tourist activity in the squares.

In addition, a brief commentary on the ecological implications is made.

The report.

A draft copy of the final report will be available at the advisory group meeting, the structure is as follows :-

i) an outline of the methodological approach that has been adopted
ii) a discussion of the factors that currently or in the future are likely to influence the type, location and amount of recreation and tourism
iii) a review of the findings of the analysis
iv) a commentary on the ecological implications.

The findings are presented as a series of schedules with each square in each land class recorded in terms of what recreation and tourism exists and what potential, activity there might be in the future. At this stage the potential in each square is expressed as being present or absent. As the physical survey of the squares continues, which extends both the available knowledge of the particular circumstances in each square and also the general awareness and understanding of the processes at work, so it will be possible to identify in which parts of those squares with a reasonable degree of potential the future activity might occur.

ECOLOGICAL CONSEQUENCES OF LAND USE CHANGE

Part 2. Alternative crops - Progress report, March 1988, from the Centre for Agricultural Strategy, University of Reading.

A. Identification of alternative crops

(i) The first stage in the project was to select the alternative crops which were to be incorporated into the study. This was done by reviewing the possibilities, and these were then narrowed down by making a selection of contrasting types of crops which also had different environmental requirements. For each of the crops selected, their product was in demand in the U.K.

(ii) The crops chosen were:-

(a) Sunflower
(b) Lupins
(c) Chickpeas & Lentils
(d) Peppermint
(e) Flax
(f) Sea Buckthorn (for juice production)
(g) Blueberry
(h) Novel Salad Crops

B. Assessment of crop requirements and where they might grow

(i) The second stage has been to identify the climatic and edaphic parameters which might govern the distribution of the crops, and then to determine how best to characterise these using the I.T.E. and other environmental data available. This stage is completed.

(ii) The third stage of this study was to annotate the sample 1km 2 squares with the potential distribution of the alternative crops, making use of the chosen criteria. Table 1 shows the areas of GB which are potentially capable of supporting the novel crops

(iii) Now that this is complete, a brief assessment will be made of the social, economic and ecological consequences of such a technically possible level of planting of alternative crops, before transferring the database to I.T.E.

Table 1. Potential for novel crops in GB

Crop	Area (km)
Flax	10 658.75
Peppermint	34 201.71
Novel salad crops	11 474.55
Chickpeas and lentils	11 933.88
Lupins	23 382.91
Sunflower	11 686.13
Blueberry	3 760.84
Buckthorn	13 816.92

ECOLOGICAL CONSEQUENCES OF LAND USE CHANGE

Part 3. Socio-economic characteristics - Progress report, March 1988, from the Centre for Agricultural Strategy, University of Reading.

A. Overview

(i) This part of the Project collated data from various sources so that distinctions could be made between I.T.E. Land Classes on the basis of some of the socio-economic characteristics of farmers and their farm businesses.

(ii) Existing CAS databases were used, supplemented from other sources where necessary, to provide adequate coverage of the 32 I.T.E. Land Classes.

(iii) Pertinent socio-economic characteristics were chosen, with the addition of a Land Class value for each observation. Where observations had not already been assigned a land class these were specially calculated.

(iv) Finally, the nature of the various socio-economic characteristics were examined for each Land Class and generalisations made wherever the number of observations in each Land Class were sufficient to permit it.

B. Current job status

(i) Three databases were selected from which to draw the required socio-economic information, these were as follows:-

(a) A database from a project on information management in agriculture(Univ. of Reading, 1984/85).

(b) A database from a project on the impact of the CAP on agricultural development (N.E.R.C./E.S.R.C. 1986/87).

(c) A database from a project on the opportunities for growing trees for fuel (Univ. of Reading, 1986/87).

(ii) Of these databases, (a) and (b) above were specific to some of the 256 I.T.E. squares, but database (c) was not, so, to date 186 farms from database (c) have been assigned Land Classes, with a further 200 or so nearing completion.

(iii) A review of the compatability of information between these databases yielded the following 13 socio-economic variables:-

(a) Farmer age.
(b) The year the farmer began farming on own account.
(c) The presence or otherwise of an heir willing to farm.
(d) Whether the farmer had any formal agricultural training or qualifications.
(e) Membership or otherwise of any farming organisations by the farmer.
(f) Presence or otherwise of any off-farm income.
(g) A code number to identify each individual farm.
(h) The total size of the farm holding.
(i) The area of the total holding which is owned.
(j) The area of the total holding which is rented.
(k) The number of full-time workers on the farm.
(l) The number of part-time workers on the farm.
(m) Farm production activities/farm type.

(iv) Each of these 13 variables were present on all 3 databases, but were often represented in different fashions. Thus, a homogenizing process had to be conducted changing variable names and the format of data representation to permit the merging of all 3 databases into a single unit containing the 13 variables listed above, Land Class by Land Class.

(v) At present, the single database is complete with 361 observations entered and checked for errors. Partial analysis of Land Class trends has been conducted. The final database will consist of over 600 farmer and farm business observations. Examples of some of the variables by Land Class are shown in the Table below.

(vi) If funds were available, a further 2000 businesses from the CAS database could also be categorised by Land Class.

I.T.E. Land Class	Number of farm businesses/ Land Class	Mean farm size (ha)	Mean area owned (ha)	Mean area rented (ha)	Average year principal began farming on own account
1	8	139.8	75.6	64.2	1964
2	5	38.9	29.6	9.3	1968
3	6	151.8	95.2	56.7	1969
4	11	287.0	206.7	80.3	1959
5	4	156.5	104.2	52.3	1966
6	7	49.5	18.4	31.1	1966
7	3	141.6	76.8	64.7	1956
8	3	158.9	56.7	102.3	1969
9	6	233.4	136.6	96.8	1969
10	12	176.0	155.8	20.2	1961
11	12	161.6	86.1	75.4	1960
12	11	329.3	212.5	116.7	1962
13	6	245.7	114.9	130.8	1961
14	4	230.6	220.6	9.9	1955
15	21	158.0	126.6	31.4	1967
16	21	142.0	48.8	93.2	1965
17	22	562.9	107.3	455.7	1964
18	5	347.3	347.3	0.0	1967
19	16	609.1	441.7	166.7	1967
20	35	357.4	308.2	79.6	1967
21	9	8884.8	8442.6	442.1	1974
22	5	214.9	54.1	160.8	1962
25	32	170.8	98.5	72.2	1963
26	18	161.1	130.6	30.5	1967
27	24	123.9	94.8	29.2	1967
28	5	212.7	119.4	93.3	1977
29	1	470.6	0.0	470.6	1938
31	3	87.9	87.9	0.0	1957

ITE PROJECT 1130 - THE ECOLOGICAL CONSEQUENCES OF LAND USE CHANGE

University of Edinburgh Sub-contract: Report

1. INTRODUCTION

Edinburgh University Geography Department has a growing reputation as a centre of excellence in the development, implementation and application of Geographical Information Systems (GIS). Many widely used software tools, including CAMAP, GIMMS and GEOLINK, were developed within the Department, while a number of other important packages including ARC/INFO, the ORACLE relational database management system, and GEMS and ERDAS image processing systems are also available.

Because of the availability of these facilities, and the proven expertise at Edinburgh University in applying them to a wide range of problems, the Geography Department was invited by the Institute of Terrestrial Ecology (ITE), Merlewood, to undertake a data capture exercise as part of their project : The Ecological Consequences of Land Use Change .

This report explains the strategies adopted in executing the sub-contract, provides a critical assessment of the data and techniques used, and offers suggestions as to how the facilities of the Department might be used for future collaborative projects.

2. THE TOPIC

To provide in machine readable form information for a variety of topics, for the approximately 5300 1-km squares which the ITE have assigned to land classes in Great Britain.

3. THE WORK PROGRAMME

3.1 Transfer to Edinburgh of the co-ordinate data for the ITE sample squares.

This was affected by electronic file transfer, over JANET (the Joint Academic NETwork). This provided locational data for the ITE sample squares for which attribute information was required.

3.2 Design of the database

It is a fundamental truism that optimal performance of any geographical information system depends on careful planning of the database architecture. Therefore, once the coordinates of the sample squares had been transferred to Edinburgh a comparative assessment was made of the various hard- and software facilities available for the project. At the same time, a critical examination was made of the sources and types of data available for input, and the final format in which the data were required by the ITE.

After careful consideration of data sources and required output, it was decided that the locational and identifying data for the ITE sample squares, and the captured data for each environmental parameter, would be stored in the ORACLE database management system. The reasons for this decision may be summarised as follows:-

(a) ORACLE is a very flexible and user-friendly system, enabling relatively rapid data capture. Therefore, optimum use could be made of the time available for the project;

(b) Graphic output can be easily obtained by using the GEOLINK software, developed within Edinburgh University Geography Department as an interface between ORACLE and GIMMS (Waugh and Healey, 1986);

(c) ORACLE is available on VAX 11/750 and MicroVAX machines and on the MicroVAX at Merlewood. Therefore, this option offered additional value, since the entire database could be transferred to the ITE as a package, complete with database tables and indices as well as the data themselves. This database could then be incorporated into a wider GIS system at a later date if required.

(d) ORACLE allows easy linking of different tables, by means of relational joins. This meant that separate tables could be created for data relating to each attribute (e.g. geology, protected land status, etc), thereby minimising risk of corruption and optimising database performance. This also enhances the GIS capabilities of the ITE machine.

(e) The widespread use of ORACLE within NERC organisations, means that the ITE data can be used as part of a wider distributed system, using the SQL*Net software utility.

Once the decision had been made to use ORACLE, consideration was then given to the design of the database tables and application. It was decided that a hierarchical application structure, based on linked tables would provide the optimum performance and flexibility.

At the apex of the hierarchy is a table called SQUARES (see fig. 1). This contains location and identification data for each of the sample squares, each square being treated as a row in the table (ie. as an individual record). The structure of SQUARES is given in table 1. Separate 'look-up' tables, called GEOLOGY, DRIFT and LANDCLASS were also created (see tables 2, 3 and 4 respectively). These provide a key to the coded information held in SQUARES.

Relational joins between the tables permit a very wide range of search criteria to be specified. For example one can search for the identifier and coordinates of all squares where the dominant geology is Granite, or where the dominant drift material is peat; where a certain combination of landclass and drift type occur; etc. Searches can also be made for squares that fulfil required attribute combinations, but which also fall within a specified grid 'window' (e.g. north of a certain point, or within a range of defined northings and eastings).

It should be noted here that the "modular" approach easily allows expansion of the system through the addition of more code fields to the SQUARES table, using the 'ALTER TABLE ADD...' function within ORACLE SQL. These additional fields can be linked to new attribute tables through relational joins, while the attribute tables can be brought into the single application by invoking the ORACLE Interactive Application Generator (IAG) utility. The whole process can be achieved in minutes by an operator with some knowledge of SQL and ORACLE, and permits a very great degree of flexibility to be built into the system.

In order to further optimise the performance of the database and the table hierarchy, selected fields within the tables were INDEXed using the SQL facility for this purpose. This gave very great noticable improvements in data retrieval, particularly in searches involving complex relational joins and/or sub-queries.

4. CAPTURE OF GEOLOGICAL ATTRIBUTE DATA

4.1 Sources of data :

Informal discussions with members of the BGS at Edinburgh and Keyworth suggested that some of the data required might already have been compiled in machine-readable form by the British Geological Survey. However, as a result of further enquiries, it was understood that this was not a feasible source for the required data. The most important reasons for this may be summarised as being:
1) that the BGS database is not complete;
2) that it is stored in a manner that would be time-consuming to convert to 1-km resolution raster format; and
3) that there might be administrative and copyright difficulties of access to these data.
These latter problems, while not being insurmountable, would add undesirable delays to the project in hand. It was therefore decided that the data would have to be obtained from published (map) sources.

Geological maps of the UK, showing a variety of geological information, are published by the BGS at a range of scales from 1: 2 500 000 to 1: 25 000. However, the largest scale for which there is complete, uniform treatment of Great Britain is that published in two sheets at 1:625 000. It was decided, therefore, to use the most recent (1979) edition of this map as the data source.

4.2 Method of data capture

A number of options were considered. The first was to digitise the entire source map, to overlay a grid, and to derive the attributes for the sample squares through automated means. However, it soon became apparent that this was not really viable with resources available: firstly, because of the time and resources required to accurately digitise the source map and to assign topology to the resulting polygon files (this problem particularly arose due to competition for available resources from teaching and other commitments within the Department); secondly, the CPU time required for abstracting the attribute data for the sample squares would have been prohibitive with the software available; thirdly, this method would have generated a high level of redundant data which, again, was considered wasteful of available resources. Therefore, the following method was adopted:

(a) The national grid co-ordinates for all sample squares in a specified 100 x 100 km block were spooled out of ORACLE, and were inserted into GIMMS mask files using the GEOLINK interfacing software. These were compiled to create plot files which were then plotted out as maps for overlaying on the 1:625,000 geology maps at a light table.

(b) As noted above, each sample square is held in the SQUARES table as a discrete record. At every session of data input, a group of 1-km squares (usually all those within a 100 x 100 km area of the source map) was selected. The record for each of these squares was retrieved to the terminal screen in turn, using the ORACLE Interactive Application Processor (IAP) facility. As each record was retrieved, the geology for that particular square was noted from the map, and was entered into the database via the terminal keyboard, in the form of the numerical code given on the map.

(c) When entries had been made for each of the 5300 squares the GEOLOGY 'look-up' table was created, as described above.

4.3 Limitations of the data

(a) As was noted above, the largest scale geological map for which complete, standardised coverage of the UK is available, is at 1:625 000. This was the source used for obtaining the data entered into the database. However, the data portrayed on this map is derived by generalising geological information from surveys carried out at much larger scale or, where basic field surveying remains to be completed, is obtained by interpolation between areas surveyed in detail. These interpolated and generalised data will, inevitably, have been transferred to the compiled database. It is difficult to see how this source of potential error could have been eliminated except, possibly, by gaining access to unpublished larger scale survey material from the British Geological Survey.

(b) It should also be noted that a 1-km grid cell, plotted at 1:625 000, results in a square measuring approximately 1.5 mm per side. Therefore when a matrix of squares at this scale is used as an overlay for data capture, the resolution that can be worked to is limited, especially when more than one geological category falls within a given sample square. In recognition of this fact, it was decided to only record the geological categories in cases where the second division occupied more than 25% of the area of the square as estimated by eye. Furthermore, the division was only made in 25% stages (i.e. 25%, 50%, 75%, 100%).

(c) Errors of data input (operator errors). This is a difficult factor to quantify, since the only truly objective way of assessing it would be to have a second operator duplicate data input for a specified sub-set of simple squares, and to compare results. Resources were not available for this, but careful re-examination of sample squares selected from ORACLE on a semi-random basis (e.g. squares were selected from an arbitrarily chosen 50x50 km window where the landclass equalled an equally arbitrarily-chosen value) revealed no serious discrepancies. Such variations that did exist almost certainly reflected different decisions made when there were two or more possible choices of 'dominant' rock type. It is felt that within the overall database such errors probably cancel each other out.

4.4 Limitations of the method of data capture

The method of data capture used, as described above, was very slow partly because frequent rests had to be taken to rest the eyes, and partly because of the number of steps required: the record for each square had to be retrieved, the square located on the map, and the attribute then recorded at the terminal keyboard.

It was found that an optimum balance between speed and accuracy was achieved at between 100 and 200 records per hour, but that two hours was the maximum that could be achieved at one session. It must also be noted that this method of data capture is extremely tedious and routine for the operator!

5. CAPTURE OF DRIFT GEOLOGY DATA

5.1 Selection of data source

Two possible sources of data were considered, namely published versus unpublished material.

Informal approaches were made to the BGS and the Macaulay Institute, Aberdeen, to see if the required data already existed on a database anywhere and, if so, whether this might be made available to this project. These enquiries failed to identify any viable sources however, and it was realised that the most readily available and suitable source of data that could be identified, at a resolution suitable for the purposes of this project, was the 1:625 000 scale map of Quaternary Deposits published by the BGS.

Having selected the data source, attention was then turned to resolving some of the limitations identified in the method of data capture used for the solid geology.

After consideration of the problem, a special digitising interface program was written by Steve Dowers, the Edinburgh System manager. Using this new method, data capture performance time was much reduced. Details of the technique are as follows:

(a) Overlay maps were prepared in the same manner as for the solid geology data, except that these overlays were then photocopied onto clear acetate.

(b) The 13 different categories of drift geology displayed on the source maps were each allocated a discrete numerical value.

(c) The source map was placed on the digitising table and the digitising program was invoked. The source map was registered, by digitising and locating four perimeter points on the map.

(d) The appropriate acetate overlay was selected and placed in position on the source map.

(e) The cross-hairs of the digitising tablet (mouse) were placed over each square in turn. Pressing one of the buttons of the mouse keypad enabled the program to identify the relevant sample square, by searching a compressed look-up file containing the ITE identification and the grid coordinates for each square. The numerical code assigned to the dominant drift type applicable to that 1-km cell was then entered, again using the keypad attached to the mouse.

(f) The data thus entered was written to an output file containing two columns of data: these were square id and drift type (in coded form) respectively. These data could then be loaded into ORACLE using ODL.

(g) A DRIFT-CODES field was creatad in the SQUARES table, and a 'look-up' table (table DRIFT: see table 3) was created to relate the code numbers to a drift type.

5.2 Limitations of this method of data capture

The main problem encountered with the technique described above was due to a persistant and irritating bug in the program that could not be traced. This bug caused the digitising interface to only recognise about 9 out of every 10 of the sample squares. This meant that, while the method was very much quicker than the purely manual method of data capture used for the solid geology, the gain was off-set by time required to identify those squares that had failed to "take" , to identify the locations of these on the source map, and to enter the drift type manually at the terminal keyboard. If this bug had not occurred then, without a doubt, this would have been the optimal means of capturing data from source maps of this level of complexity.

It should also be noted that most of the remarks made above, regarding the limitations and possible sources of error of the solid geology data, also apply to the drift data. The resolution of the map is the same in both cases.

7. LAND CLASS DATA

These data were provided by the ITE, and were loaded into suitable ORACLE tables by means of the ODL facility. These data were incorporated into the database for the sake of completeness, and to enable a series of distribution maps to be compiled as part of a separate exercise.

8. CONCLUSIONS AND FUTURE RECOMMENDATIONS

This was a valuable exercise on a number of counts. At the time of iniation of the project, the ITE had only recently acquired ORACLE, and were therefore still new to the system. By assigning this project to the University, the ITE were able to draw on greater experience of the system, acquired over considerably longer period. Furthermore, the expertise of the Geography Department in interfacing ORACLE to mapping and other software was made available to the project.

As was noted in the introduction, the Department of Geography at Edinburgh University is widely regarded as a centre of excellence for the application of GIS. In addition to the project described above, recent and current GIS activities include the development of CARTO-NET, a cartographic information retrieval system; work on the creation of a system for administering and monitoring environmentally sensitive areas in Islay and Breadalbane; and development of a software interface between the ORACLE database management system and the ARC/INFO geographic information system. This latter object may be of especial interest to the ITE, since ORACLE (as noted above) is becoming increasingly widespread as a database system in the UK, while ARC/INFO is probably the most powerful and popular turnkey GIS in North America and Europe. The Department is also currently enjoying renewed vigour in its research in the realms of physical geography and ecology, and in other aspects of landscape ecology. In these areas computer applications also feature strongly.

It is therefore suggested that in these areas in particular, there is scope for future collaboration between the ITE and the Department of Geography.

One area where collaboration would be particularly worth investigation is the MSc program in Geographical Information Systems run by the Department of Geography. This course attracts some 15 top-calibre students every year, from home and abroad. As part of the requirements for the MSc, the students are expected to complete an independent piece of research, and to write a thesis. This research may be based on an application of existing hard- or software, but previous students have on occasions written their own softmare, for example to interface digital image processing with map overlay packages.

Experience has shown that students on this course are normally particularly anxious to undertake projects based on real-world problems or applications. Previous students have worked with a variety of Public, Private and Government-related bodies including the Marine Laboratory at Oban, British Gas and the Ordnance Survey.

FIG 1: The Architecture of the database.

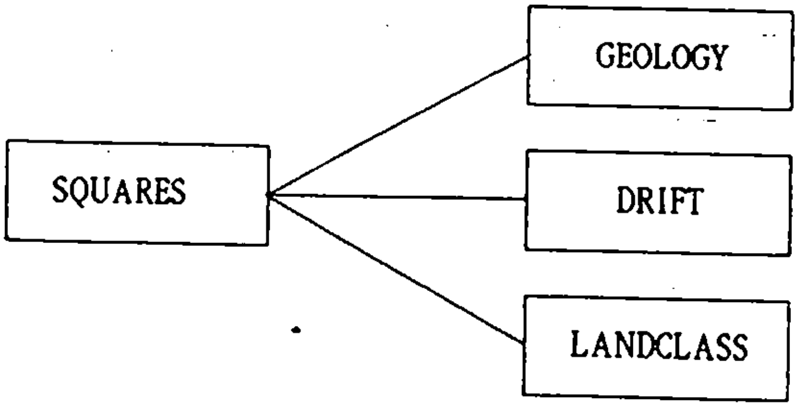


TABLE 1 : The SQUARES table

Name	Type
SEQNO	NUMBER
GRID_SQ_ID	CHAR(20)
GBLE	NUMBER
GBLN	NUMBER
GEOLCODE1	CHAR(20)
GEOL1-AREA	NUMBER
GEOLCODE2	CHAR(20)
GEOL2-AREA	NUMBER
DRIFT-CODE	NUMBER
LANDCLASS	NUMBER

TABLE 2 : The GEOLOGY table

Name	Type
STRATIG1	CHAR(100)
STRATIG2	CHAR(40)
STRATIG3	CHAR(40)

TABLE 3: The DRIFT table

Name	Type
DRIFT-CODE	NUMBER
DRIFT	CHAR(60)

TABLE 4: The LANDCLASS table

Name	Type
GRID_SQ_ID	CHAR(20)
LCLASS	NUMBER
COUNTY-CODE	NUMBER

SCHEDULE 1

PROGRAMME OF WORK

1. OBJECTIVES

i). Ultimate: To identify and map appropriate criteria for maximising the environmental benefits of agricultural set-aside.

ii). Proximate: To apply Wye College methodology to the 256 sample squares in the ITE Land Classification Model.

2. BACKGROUND

The diversion of land from intensive agricultural use (set-aside) is an important potential means of reducing food surpluses. The environmental benefits of such programmes will be greatly influenced by the location and extent of the land to be set aside. Environmental Sensitive Areas such as the South Downs and Breckland are already being used to target voluntary set-aside, and a wider scheme to encourage 20% voluntary set-aside is under discussion. Dr Burnham and Professor Green of Wye College have proposed criteria for the selection of target areas for set-aside during a recently completed research programme funded by the ESRC. Dr Potter and Dr Gasson have devised a questionnaire centring on attitudes to set-aside which has been the basis of 150 interviews with farmers.

It is recognised that the present project is to develop the approach, which can be made more precise when more detailed soil information for individual squares is available.

3. THE WORK PROGRAMME

i). A farmer survey of attitudes to set-aside using Potter and Gasson's questionnaire in the sample squares of land classes 10 and 11 (considered to be particularly susceptible to land use change).

ii). The 'Environmental Opportunities' evaluation forming part of the Wye College methodology includes an assessment of potential vegetation. This methodology would be applied to the 256 sample squares using soil association maps and other available data.

For England and Wales soil series of significant extent have been allocated to one of 16 edaphic groups and this will be extended to Scotland. Four climatic groups have also been recognised, but others would need to be established to cover Scotland adequately.

The approximate total extent of edaphic/climatic groups in the country would be determined and a weight assigned to each in terms of scarcity. The edaphic/climatic combinations present in significant extent each of the 256 squares would be predicted. An index of potential ecological interest taking both diversity and scarcity into account would be computed for each square.

iii). The 'Environmental Hazards' evaluation in the methodology would be exemplified by identifying the approximate incidence within the 256 sample squares of areas vulnerable to soil erosion by water and wind and nitrate pollution of aquifier.

iv). The 'Mismatch' evaluation in the methodology would be applied to the 256 sample squares using land utilisation data supplied for the squares by ITE and comparing the extent of arable cropping with categorisation of the square in terms of grades of the Agricultural Land Classification (England and Wales) and the equivalent Land Use Capability Classes (Scotland).

v). Production of a report summarising the approach adopted and the findings.