INSTITUTE OF TERRESTRIAL ECOLOGY

(NATURAL ENVIRONMENT RESEARCH COUNCIL)

ITE Project T02074c5

SNH Project SNH/054/94/CSA

BIOGEOGRAPHICAL ZONES IN SCOTLAND

P D Carey, J C M Dring, M O Hill, C D Preston and S M Wright

Institute of Terrestrial Ecology
Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

January 1994

CONTENTS

SUMMARY

1 Methods for identifying biogeographical zones in Scotland were developed in a pilot study and applied to the liverworts. This report describes the extension of the work to other groups and the integration of the results to produce a set of zones based on all groups. The work was jointly funded by the Institute of Terrestrial Ecology and Scottish Natural Heritage.

2 Species distribution data and environmental data for 10km squares were used in the study. Species data were obtained for seven groups of organisms (breeding birds, diurnal insects, molluscs, two randomly selected groups of vascular plants, mosses and liverworts). The environmental data included twelve climate variables, three altitude variables and the percentage of sea in the square.

3 Each of the species groups was analysed seperately. Data were analysed by detrended canonical correspondence analysis, and ten zones were defined by k–means clustering of the resulting 4–axis ordination, defined by linear combinations of environmental variables. The groups of 4–axis ordinations were combined in one file consisting of 24 axes. K–means clustering was employed to create 10 groups from the 24 axes. The similarity of the zones based on all groups to those for individual groups was assessed by a simple similarity index. Characteristic species were identified for each zone by calculating the contribution of each species to a contingency table chi–square.

4 Biogeographical zones based on all groups are mapped and briefly described. Ten characteristic species are identified for each zone and their distribution in Scotland is mapped. The mean and range of environmental variables in each zone is tabulated.

5 Biogeographical zones are mapped for the individual species groups studied. The similarity index values are tabulated to give a measure of the similarity of the zones to those recognised for all groups, and the position of the zones on the first two axes of the ordination is plotted to provide a measure of their resemblance to each other. Five characteristic species are identified for each zone.

6 There is a broad correspondence between the results of the analysis for different groups. Some of the differences appear to result from biological differences between the groups and others from the fact that similar areas are apportioned in different ways for different groups. The results are least satisfactory for areas where the smaller species groups have low diversity.

1 INTRODUCTION

In this report we demonstrate that the method that we developed in an earlier report (Carey *et al.* 1993) to identify biogeographic zones in Scotland using liverwort distributions was applicable to other taxonomic groups. We also demonstrate that biogeographic zones for Scotland can be produced by combining the biogeographic zones of different taxonomic groups. The work has been jointly funded by the Institute of Terrestrial Ecology and Scottish Natural Heritage.

2 OBJECTIVES

1 Define biogeographic zones for 6 taxonomic groups:
- breeding birds
- diurnal insects
- molluscs
- vascular plants
- mosses
- liverworts

2 Identify indicator species of each zone in each taxonomic group.

3 Define biogeographic zones for Scotland by combining the results from the 6 different taxonomic groups.

4 Identify the indicator species in those zones.

5 Identify the environmental parameters typical of each zone.

3 AVAILABILITY OF DATA

Species distribution data

The distribution data used are held by the Biological Records Centre as tables in the ORACLE database management system. The 10km squares of the National Grid provide an appropriate scale for this analysis, and records in the database were therefore extracted as 10km square summaries. The species of each taxonomic group used in the analysis are given in Appendix 1. All records of these taxa were taken into account, irrespective of date. Data were exported from the database in Cornell condensed format.

Distribution data were extracted for the following taxonomic groups. Unless stated, all available Scottish records from the group were used to define the zones.

Birds: breeding bird data. Coastal species were excluded to avoid an undue bias towards the coastal zone.

Diurnal insects: data for Lepidoptera, Orthoptera and Odonata were combined to give a group of diurnal insects.

Molluscs.

Vascular plants: two randomly selected groups of 200 native or long-established vascular plants were used in the analysis. The species for the second group were selected from those vascular plants which had not been selected for the first group, so the groups do not have any species in common.

Mosses: a randomly selected group of 200 mosses was used in the analysis.

Liverworts.

The data for birds and molluscs are those mapped by Sharrock (1976) and Kerney (1976) respectively; those for liverworts and mosses are those mapped by Hill, Preston & Smith (1991, 1992, 1994) with minor updates; those for Lepidoptera are those mapped by Heath, Pollard & Thomas (1984) with minor updates; those for Odonata and Orthoptera are those datasets assembled for publication in forthcoming atlases; earlier distribution maps of these taxa have been published by Marshall & Haes (1988) and Hammond (1983) respectively. The data for vascular plants are based on those published by Perring & Walters (1962) but have been extensively updated.

Environmental data

In the pilot study (Carey *et al.* 1993) we indicated that the climate data set we had used was on an unsatisfactory 40km grid. For this study we were able to use twelve variables from a new 10km climate data set for the period 1961–1990 provided by the Meteorological Office via the Climate Research Unit under the Terrestrial Initiative in Global Environmental Research (TIGER). Three altitude variables and the percentage of sea in the 10km square were taken from the Natlac database (Ball, Radford & Williams 1983). The sixteen variables used in the analysis were:

Mean minimum January temperature at low altitude
Mean minimum January temperature at high altitude
Mean maximum July temperature at low altitude
Mean maximum July temperature at high altitude
Mean annual precipitation at low altitude
Mean annual precipitation at high altitude
Mean total number of sunshine hours per year at low altitude
Mean total number of sunshine hours per year at high altitude
Mean average relative humidity at low altitude
Mean average relative humidity at high altitude
Mean number of rain days per year at low altitude
Mean number of rain days per year at high altitude
High spot (in metres)
Mean altitude (in metres)
Low spot (in metres)
Percentage of sea in square

The low altitude and high altitude values are for the lowest and highest altitudes in the 10km square.

4 METHODS

Stage 1: Detrended canonical correspondence analysis (DCCA)

Each 10km square was classified according to whether it was well recorded or under-recorded. Squares with fewer than 10% of the total number of species in the taxonomic group were assigned to the under-recorded category and given a notional weight of 0.001 (effectively zero) in the subsequent analysis. Of the total of 1125 10km squares, 1050 were well recorded squares for birds, 718 were well recorded squares for diurnal insects, 546 were well recorded squares for liverworts, 620 were well recorded squares for molluscs, 649 were well recorded squares for mosses, 1002 were well recorded squares for vascular plants (set 1) and 992 were well recorded squares for vascular plant (set 2). In order to ensure that every square had at least one species, a dummy species was added to the analysis. This was also given weight 0.001.

The data were then analyzed by DCCA with detrending by segments (Ter Braak 1986,1988) and the 4-axis environmental ordination was used in further analysis. Effectively, the species data were used to "train" the environmental analysis in a very similar way to that used in multiple discriminant analysis (also known as canonical variates analysis). In that case a disjoint partition of the data is used to derive discriminant functions which predict the given partition as well as possible. In this case, canonical variables are derived so as to predict the occurrence of species as well as possible.

Because environmental data were available for all squares, the further analysis was not restricted to those squares which were well recorded for species. The squares with good data were used to select new, derived environmental variables, but these variables were well-defined for all squares.

Stage 2: k-means clustering

The 4-axis ordination obtained in stage 1 was clustered to 10 groups by a k-means (minimum variance) clustering algorithm, using a computer program written by Moss (1985). The hierarchical clustering used in the pilot study proved unecessary in this study as the 10 groups obtained by k-means clustering were usually more or less contiguous. The separation of the ten groups was demonstrated by plotting the position of each group in two dimensional space with principal axis 1 as one dimension and principal axis 2 as the second dimension. Groups are, of course, also separated by the third and fourth axis but these are less significant and have been omitted for simplicity. Groups appearing close together will be similar whilst those well separated will not. Our aim in this study was to get groups which were well separated.

A dissection algorithm such as k-means clustering will always produce clusters; for k-means the number of clusters is specified in advance. The fact these clusters can be defined numerically does not guarantee that they are in any way "real", nor that their boundaries correspond to discontinuities in the data. Indeed, for some initial configurations (e.g. for raisins in a fruit cake), there may be multiple optima for k-means clustering. So far as we know, the clusterings derived here did not have multiple optima. However, even without this

possibility, relatively small differences in the configuration of points in ordination space can produce discontinuous changes in the resulting classifications. Thus, the fact that a given class appears different when derived from differing ordinations does not guarantee that the ordinations are themselves markedly different. The correct way to study differences between ordinations is by Procrustes analysis (Digby & Kempton 1987, Chapter 4), not by comparing clusterings that are based on them.

Stage 3: reporting on characteristic species

The "characteristicness" of a species was graded according to its contribution to the contingency-table chi-square. Specifically, for a given species and class, its observed frequency in the group, o, is compared with its expected frequency e, which is defined as its frequency in the non-zero-weighted squares (its observed value o is also restricted to non-zero-weighted squares). Then the preference

$$P= (o-e)* abs(o-e)/e$$

which is related to X the contribution to chi-square by the relation

$$X=abs(np)$$

where n is the number of non-zero-weighted squares in the class. note that this chi-square is calculated just for the presences and absences of the given species in the 10 classes, and is not the chi-square for the two-way contingency-table consisting of the occurrence of all species in all classes. The reason for using P rather than X is that P does not depend on the group size and can therefore be used to compare the degree of preference of species to large and small groups.

The ten species with the highest preference index were selected as the characteristic species for the zones based on all taxonomic groups, provided that they were present in at least 10% of the 10km squares in that zone. The five species with the highest preference index have been chosen as the characteristic species for the zones based on a single taxonomic group, irrespective of their frequency in that zone. All the moss species in Scotland have been used to select the characteristic species of the moss zones and the zones based on all taxonomic groups, even though these zones were defined using a sample of 200 mosses. The characteristic species of the two sets of zones based on vascular plants were drawn solely from the species used to define those zones; both groups of 200 species were pooled to provide characteristic species for the zones based on all taxonomic groups.

Stage 4: k-means clustering to create biogeographic zones based on all taxonomic groups

The six groups of 4-axis ordinations were combined into one file consisting of 24 axes (only one of the two sets of vascular plants was selected for this file). K-means clustering was employed to create 10 groups from the 24 axes.

Stage 5: reporting on the charactieristic species of each zone

The same method that was used in stage 3 was employed to determine the characteristic species of each zone of the amalgamated map. Each taxonomic group was analysed separately and the ten species with the highest preference for each zone and a frequency in that zone of at least 10% were chosen, irrespective of taxonomic group. The species with low frequencies

were eliminated as there are usually numerous species with a high preference for each zone and it is is more realistic to list characteristic species with a high frequency rather than extreme rarities with a marginally higher preference index. The species excluded on these grounds are noted in the text below.

Stage 6: testing the similarity between zones from each taxonomic group with zones from all taxonomic groups

A simple Pascal program was created to test the similarity between the biogeographic zones for each taxonomic group and the final biogeographic zones created from all groups. The similarity index S was calculated:

$$S = 2C/ (a_1 + a_2)$$

where C is the number of 10km squares in common between zone a_1 and zone a_2. The index S which varies from 0 (no similarity) to 1 (identical) was calculated for each pairwise interaction between the ten zones of a taxonomic group and the ten zones of the map created from all the taxonomic groups to give a total of 100 values for each table.

5 LIST OF THE ZONES

The ten zones defined from a combination of all taxonomic groups have been numbered 1.0, 2.0, 3.0 etc. In most cases the zones defined in the analyses of individual taxonomic groups can be equated with one of the zones and they have therefore been given the same number. In some cases a zone defined for a particular taxonomic group is clearly not equivalent to one of the main zones; these have been numbered 1.1, 2.1 etc. where 1.0, 2.0 etc. are the most similar zones derived from the analysis of all groups. For example, a Southern Inland zone defined for diurnal insects has been numbered 2.1 as it is related to the High Southern Upland and Highland Fringe zone (2.0) defined for all taxonomic groups.

The zones are listed below; those recognised in the analysis of all taxonomic groups are in bold. Each zone has been allocated a particular colour which is used on all the maps on which it appears.

1.0 Central Highland zone

1.1 Western Highland and Southern Upland zone

1.2 Southern Upland and Eastern Upland zone

2.0 High Southern Upland and Highland Fringe zone

2.1 Southern Inland zone

3.0 Western Mainland zone

3.1 Western Mainland (East) zone

4.0 Northern Isles zone

5.0 Western Isles zone

6.0 Southern Isles zone

7.0 Caithness and Sutherland zone

8.0 Buchan zone

8.1 East coast zone

9.0 Southern Lowland zone

10.0 Southern Coast zone

10.1 Galloway zone

6 ZONES DEFINED ON THE BASIS OF ALL GROUPS

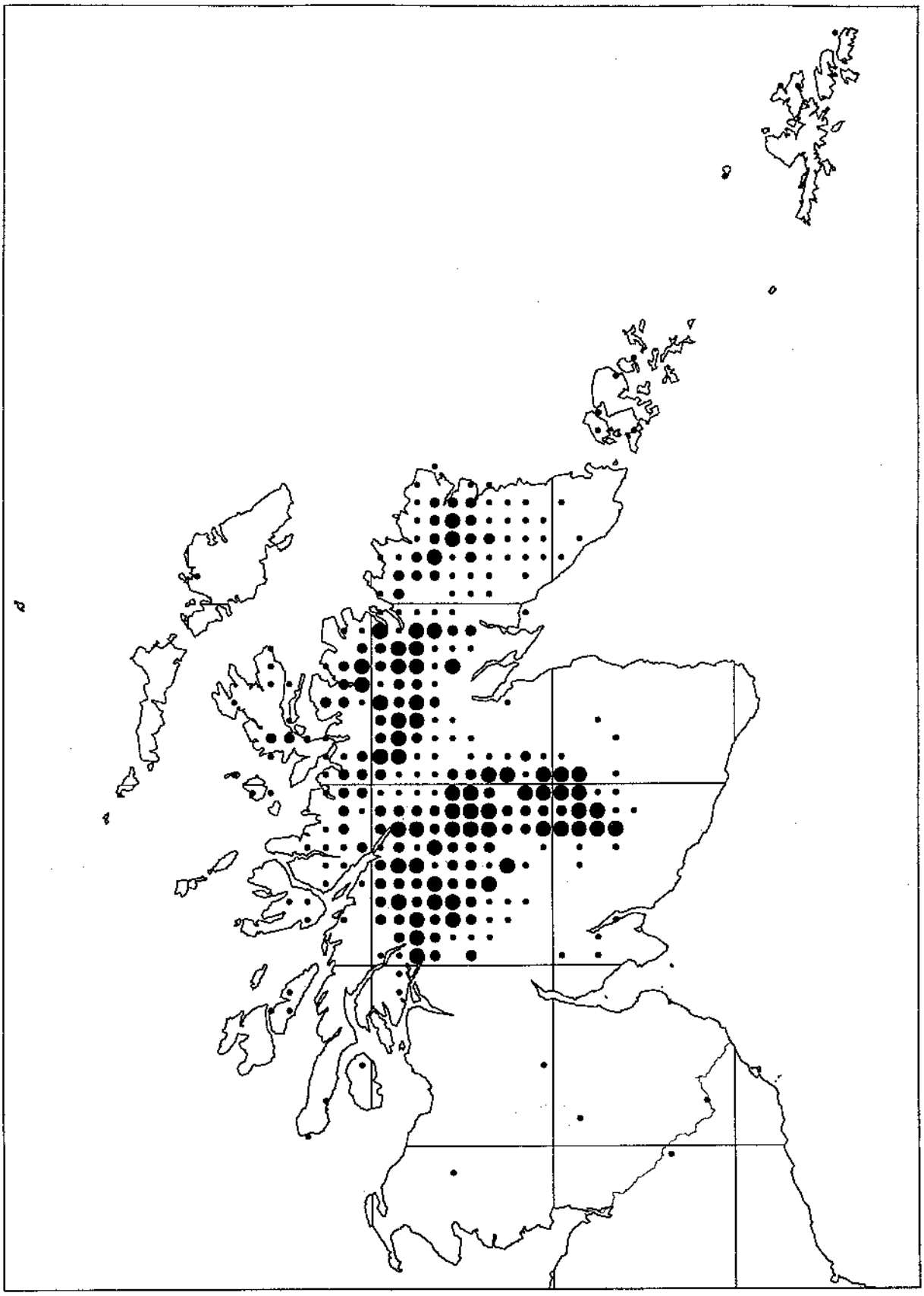
The zones are mapped on the accompanying map. Each of the zones is described briefly below. The characteristic species of each zone are also tabulated together with their preference index and their frequency in the 10km squares of the zone. Species which have not been selected as characteristic species solely because of their low frequency in the zone are noted. The environmental data for the zones are summarised in two tables.

1.0 Central Highland zone

This zone has a substantially higher mean altitude than the others and is characterised by birds, vascular plants and bryophytes associated with the alpine zone. The characteristic species vary from those such as Salix lapponum which are found in the mountains but do not reach the highest altitudes, to those like Ptarmigan and Juncus trifidus which are typical of higher and more windswept ground; the three bryophytes in the list are particularly characteristic of late snow-beds. All the species are confined to Scotland in Britain or are much commoner there than elsewhere; none are found in Ireland. They all have arctic-alpine distributions in Europe.

Species		Preference index	Frequency %
Salix lapponum		3.05	63
Lagopus mutus	*Ptarmigan*	2.81	91
Gnaphalium supinum		2.52	76
Loiseleuria procumbens		2.50	74
Vaccinium uliginosum		2.43	82
Kiaeria starkei		2.43	50
Moerckia blyttii		2.41	51
Betula nana		2.40	65
Juncus trifidus		2.35	74
Pohlia ludwigii		2.20	46

Central Highland zone



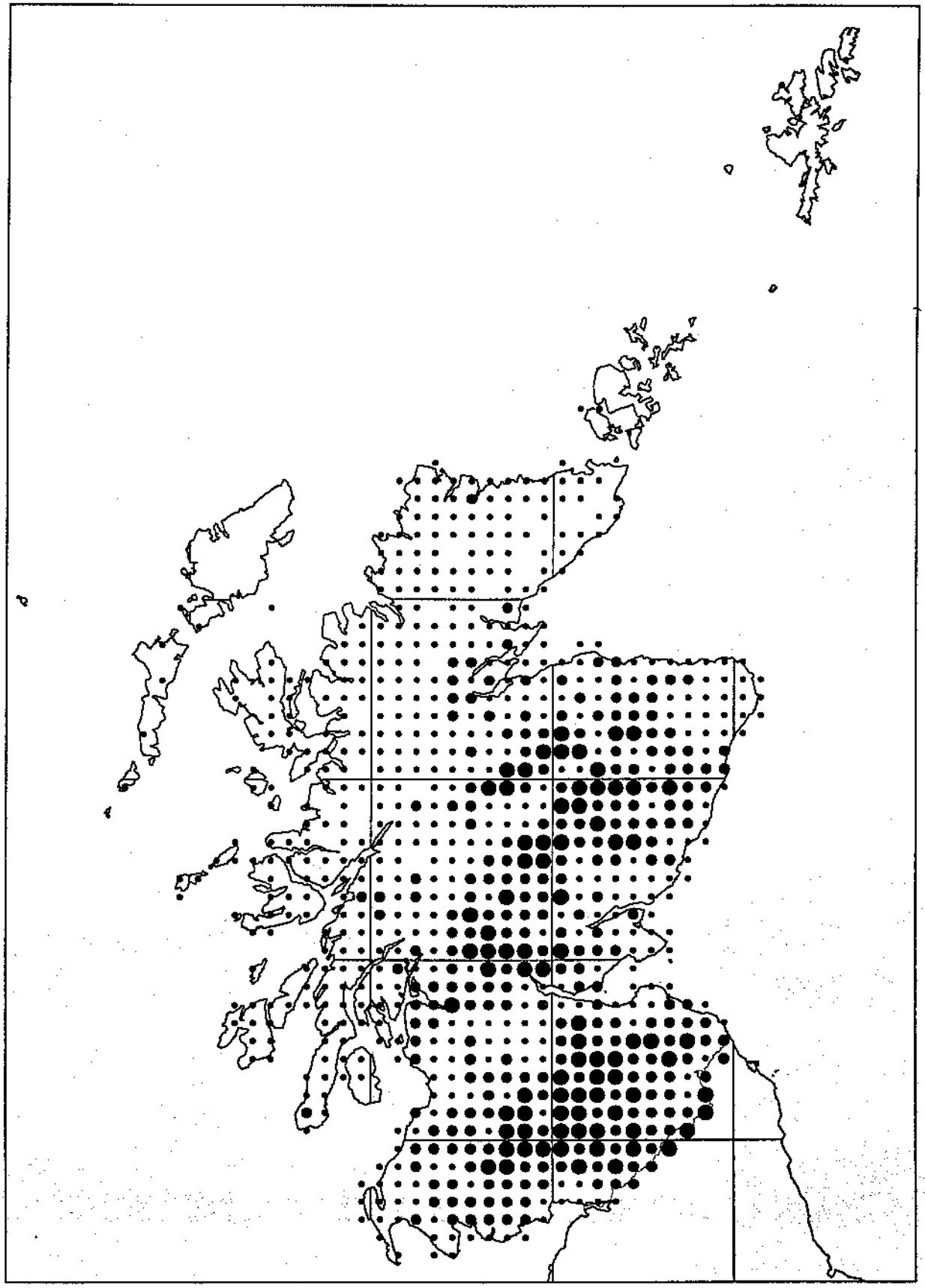
Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium-sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

2.0 High Southern Upland and Highland Fringe zone

This is primarily a zone of upland but not alpine country. The preference index values are lower than those of any other zone, suggesting that the area is defined as much by the species that are absent from it as by those that are present. The most characteristic species, Black Grouse, has a strong affinity with this zone even when its distribution in the British Isles as a whole is considered, and the Capercaillie and Sedum villosum are similarly associated with the Southern Uplands and the eastern highlands respectively. The remaining species are a rather heterogeneous group which includes widespread upland taxa (Ring Ouzel, Viola lutea) and species which are widespread in England but have an eastern distribution in Scotland (Grey Partridge, Orange Tip, Pimpinella saxifraga).

Species		Preference index	Frequency %
Tetrao tetrix	*Black Grouse*	0.63	91
Sedum villosum		0.59	48
Viola lutea		0.48	55
Pimpinella saxifraga		0.41	61
Perdix perdix	*Grey Partridge*	0.35	86
Turdus torquatus	*Ring Ouzel*	0.31	82
Galium uliginosum		0.28	53
Dicranum spurium		0.28	14
Anthocharis cardamines	*Orange Tip*	0.28	46
Tetrao urogallus	*Capercaillie*	0.27	39

High Southern Upland and Highland Fringe zone



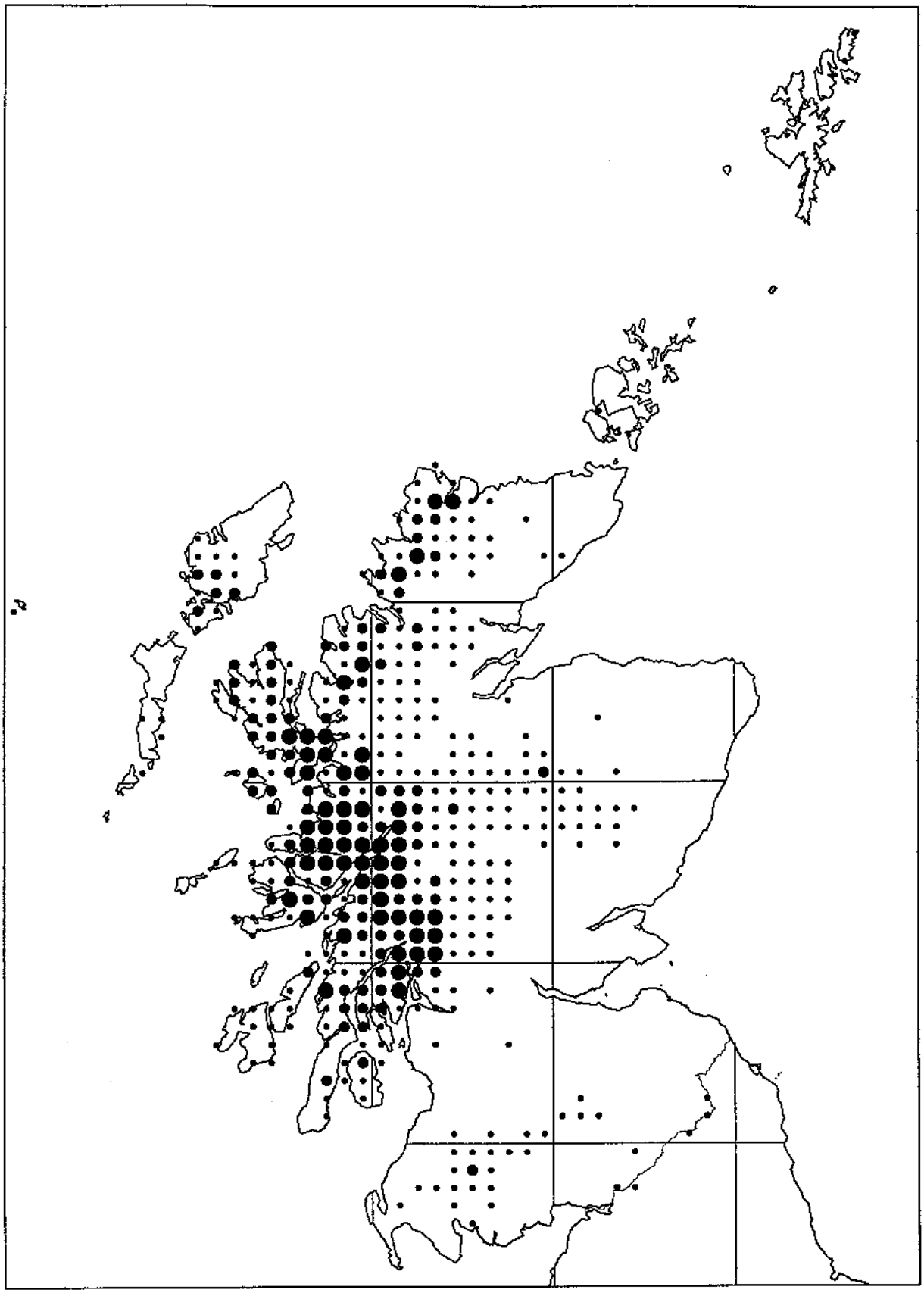
Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium–sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

3.0 Western Mainland zone

This western zone is an area of high relief and high rainfall. It is primarily a mainland zone but it also includes much of Skye and the mountains on Mull and Arran. Eight of the characteristic species are bryophytes, which (unlike the other taxonomic groups included in the analysis) become more numerous and ecologically more significant in the north and west. The bryophytes range from those which are widespread in western Europe (e.g. Hylocomium brevirostre) to those with strictly Atlantic distributions (e.g. Leptoscyphus cuneifolius). The two remaining species are the Chequered Skipper, which rather surprisingly in view of its somewhat continental distribution in Europe has its only remaining colonies in the British Isles in this area, and the Ptarmigan, which descends to lower levels in this area than in the more easterly mountains.

Species		Preference index	Frequency %
Leptoscyphus cuneifolius		0.94	52
Carterocephalus palaemon	*Chequered Skipper*	0.83	18
Lagopus mutus	*Ptarmigan*	0.83	58
Hylocomium brevirostre		0.81	86
Herbertus aduncus		0.81	70
Hylocomium umbratum		0.77	72
Sphagnum strictum		0.74	55
Sematophyllum micans		0.74	25
Rhabdoweisia crenulata		0.73	36
Plagiochila punctata		0.71	86

Western Mainland zone



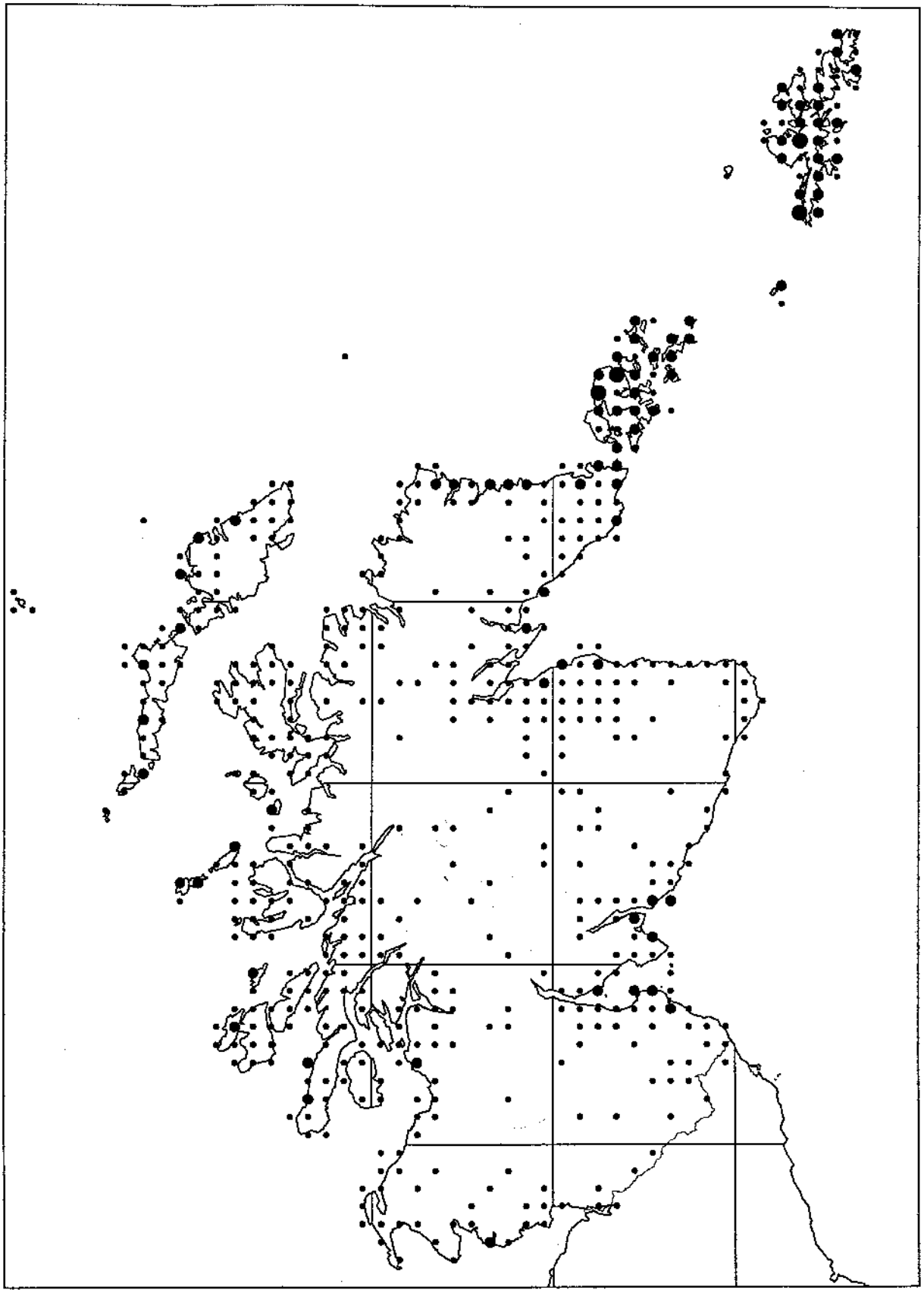
Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium–sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

4.0 Northern Isles zone

This zone encompasses most of Orkney and Shetland, as well as a few outlying squares on the north coast of Scottish mainland. Much the most characteristic species is Scilla verna, which is frequent and locally abundant in short, dry coastal heath. The remaining species are an ecologically diverse group, including other species of dry coastal habitats (Pupilla muscorum, Cerastium diffusum, Leymus arenarius), birds and bryophytes of heathland and moorland (Whimbrel, Campylopus brevipilus and Kurzia sylvatica), a moss of wet ground (Pseudobryum cinclidioides), an aquatic plant (Ranunculus baudotii) and a weed (Lamium confertum). Only three of these species (Whimbrel, Lamium confertum and Pseudobryum cinclidioides) have northern distributions in the British Isles as a whole.

Species		Preference index	Frequency %
Scilla verna		5.28	90
Campylopus brevipilus		1.79	78
Numenius phaeopus	*Whimbrel*	1.35	32
Pupilla muscorum		1.33	36
Kurzia sylvatica		1.13	33
Ranunculus baudotii		0.89	31
Pseudobryum cinclidioides		0.83	26
Leymus arenarius		0.81	48
Lamium confertum		0.80	59
Cerastium diffusum		0.74	81

Northern Isles zone



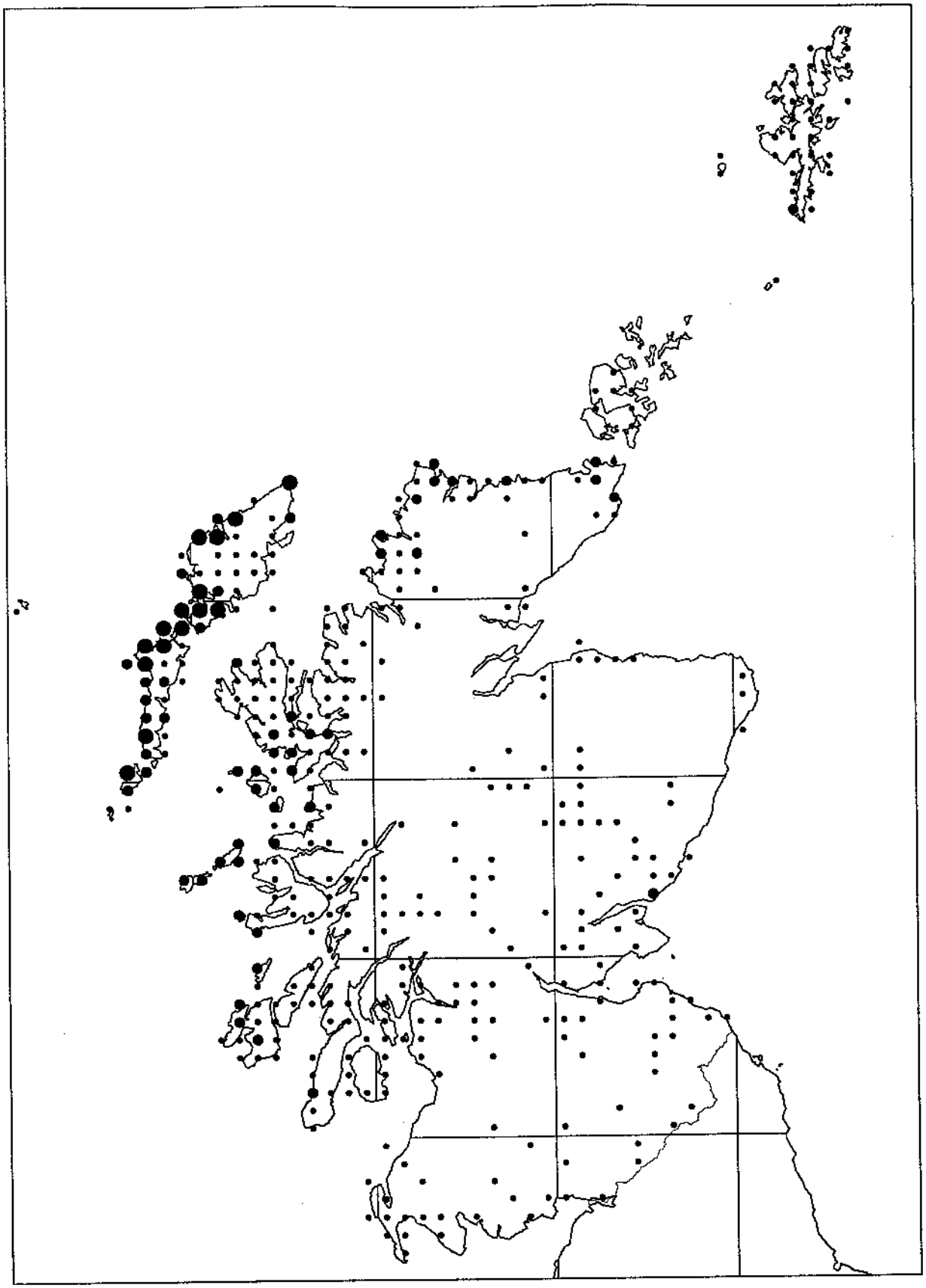
Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium–sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

5.0 Western Isles zone

The Western Isles zone not only encompasses the whole of the Outer Hebrides but also includes N.W. Skye and a few scattered squares elsewhere on the Atlantic fringe. The two most characteristic species are the mosses Campylopus shawii and Myurium hochstetteri (formerly M. hebridarum) which are much more frequent in the Outer Hebrides than elsewhere in the British Isles, unknown in mainland Europe but which are also found in Macaronesia (and, in the case of C. shawii, the Caribbean Islands!). Four of the remaining species, two molluscs (Cochlicella acuta and Helicella itala) and two mosses (Amblyodon dealbatus and Distichium inclinatum) are calcicoles which in the Hebrides are confined to coastal sands, and highlight the importance of this habitat.

Species	Preference index	Frequency %
Campylopus shawii	5.08	71
Myurium hochstetteri	4.99	63
Cochlicella acuta	4.00	77
Helicella itala	2.87	73
Fumaria bastardii	1.32	35
Osmunda regalis	1.16	54
Campylopus brevipilus	1.08	66
Amblyodon dealbatus	1.03	34
Distichium inclinatum	0.98	31
Drepanocladus aduncus	0.90	60

Western Isles zone



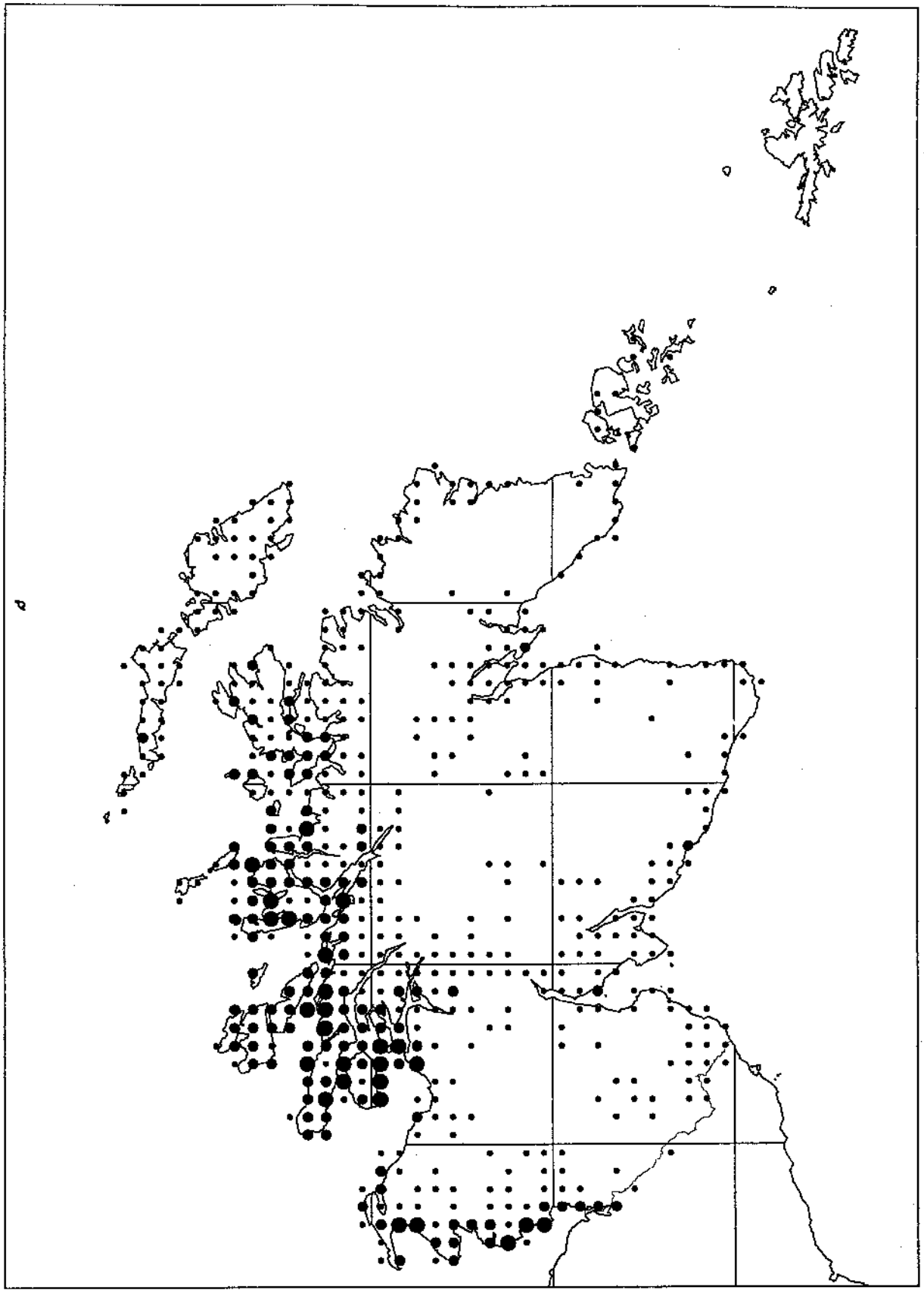
Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium–sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

6.0 Southern Isles zone

This zone includes most of the Inner Hebrides, including lowland Arran, Islay, Jura, lowland Mull, Coll, and Tiree; it also covers the adjacent mainland including the whole of Kintyre. Although most of Skye lies outwith it, the zone does extend in a narrow fringe along the mainland coast north of Skye as far as Point of Stoer. With the possible exception of Aster tripolium, all the characteristic species are more frequent in England and Wales than Scotland and it is interesting to note that at least five occur inland in England but in Scotland are confined to coastal habitats (Umbilicus rupestris, Oenanthe lachenalii, Scutellaria minor, Eupatorium cannabinum and Grayling). The predominantly southern affinities of this group are further demonstrated by the fact that no less than six of the ten characteristic species reach the northern limit of their world distribution on the west coast of Scotland (Umbilicus rupestris, Oenenthe lachenalii, Scutellaria minor, Jubula hutchinsiae, Juncus maritimus and Marchesinia mackaii).

Species		Preference index	Frequency %
Umbilicus rupestris		1.57	34
Oenanthe lachenalii		0.96	33
Aster tripolium		0.93	68
Scutellaria minor		0.91	41
Jubula hutchinsiae		0.87	37
Eupatorium cannabinum		0.84	50
Juncus maritimus		0.78	30
Scutellaria galericulata		0.77	85
Hipparchia semele	*Grayling*	0.66	69
Marchesinia mackaii		0.66	43

Southern Isles zone



Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium-sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

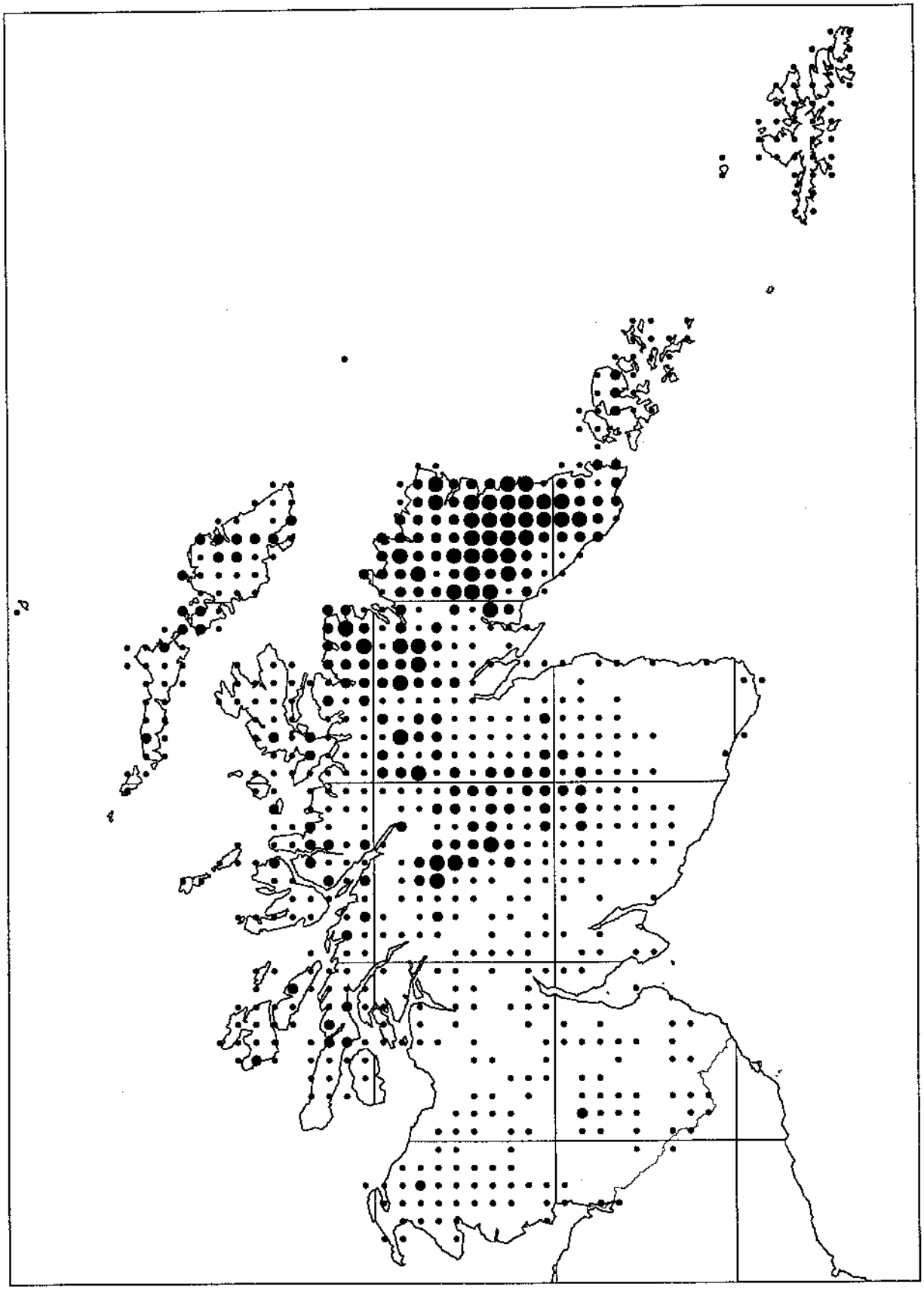
7.0 Caithness and Sutherland zone

This zone includes the peat-covered lowlands of N.E. Scotland, including the 'Flow Country'. The characteristic bird species are waders which breed on open moorland (Greenshank, Dunlin) or waterfowl of moorland lochs and streams (Black-throated Diver, Red-throated Diver, Wigeon). Not surprisingly in this area of extensive peatland, two of the characteristic species are sphagna found on deep peat-bogs; Betula nana is also a plant of peatland. The two remaining characteristic species have a different ecology: Ajuga pyramidalis is a plan of well-drained, species-rich heathland and Bryum violaceum is a weed of disturbed soil. The presence of the latter as a characteristic species of this zone probably reflects recording bias rather than ecological reality: the species was only described in 1963 and almost all the records from the area were made in Caithness on a British Bryological Society meeting when one member paid particular attention to the mosses of oatfields (Long 1975).

Species		Preference index	Frequency %
Ajuga pyramidalis		1.17	40
Tringa nebularia	*Greenshank*	1.15	77
Sphagnum imbricatum		1.03	65
Sphagnum fuscum		0.91	59
Gavia arctica	*Black-throated Diver*	0.74	59
Betula nana		0.53	37
Bryum violaceum		0.52	18
Gavia stellata	*Red-throated Diver*	0.48	67
Anas penelope	*Wigeon*	0.47	52
Calidris alpina	*Dunlin*	0.41	73

Petalophyllum ralfsii (preference index 0.73) and *Brachythecium erythrorrhizon* (preference index 0.50) were excluded from the above table because of their low frequency (4% and 3% respectively).

Caithness and Sutherland zone



Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium-sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

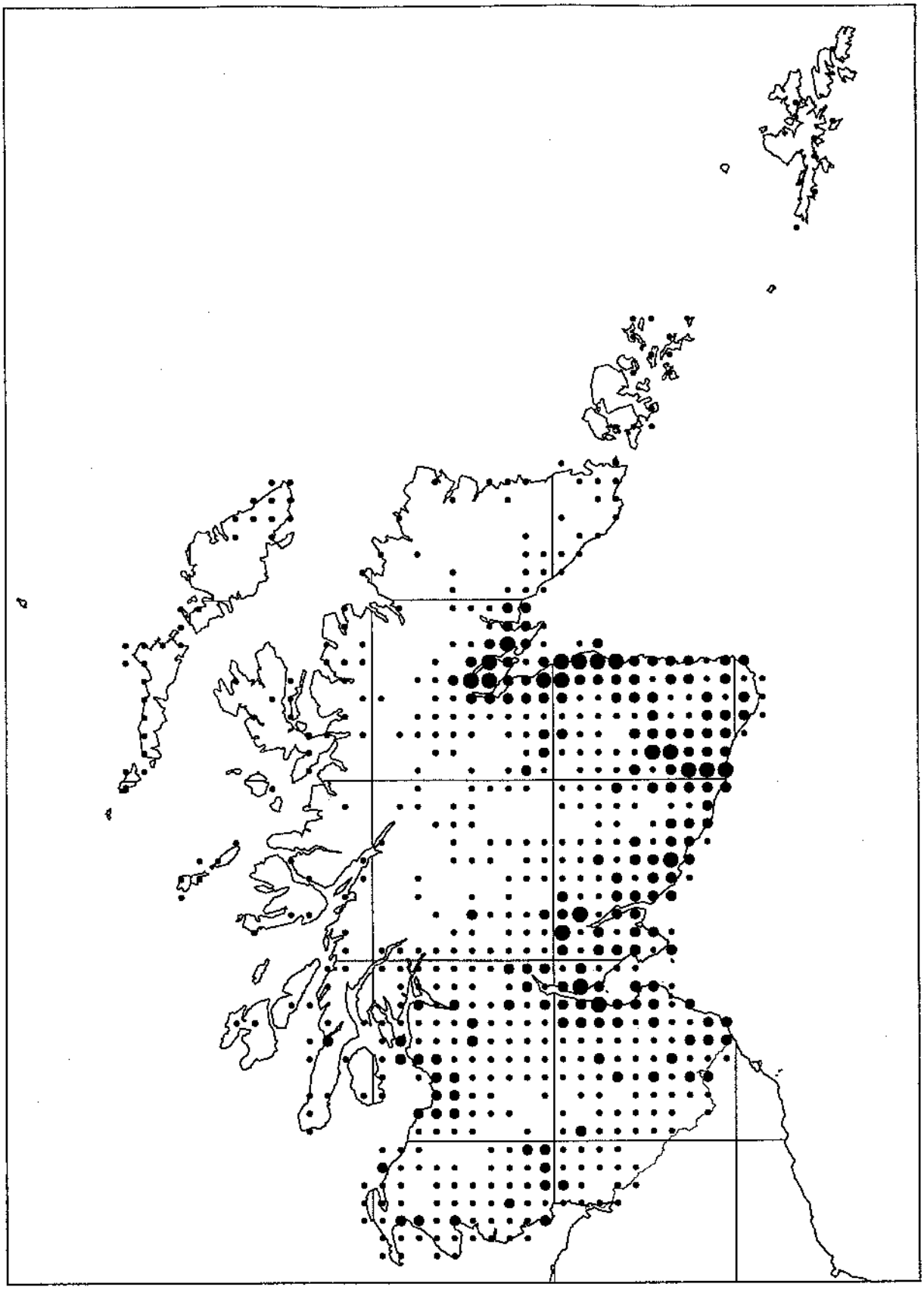
8.0 Buchan zone

This resembles the Caithness and Sutherland zone in being a low-lying eastern area but differs in that there are no extensive peatlands.The land-use is predominantly agricultural, with arable land predominating in many areas. Three of the four most characteristic species have a preference for farmland: Corn Bunting, Magpie and the arable weed Centaurea cyanus. Most of the records of Centaurea cyanus are old as the species has declined markedly in this area, as in other parts of the British Isles. More recently the Corn Bunting has also declined in this area, as elsewhere (Gibbons, Reid & Chapman 1993). These species are all more frequent in England than in Scotland, as are the three characteristic species which are coastal plants in this area although they occur inland elsewhere (Vicia lathyroides, Tortella inclinata and Pottia intermedia). Two of the other characteristic species, however, have boreal-montane and somewhat continental distributions (Linnaea borealis and Capercaillie); this is also true of Orthotrichum obtusifolium.

Species		Preference index	Frequency %
Miliaria calandra	*Corn Bunting*	1.12	95
Linnaea borealis		0.88	37
Pica pica	*Magpie*	0.83	73
Centaurea cyanus		0.80	33
Symphytum tuberosum		0.78	76
Senecio sylvaticus		0.70	77
Vicia lathyroides		0.68	31
Tortella inclinata		0.68	10
Tetrao urogallus	*Capercaillie*	0.67	51
Pottia intermedia		0.65	19

Orthotrichum obtusifolium (preference index 0.77) was excluded from the above table because of its low frequency (6%).

Buchan zone



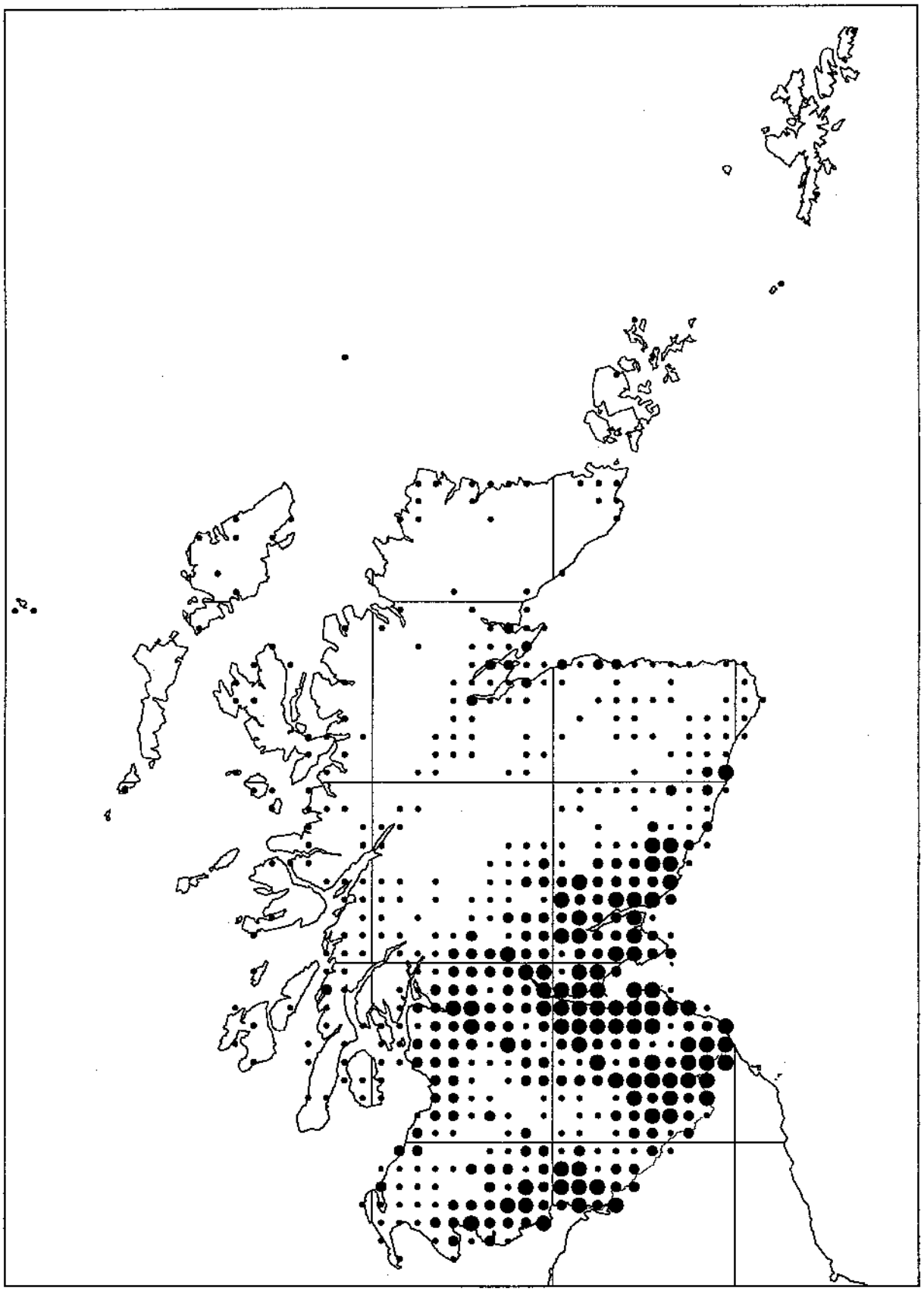
Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium-sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

9.0 Southern lowland zone

This zone and the next are two zones characterised by high July temperatures, high sunshine totals and low rainfall. The characteristic species of both zones have predominantly southerly distributions in Britain, and they tend to be frequent or even common in England and Wales. Some of the species characteristic of the Southern Lowland zone have a distinctly eastern bias, becoming rare in south-west England and west Wales (e.g. Tree Sparrow, Lophocolea heterophylla) but others are as frequent in the west as they are in the east (e.g. Garden Warbler, Alisma plantago-aquatica).

Species		Preference index	Frequency %
Picus viridis	*Green Woodpecker*	1.55	68
Alisma plantago-aquatica		1.19	73
Podiceps cristatus	*Great Crested Grebe*	1.09	44
Sylvia borin	*Garden Warbler*	1.09	84
Lophocolea heterophylla		1.01	65
Juncus inflexus		1.00	46
Rorippa palustris		1.00	48
Passer montanus	*Tree Sparrow*	0.98	85
Alliaria petiolata		0.92	70
Tragopogon pratensis		0.90	51

Southern Lowland zone



Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium–sized dots the presence of 4–6 species and small dots the presence of 1–3 species.

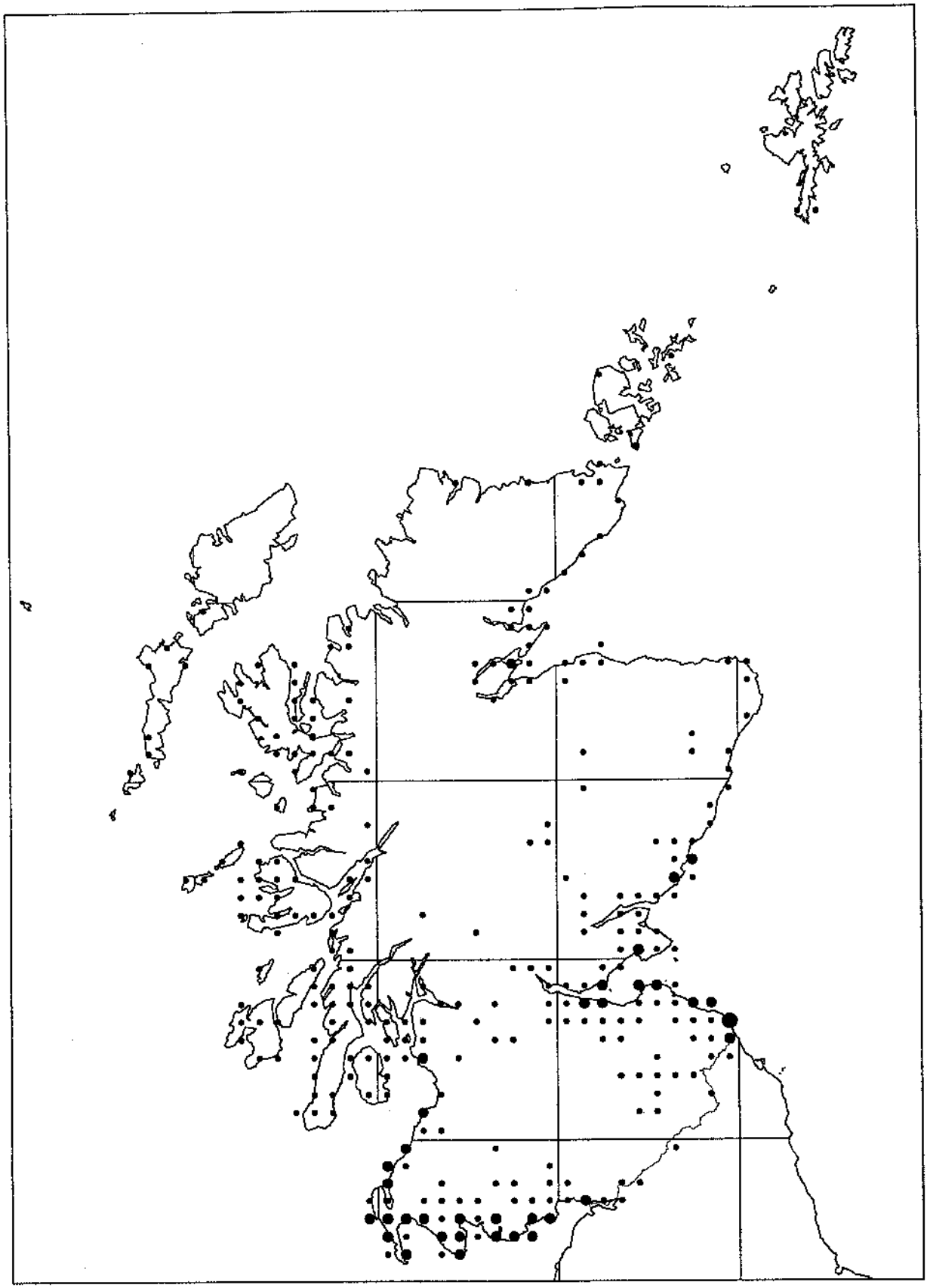
10.0 Southern Coast zone

As mentioned under the previous zone, this is one of two warm zones characterised by high July temperatures. The most significant environmental difference between this and the preceding zone is perhaps the higher January minimum temperature. The characteristic species of this zone include some which are coastal throughout their British range (Crambe maritima, Euphorbia paralias, Limonium vulgare) and others which are not particularly coastal in England and Wales but tend to become increasingly so further north (Fissidens incurvus, Lasiommata megera, Eupatorium cannabinum).

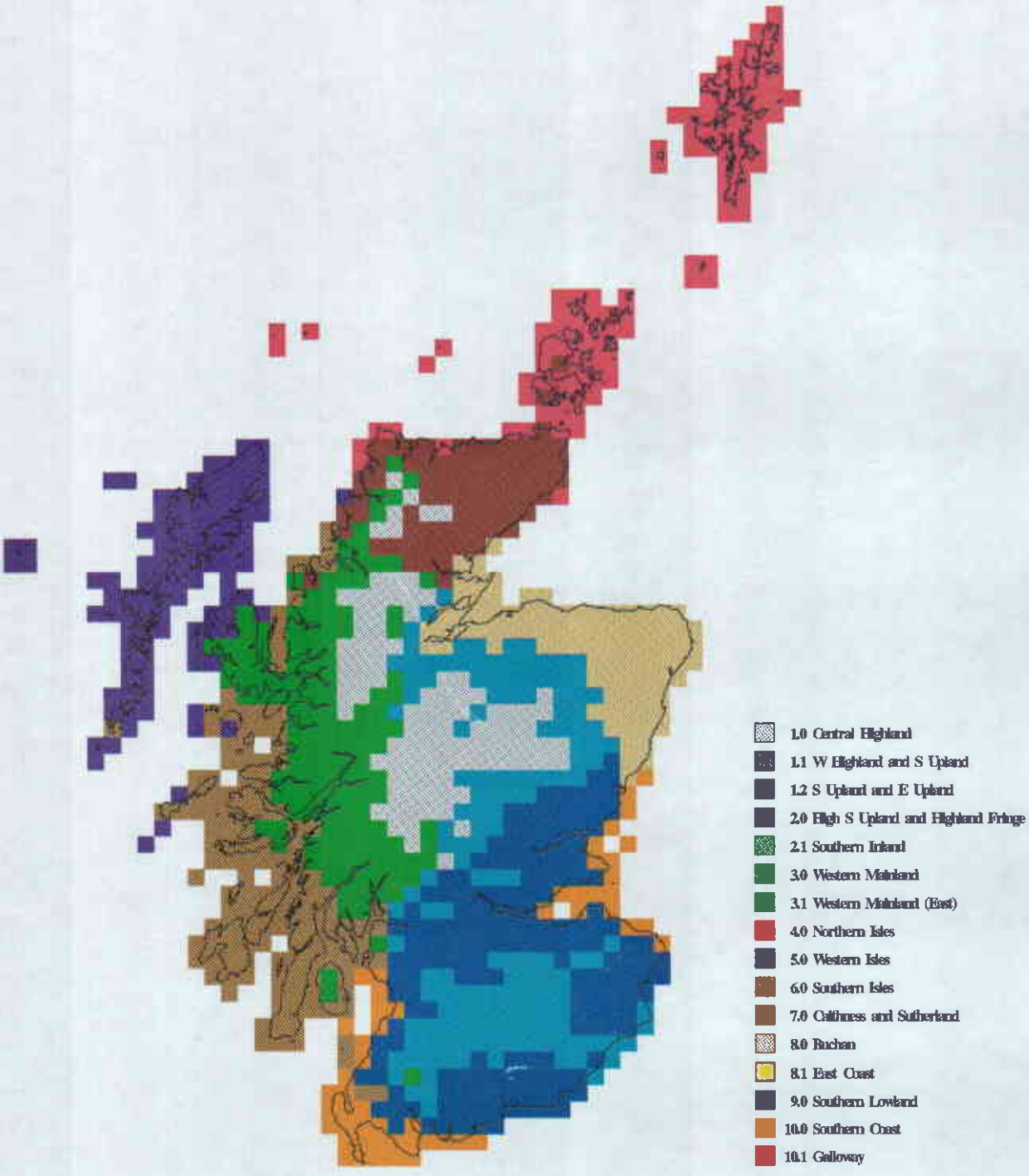
Species	Preference index	Frequency %
Fissidens incurvus	4.05	29
Crambe maritima	3.82	36
Geranium sanguineum	3.78	61
Pottia lanceolata	3.13	35
Euphorbia paralias	2.70	12
Limonium vulgare	2.62	18
Lasiommata megera *Wall*	2.54	59
Eupatorium cannabinum	2.50	76
Candidula intersecta	2.36	76
Pottia davalliana	2.36	29

Erodium maritimum (preference index 2.54) was excluded from the above table because of its low frequency (9%).

Southern Coast zone



Distribution of the ten most characteristic species of the zone. Large dots indicate the presence of 7–10 species, medium-sized dots the presence of 4–6 species and small dots the presence of 1–3 species.



Scottish Biogeographical Zones

		All	1	2	3	4	5	6	7	8	9	10
Mean minimum January temperature (°C)	mean	−1.0	−4.6	−2.8	−2.3	0.8	0.9	0.9	−0.6	−0.7	−0.8	1.1
	range	−7.0–3.4	−7.0–−2.1	−5.2–−0.1	−5.7–0.6	−0.9–2.5	−1.9–3.4	−0.8–3.1	−3.1–0.8	−2.5–1.0	−2.6–1.1	−0.2–2.7
Mean maximum July temperature (°C)	mean	14.4	11.6	14.5	12.3	13.7	14.1	14.8	13.5	16.0	16.7	17.0
	range	8.7–18.9	9.5–13.9	11.9–16.6	8.7–15.1	11.4–15.6	10.2–16.2	10.8–16.8	9.1–15.5	14.3–17.7	13.4–18.9	15.1–18.4
Mean annual precipitation (mm)	mean	1667	2376	1647	2839	1199	1747	1655	1426	927	1243	1002
	range	552–3896	1322–3838	1048–2839	1746–3896	766–1669	748–2680	952–3123	842–2513	552–1316	646–2469	589–1673
Mean total no. of sunshine hours per year	mean	1088	795	1059	860	1062	1194	1166	1061	1211	1232	1383
	range	595–1476	600–1066	785–1224	595–1137	879–1220	937–1400	971–1341	849–1211	947–1368	1071–1427	1252–1476
Mean average relative humidity (%)	mean	89	91	90	93	89	90	90	89	86	87	86
	range	82–96	88–94	87–95	87–96	86–93	87–96	85–95	86–93	83–88	83–95	82–91
Mean number of rain days per year	mean	270	329	274	326	264	283	269	273	220	228	204
	range	167–360	284–352	227–334	279–360	229–311	232–341	220–326	231–337	191–258	170–289	167–244
High spot (metres)	mean	440	979	637	757	147	231	297	398	232	319	127
	range	3–1344	671–1309	356–1083	269–1344	5–479	3–812	3–785	62–961	10–494	4–701	4–319
Mean altitude (metres)	mean	202	542	337	299	58	76	115	166	232	138	61
	range	31–882	313–882	113–553	115–532	31–268	31–358	31–336	31–319	10–494	31–326	31–162

Mean and range of environmental variables for Scotland (all zones) and for the individual zones (high altitude values).

		All	1	2	3	4	5	6	7	8	9	10
Mean minimum January temperature (°C)	mean	0.9	−0.9	−0.5	1.1	1.6	2.0	2.3	1.1	0.3	0.5	1.7
	range	−3.6–3.4	−3.6–1.8	−2.2–1.6	0.0–2.4	1.0–2.6	1.5–3.4	0.8–3.4	0.1–2.3	−1.0–1.2	−0.7–1.8	0.7–3.1
Mean maximum July temperature (°C)	mean	17.1	16.8	17.9	17.4	14.8	15.7	16.8	16.0	17.4	18.6	17.9
	range	13.9–19.3	14.8–18.6	16.6–19.1	15.5–18.5	13.9–16.3	14.8–16.7	15.6–18.1	15.1–17.1	16.3–18.2	17.2–19.3	16.8–19.0
Mean annual precipitation (mm)	mean	1285	1643	1163	2106	1052	1518	1363	1070	728	964	876
	range	514–3068	840–3068	671–2229	1136–2926	667–1358	738–2114	810–2886	595–1842	530–953	514–1811	544–1380
Mean total no. of sunshine hours per year	mean	1224	1052	1231	1119	1114	1276	1270	1187	1282	1331	1428
	range	904–1491	904–1291	1006–1390	979–1352	1019–1241	1159–1401	1107–1391	1062–1242	1092–1445	1210–1460	1337–1491
Mean average relative humidity (%)	mean	86	86	85	86	87	88	86	85	84	84	85
	range	82–90	84–89	83–89	83–88	85–89	85–90	83–89	83–87	82–87	82–88	82–88
Mean number of rain days per year	mean	222	242	211	238	245	254	230	226	193	191	187
	range	166–278	204–278	182–231	211–258	216–261	232–263	205–251	204–244	172–207	167–216	166–213
Low spot (metres)	mean	55	239	149	18	0	0.7	1.8	39	31	37	0.5
	range	0–580	0–580	0–301	0–126	0	0–60	0–137	0–180	0–183	0–183	0–26
Mean altitude (metres)	mean	202	542	337	299	58	76	115	166	232	138	61
	range	31–882	313–882	113–553	115–532	31–268	31–358	31–336	31–319	10–494	31–326	31–162
Amount of sea in square (%)	mean	28	0	0.1	11	75	61	61	12	24	5	71
	range	0–99	0	0–7	0–77	9–99	0–99	0–99	0–65	0–99	0–59	0–99

Mean and range of environmental variables for Scotland (all zones) and for the individual zones (low altitude values).

7 ZONES DEFINED ON THE BASIS OF A SINGLE GROUP

The zones based on single groups are outlined below. A brief introduction for each group compares the zones with those based on all groups. The characteristic species of each zone are tabulated together with their preference index and their frequency in the 10km squares of the zone. The similarity index S which compares the zones numerically is tabulated. S values of 0.5 or more are in bold type. The zones for each group are mapped and plotted on the first two axes of the ordination.

7.1 BIRD ZONES

The zones for birds are very similar to those based on all groups. The only substantial difference is the absence of the Buchan zone, which is present in all the other classifications. It is replaced by a zone which picks out the higher ground in the Southern Uplands and the eastern edge of the Highlands.

1.0 Central Highland zone

Species		Preference index	Frequency %
Charadrius morinellus	*Dotterel*	3.17	35
Lagopus mutus	*Ptarmigan*	2.56	88
Tringa nebularia	*Greenshank*	1.14	76
Plectrophenax nivalis	*Snow Bunting*	1.02	13
Turdus torquatus	*Ring Ouzel*	0.69	100

1.2 Southern Upland and Eastern Upland zone

Species		Preference index	Frequency %
Tetrao urogallus	*Capercaillie*	0.71	52
Loxia spp.	*Crossbill*	0.61	47
Tetrao tetrix	*Black Grouse*	0.38	80
Turdus iliacus	*Redwing*	0.36	30
Carduelis spinus	*Siskin*	0.33	88

2.0 High Southern Upland and Eastern Upland zone

Species		Preference index	Frequency %
Perdix perdix	*Grey Partridge*	0.50	94
Pica pica	*Magpie*	0.48	62
Tetrao tetrix	*Black Grouse*	0.47	84
Columba oenas	*Stock Dove*	0.44	73
Carduelis carduelis	*Goldfinch*	0.33	77

3.0 Western Mainland zone

Species		Preference index	Frequency %
Lagopus mutus	*Ptarmigan*	1.50	71
Aquila chrysaetos	*Golden Eagle*	0.57	82
Carduelis spinus	*Siskin*	0.39	91
Phylloscopus sibilatrix	*Wood Warbler*	0.35	68
Turdus torquatus	*Ring Ouzel*	0.29	80

4.0 Northern Isles zone

Species		Preference index	Frequency %
Numenius phaeopus	*Whimbrel*	2.43	41
Phalaropus lobatus	*Red-necked Phalarope*	0.99	13
Anthus petrosus	*Rock Pipit*	0.69	100
Gavia stellata	*Red-throated Diver*	0.51	68
Carduelis flavirostris	*Twite*	0.28	93

5.0 Western Isles zone

Species		Preference index	Frequency %
Anthus petrosus	*Rock Pipit*	0.41	87
Carduelis flavirostris	*Twite*	0.36	98
Pyrrhocorax pyrrhocorax	*Chough*	0.35	9
Gavia stellata	*Red-throated Diver*	0.26	57
Crex crex	*Corncrake*	0.19	65

6.0 Southern Isles zone

Species		Preference index	Frequency %
Anthus petrosus	*Rock Pipit*	0.53	93
Caprimulgus europaeus	*Nightjar*	0.23	16
Mergus serrator	*Red-breasted Merganser*	0.20	90
Sterna hirundo	*Common Tern*	0.19	70
Saxicola torquata	*Stonechat*	0.18	93

7.0 Caithness and Sutherland zone

Species		Preference index	Frequency %
Tringa nebularia	*Greenshank*	0.66	64
Gavia stellata	*Red-throated Diver*	0.52	69
Gavia arctica	*Black-throated Diver*	0.51	52
Carduelis flavirostris	*Twite*	0.32	96
Calidris alpina	*Dunlin*	0.18	60

9.0 Southern Lowland zone

Species		Preference index	Frequency %
Picus viridis	*Green Woodpecker*	1.66	70
Passer montanus	*Tree Sparrow*	1.04	87
Podiceps cristatus	*Great Crested Grebe*	1.01	42
Sylvia borin	*Garden Warbler*	0.97	81
Columba oenas	*Stock Dove*	0.88	89

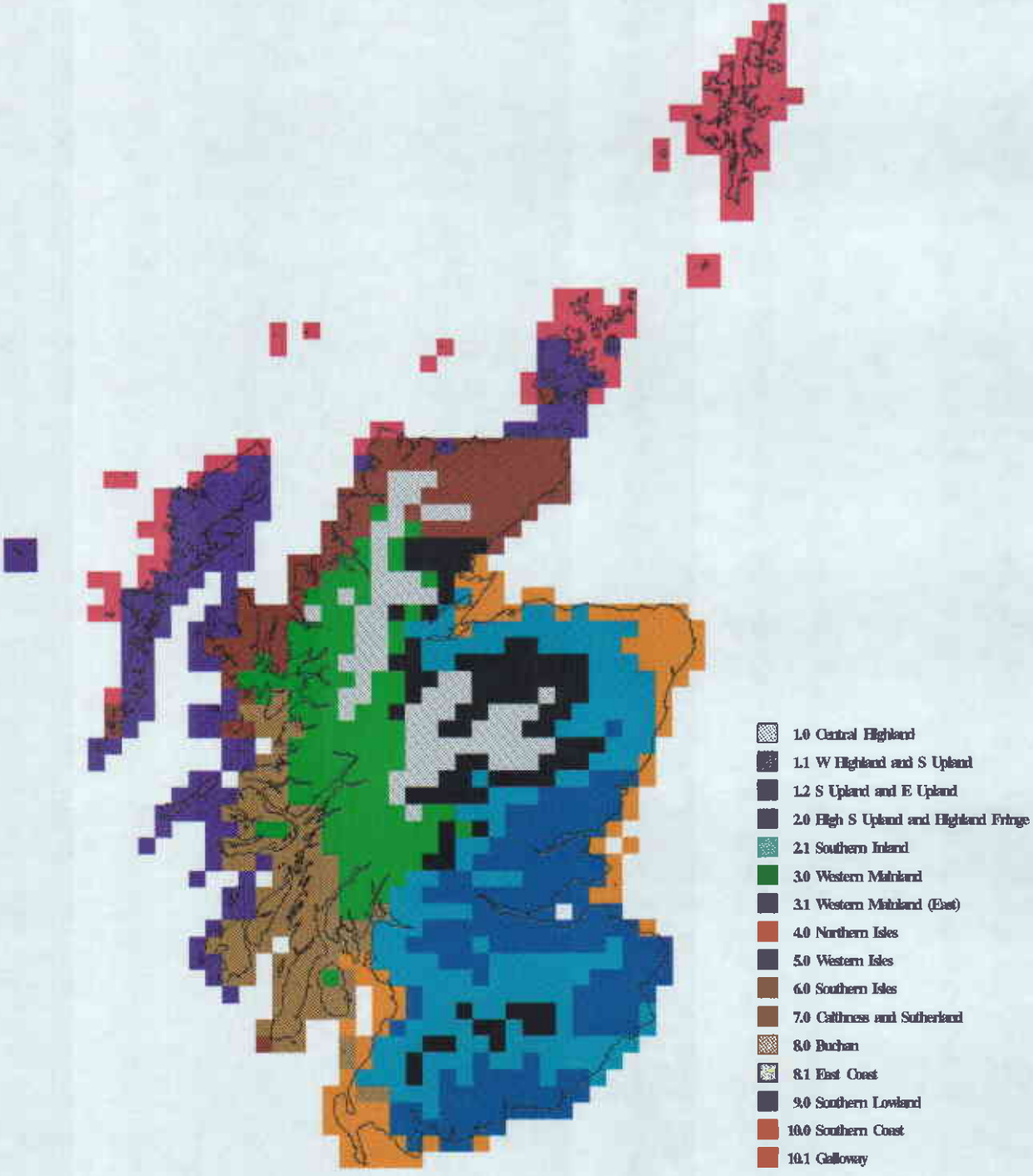
10.0 Southern Coast zone

Species		Preference index	Frequency %
Miliaria calandra	*Corn Bunting*	0.84	87
Pica pica	*Magpie*	0.42	60
Perdix perdix	*Grey Partridge*	0.42	90
Phasianus colchicus	*Pheasant*	0.23	97
Carduelis cannabina	*Linnet*	0.21	100

Main zone

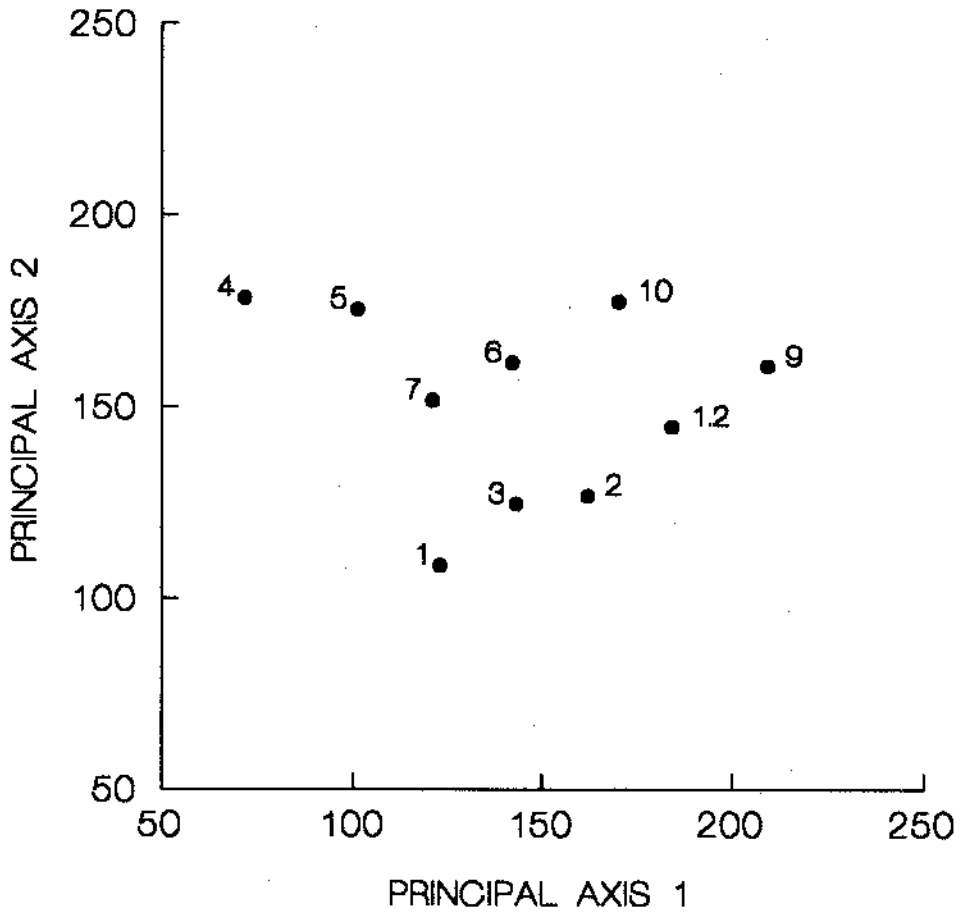
Bird zone	1	2	3	4	5	6	7	8	9	10
1	**0.76**	·	0.037	·	·	·	0.041	·	·	·
1.2	·	**0.58**	0.019	·	·	0.013	·	0.34	0.16	·
2	0.17	0.49	0.026	·	·	·	0.11	0.011	·	·
3	0.15	·	**0.78**	·	·	·	0.021	·	·	·
4	·	·	·	**0.80**	0.20	·	·	·	·	·
5	·	·	·	0.17	**0.66**	0.25	0.019	·	·	·
6	·	·	0.099	·	·	**0.74**	·	·	·	·
7	·	·	0.14	0.01	0.05	0.11	**0.68**	0.011	·	·
9	·	·	·	·	·	·	·	0.017	**0.86**	0.12
10	·	·	·	·	·	0.018	·	0.46	0.016	**0.6**

Table of similarity index (S) values.


1.0 Central Highland
1.1 W Highland and S Upland
1.2 S Upland and E Upland
2.0 High S Upland and Highland Fringe
2.1 Southern Inland
3.0 Western Mainland
3.1 Western Mainland (East)
4.0 Northern Isles
5.0 Western Isles
6.0 Southern Isles
7.0 Caithness and Sutherland
8.0 Buchan
8.1 East Coast
9.0 Southern Lowland
10.0 Southern Coast
10.1 Galloway

Birds

BIRDS


250
200
150
100
50
PRINCIPAL AXIS 2
4
5
10
6
9
7
12
3
2
1
50
100
150
200
250
PRINCIPAL AXIS 1

7.2 DIURNAL INSECT ZONES

The diurnal insects are the smallest of the groups which has been selected for study, despite the fact that to assemble it we have included representatives of three major taxonomic groups. This is reflected in the low preference index values for some of the zones. The zones themselves are similar to the zones based on all groups for northern and eastern Scotland, but differ considerably in the south and east of the country.

1.0 Central Highland zone

Species		Preference index	Frequency %
Aeshna caerulea		1.15	36
Erebia epiphron	*Mountain Ringlet*	1.14	25
Leucorrhinia dubia		1.00	23
Somatochlora arctica		0.81	27
Coenonympha tullia	*Large Heath*	0.26	77

2.1 Southern Inland zone

Species		Preference index	Frequency %
Coenagrion puella		0.22	22
Aphantopus hyperantus	*Ringlet*	0.19	43
Quercusia quercus	*Purple Hairstreak*	0.10	12
Pieris rapae	*Small White*	0.09	74
Anthocharis cardamines	*Orange Tip*	0.07	34

3.0 Western mainland zone

Species		Preference index	Frequency %
Carterocephalus palaemon	*Chequered Skipper*	0.69	17
Erebia aethiops	*Scotch Argus*	0.43	77
Calopteryx virgo		0.32	16
Somatochlora arctica		0.30	18
Cordulegaster boltonii		0.28	77

4.0 Northern Isles zone

Species		Preference index	Frequency %
Libellula quadrimaculata		0.89	97
Chorthippus brunneus		0.64	49
Aeshna juncea		0.40	97
Sympetrum striolatum		0.21	49
Hipparchia semele	*Grayling*	0.18	49

5.0 Western Isles zone

Species		Preference index	Frequency %
Coenonympha tullia		0.20	72
Sympetrum striolatum		0.14	44
Polyommatus icarus	*Common Blue*	0.07	98
Myrmeleotettix maculatus		0.04	33
Argynnis aglaja	*Dark Green Fritillary*	0.03	49

6.0 Southern Isles zone

Species		Preference index	Frequency %
Hipparchia semele	*Grayling*	0.51	64
Sympetrum striolatum		0.28	52
Orthetrum coerulescens		0.26	12
Pararge aegeria	*Speckled Wood*	0.17	31
Eurodryas aurinia	*Marsh Fritillary*	0.16	20

7.0 Caithness and Sutherland zone

Species		Preference index	Frequency %
Sympetrum striolatum		0.33	55
Sympetrum danae		0.23	79
Coenonympha tullia	*Large Heath*	0.18	71
Aeshna juncea		0.11	76
Chorthippus parallelus		0.07	42

8.0 Buchan zone

Species		Preference index	Frequency %
Anthocharis cardamines	*Orange Tip*	0.89	65
Coenagrion hastulatum		0.15	4
Aricia artaxerxes	*Northern Brown Argus*	0.14	28
Erynnis tages	*Dingy Skipper*	0.03	10
Boloria selene	*Small Pearl-bordered Fritillary*	0.03	48

8.1 East Coast zone

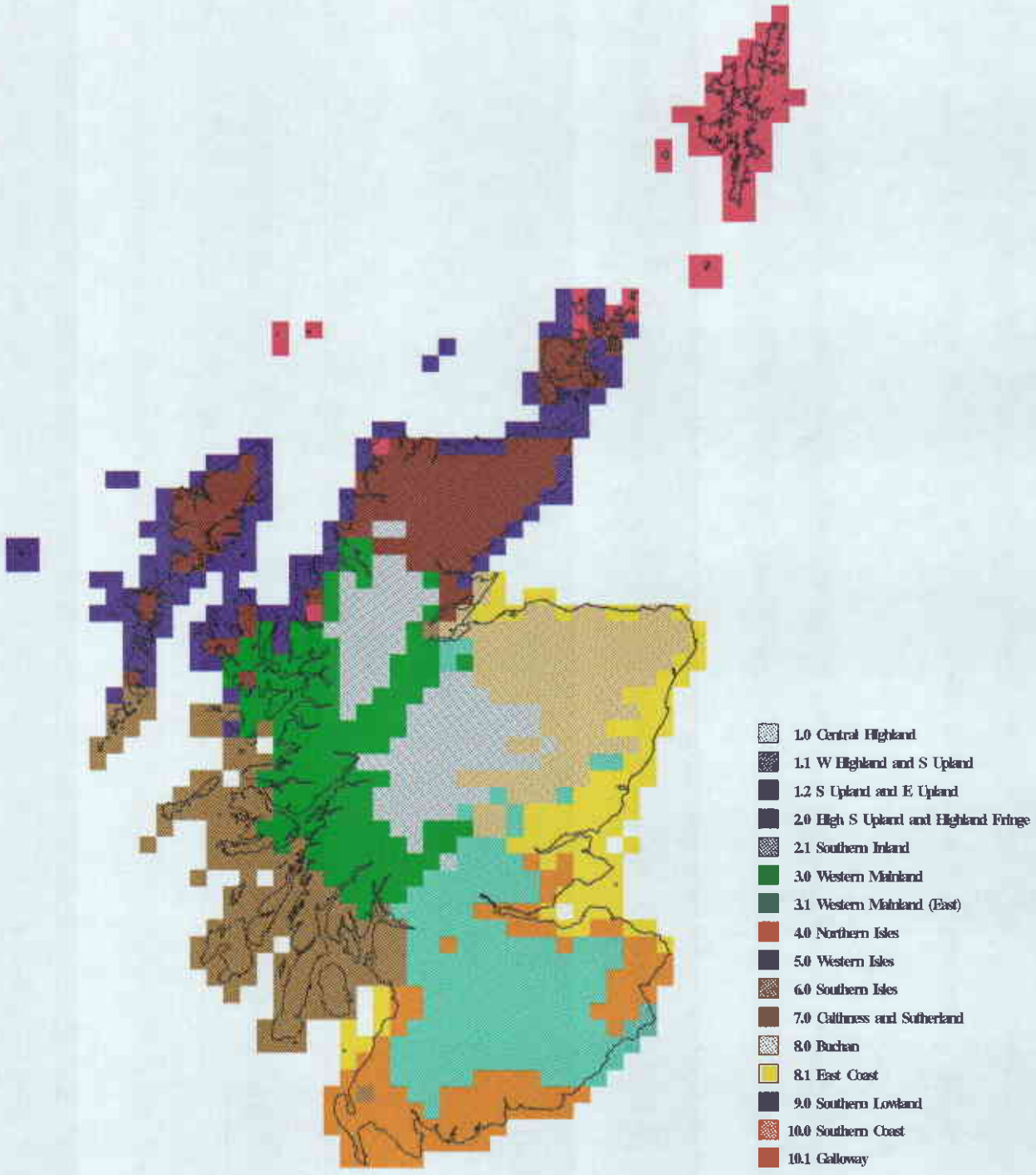
Species		Preference index	Frequency %
Gonepteryx rhamni	*Brimstone*	0.20	4
Chorthippus brunneus		0.19	34
Cupido minimus	*Small Blue*	0.18	21
Pieris rapae	*Small White*	0.12	78
Myrmeleotettix maculatus		0.12	40

10.0 Southern coast zone

Species		Preference index	Frequency %
Lasiommata megera	*Wall*	1.74	50
Ochlodes venata	*Large Skipper*	1.55	39
Chorthippus brunneus		0.89	54
Aphantopus hyperantus	*Ringlet*	0.85	66
Erynnis tages	*Dingy Skipper*	0.62	25

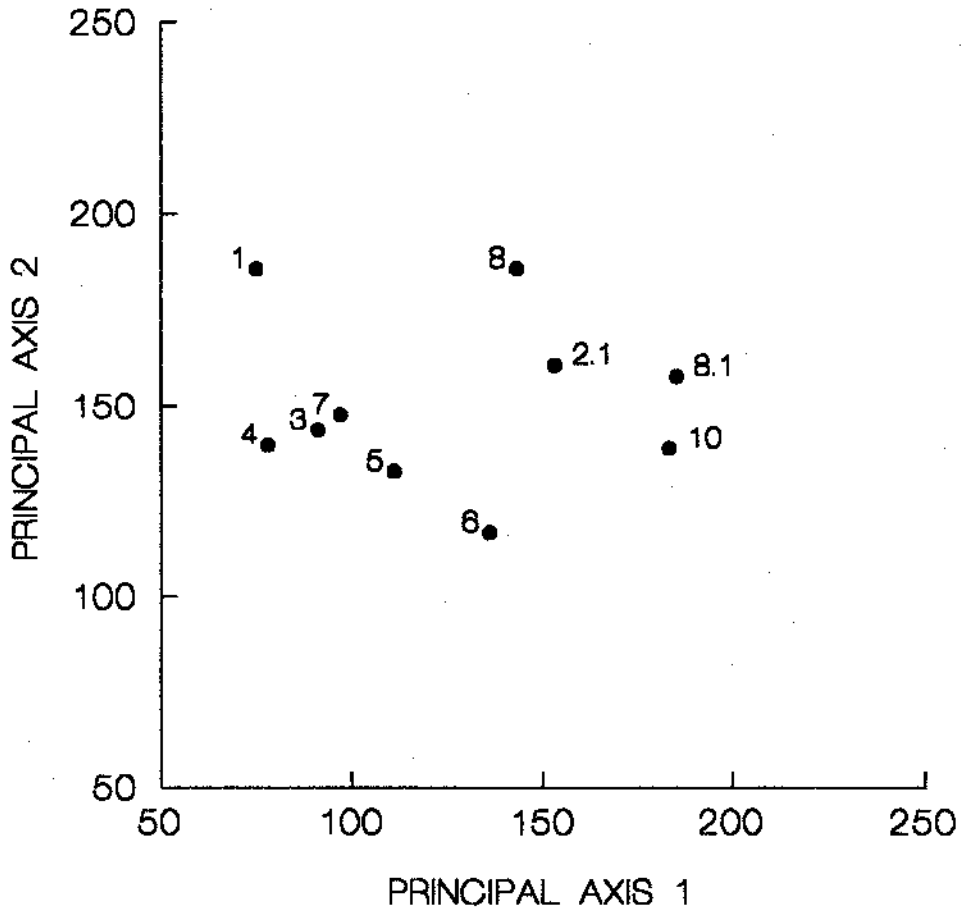
Diurnal insect zone	Main zone 1	2	3	4	5	6	7	8	9	10
1	**0.87**	0.024	0.083	·	·	·	·	·	·	·
2.1	·	**0.56**	0.0067	·	·	·	·	0.0082	0.41	·
3	0.0084	0.089	**0.8**	·	·	0.086	·	0.0088	·	·
4	·	·	0.0097	**0.73**	·	·	0.015	·	·	·
5	·	·	0.015	0.27	**0.59**	0.076	0.11	0.028	·	·
6	·	0.0068	0.028	·	0.11	**0.82**	·	0.0088	0.019	0.021
7	0.046	0.0074	0.092	0.11	0.22	·	**0.64**	0.029	·	·
8	0.07	0.37	·	·	·	·	·	**0.51**	0.0073	·
8.1	·	·	·	·	·	0.018	·	0.35	0.22	0.35
10	·	·	·	·	·	0.0084	·	·	**0.53**	0.36

Table of similarity index (S) values.



Diurnal Insects

DIURNAL INSECTS



7.3 MOLLUSC ZONES

The mollusc zones show a clear, and not unexpected, coastal influence. The East Coast is picked out as a distinct zone and the Southern Isles zone is much more coastal than the equivalent zone based on all groups. The Western Highland and Southern Upland zone is unique to this particular taxonomic group but the preference index value for the most characteristic species is the lowest of any of the zones identified in this study. The values for the Buchan zone (which is scarcely separated from the Western Highland and Southern Upland zone by the first two axes of the ordination) and the Southern Lowland zone are also low, and indicate the limitations of applying our approach to the definition of biogeographical zones to areas which have rather a poor mollusc fauna.

1.0 Central Highland zone

Species	Preference index	Frequency %
Pisidium lilljeborgii	0.24	36
Limax cinereoniger	0.13	20
Columella aspera	0.11	36
Limax tenellus	0.07	8
Pisidium casertanum	0.03	60

1.1 Western Highland and Southern Upland zone

Species	Preference index	Frequency %
Columella aspera	0.11	36
Vitrea crystallina	0.09	67
Vertigo lilljeborgi	0.05	11
Deroceras agreste	0.05	20
Limex cinereoniger	0.04	15

3.0 Western Mainland zone

Species	Preference index	Frequency %
Zonitoides excavatus	0.59	47
Clausilia bidentata	0.29	83
Ashfordia granulata	0.20	35
Acicula fusca	0.12	10
Balea perversa	0.11	40

4.0 Northern Isles zone

Species	Preference index	Frequency %
Leucophytia bidentata	0.83	10
Pupilla muscorum	0.81	30
Armiger crista	0.79	50
Pisidium obtusale	0.73	50
Gyraulus laevis	0.49	30

5.0 Western Isles zone

Species	Preference index	Frequency %
Cochlicella acuta	4.18	78
Helicella itala	3.03	75
Helix aspersa	0.30	50
Vallonia excentrica	0.29	31
Vallonia costa	0.19	16

6.0 Southern Isles zone

Species	Preference index	Frequency %
Cochlicella acuta	1.98	57
Helix aspersa	1.30	79
Helicella itala	0.95	48
Candidula intersecta	0.48	43
Leiostyla anglica	0.46	48

7.0 Caithness and Sutherland zone

Species	Preference index	Frequency %
Potamopyrgus jenkinsi	0.58	67
Pupilla muscorum	0.42	23
Pisidium subtruncatum	0.36	60
Theodoxus fluviatilis	0.36	5
Pisidium pulchellum	0.33	16

8.0 Buchan zone

Species	Preference index	Frequency %
Limax tenellus	0.42	15
Aegopinella pura	0.14	81
Margaritifera margaritifera	0.11	32
Cepaea hortensis	0.08	74
Spermodea lamellata	0.08	28

8.1 East Coast zone

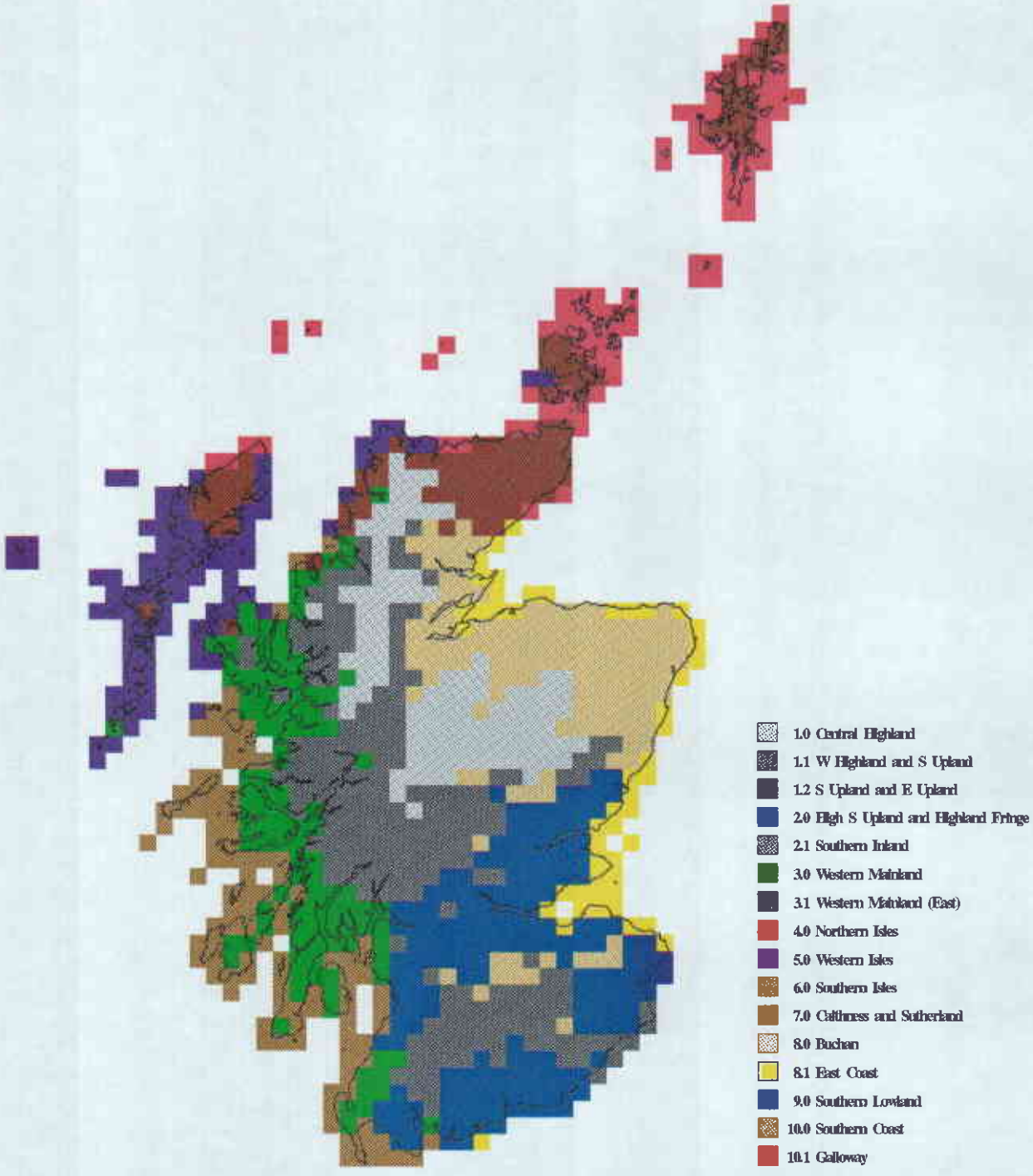
Species	Preference index	Frequency %
Pupilla muscorum	1.86	42
Candidula intersecta	1.69	67
Cernuella virgata	1.47	25
Vallonia costa	1.02	29
Helix aspersa	0.80	67

9.0 Southern Lowland zone

Species	Preference index	Frequency %
Physa fontinalis	0.42	39
Bithynia tentaculata	0.40	20
Gyraulus albus	0.36	49
Valvata cristata	0.36	20
Sphaerium corneum	0.30	43

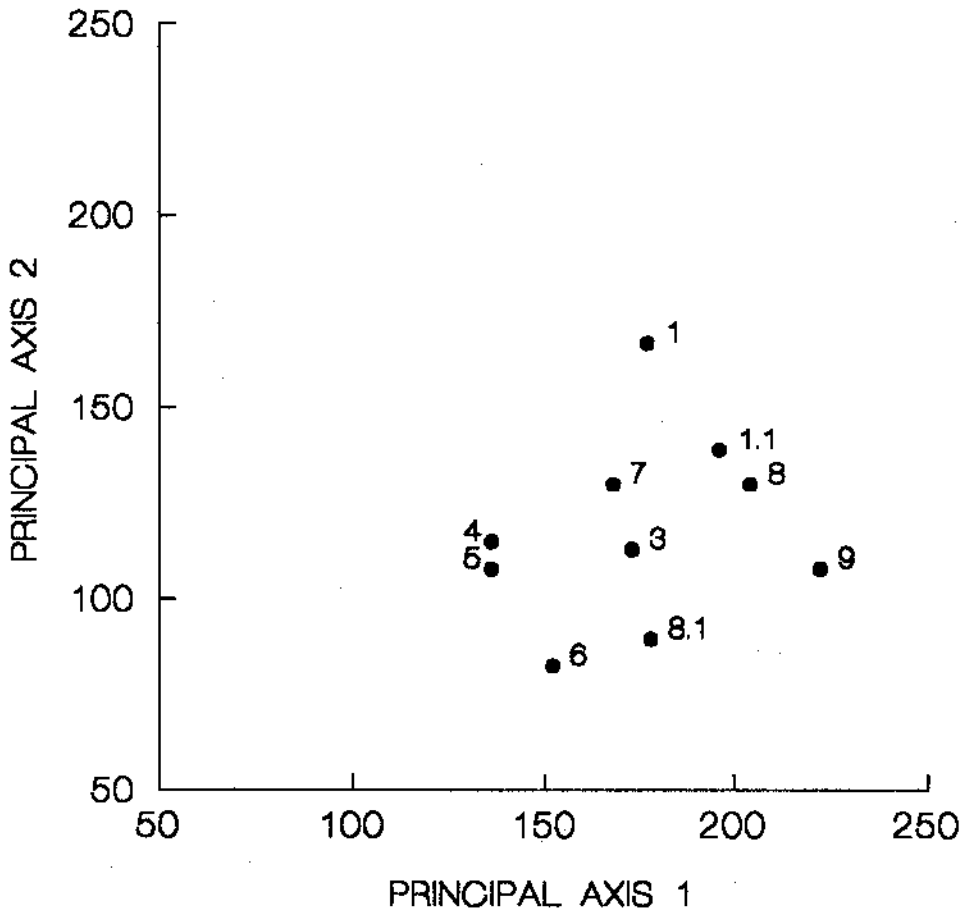
	Main zone									
Mollusc zone	1	2	3	4	5	6	7	8	9	10
1	**0.79**	0.095	0.058	·	·	·	0.035	·	·	·
1.1	0.13	0.47	**0.55**	·	·	·	0.022	·	·	·
3	0.0094	0.0075	0.33	·	·	0.48	0.011	·	0.028	0.048
4	·	·	·	**0.81**	0.043	·	0.026	·	·	·
5	·	·	·	0.061	**0.83**	0.0087	0.037	·	·	·
6	·	·	·	·	0.048	**0.63**	·	·	·	0.28
7	·	·	·	0.24	0.15	0.0087	**0.62**	·	·	·
8	·	0.35	·	·	·	·	0.1	**0.59**	0.027	·
8.1	·	·	·	·	·	·	0.016	0.35	0.045	0.39
9	·	0.043	·	·	·	·	·	·	**0.92**	0.063

Table of similarity index (S) values.


1.0 Central Highland
1.1 W Highland and S Upland
1.2 S Upland and E Upland
2.0 High S Upland and Highland Fringe
2.1 Southern Inland
3.0 Western Mainland
3.1 Western Mainland (East)
4.0 Northern Isles
5.0 Western Isles
6.0 Southern Isles
7.0 Caithness and Sutherland
8.0 Buchan
8.1 East Coast
9.0 Southern Lowland
10.0 Southern Coast
10.1 Galloway

Molluscs

MOLLUSCS


250
200
150
100
50
PRINCIPAL AXIS 2
1
1.1
7
8
4
5
3
9
8.1
6
50
100
150
200
250
PRINCIPAL AXIS 1

7.4 VASCULAR PLANT (SET 1) ZONES

These vascular plant zones are broadly similar to the overall zones. There is an even closer similarity to18`tlhird zones. For both groups a Southern Upland and Eastern Upland zone has been identified, and the East Coast plant zone has clear affinities with the Southern Coast zone which appears on the bird map. To accommodate these new zones the Western Isles have been partitioned between the Northern Isles and the Caithness and Sutherland zones. This is the only map on which the Western Isles do not appear as a separate zone.

1.0 Central Highland zone

Species	Preference index	Frequency %
Gnaphalium supinum	3.49	86
Veronica alpina	3.07	36
Carex vaginata	2.81	54
Epilobium alsinifolium	2.11	70
Betula nana	1.85	59

1.2 Southern Upland and Eastern Upland zone

Species	Preference index	Frequency %
Alchemilla alpina	0.71	80
Gnaphalium supinum	0.43	40
Vaccinium vitis-idaea	0.39	93
Cerastium alpinum	0.36	23
Betula nana	0.31	31

2.0 High Southern Upland and Highland Fringe zone

Species	Preference index	Frequency %
Galium uliginosum	0.46	60
Carex hirta	0.27	52
Ribes uva-crispa	0.23	71
Carex caryophyllea	0.23	72
Chrysosplenium alternifolium	0.21	31

3.0 Western Mainland zone

Species	Preference index	Frequency %
Scutellaria galericulata	0.78	85
Aster tripolium	0.67	61
Cephalanthera longifolia	0.66	19
Sanicula europaea	0.45	91
Triglochin maritimum	0.42	78

4.0 Northern Isles zone

Species	Preference index	Frequency %
Cakile maritima	0.54	49
Lamium molucellifolium	0.54	52
Cerastium diffusum	0.46	70
Armeria maritima	0.28	93
Glaux maritima	0.27	75

6.0 Southern Isles zone

Species	Preference index	Frequency %
Triglochin maritimum	0.61	86
Atriplex laciniata	0.59	35
Fumaria bastardii	0.56	26
Scutellaria galericulata	0.54	77
Valerianella locusta	0.53	42

7.0 Caithness and Sutherland zone

Species	Preference index	Frequency %
Plantago maritima	0.17	95
Potamogeton perfoliatus	0.16	53
Salix repens	0.15	90
Osmunda regalis	0.14	28
Coeloglossum viride	0.11	42

8.0 Buchan zone

Species	Preference index	Frequency %
Linnaea borealis	1.31	43
Anthemis arvensis	0.38	16
Bromus lepidus	0.31	28
Ribes uva-crispa	0.25	72
Centaurea cyanus	0.25	22

8.1 East Coast zone

Species	Preference index	Frequency %
Cakile maritima	2.30	83
Atriplex laciniata	1.88	54
Cerastium semidecandrum	1.60	51
Elytrigia juncea	1.39	66
Valerianella dentata	1.36	20

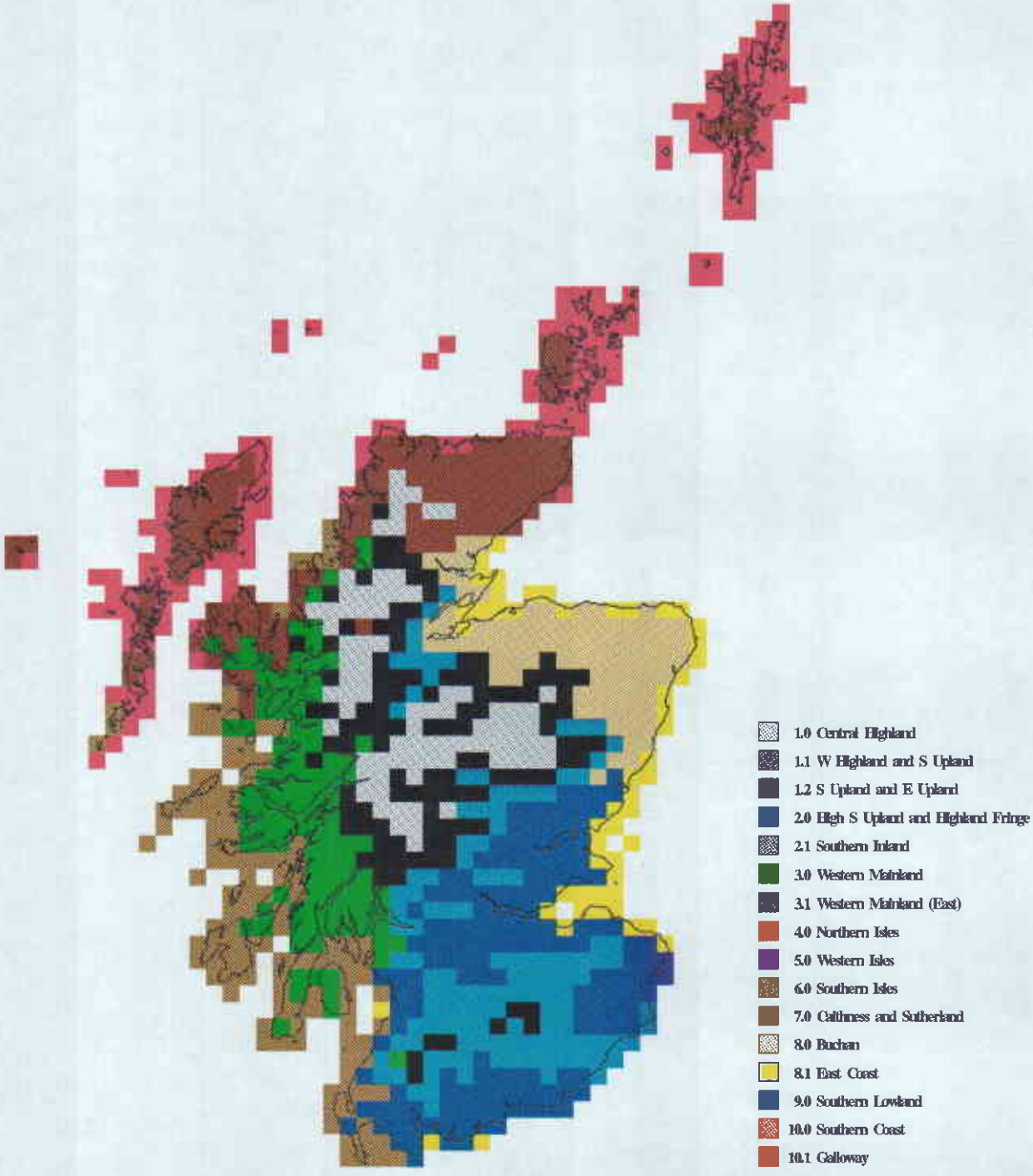
9.0 Southern Lowland zone

Species	Preference index	Frequency %
Juncus inflexus	1.20	49
Rorippa palustris	1.04	49
Alliaria petiolata	0.96	71
Tragopogon pratensis	0.89	50
Carex hirta	0.79	71

Main zone

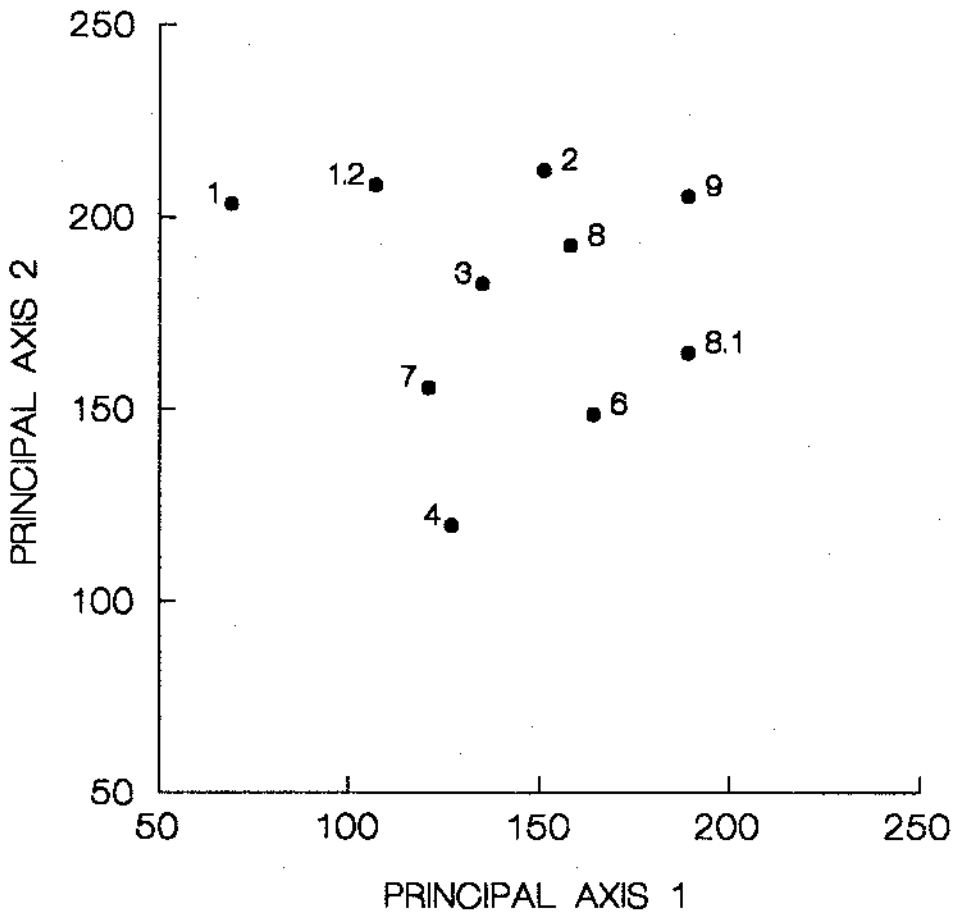
Vascular Plant (1) zone	1	2	3	4	5	6	7	8	9	10
1	**0.75**	·	0.12	·	·	·	·	·	·	·
1.2	0.28	0.26	0.35	·	·	·	0.032	·	·	·
2	·	**0.73**	0.015	·	·	·	·	·	0.14	·
3	·	0.015	**0.52**	·	0.0093	0.33	·	·	·	·
4	·	·	·	**0.73**	0.44	·	0.018	·	·	·
6	·	·	·	·	0.062	**0.72**	·	·	·	0.23
7	0.0085	·	0.12	0.091	0.33	0.036	**0.6**	·	·	·
8	·	0.12	·	·	·	·	0.065	**0.72**	0.016	·
8.1	·	·	·	·	·	·	·	0.37	0.036	0.42
9	·	·	·	·	·	·	·	·	**0.89**	0.11

Table of similarity index (S) values.



Vascular Plants (set 1)

VASCULAR PLANTS SET 1



7.5 VASCULAR PLANT (SET 2) ZONES

These zones are clearly similar to the zones based on the alternative set of vascular plants, but differ in the fact that the Southern Coast zone rather than the Western Isles zone has been dropped to make way for the Southern Upland and Eastern Upland zone. The differences between the vascular plant zones are sufficiently significant to suggest that an analysis of all the Scottish vascular plant data rather than two random samples of 200 would have been worthwhile.

1.0 Central Highland zone

Species	Preference index	Frequency %
Juncus trifidus	2.97	81
Luzula spicata	2.76	84
Vaccinium uliginosum	2.64	84
Loiseleuria procumbens	2.53	74
Carex saxatilis	2.29	46

1.2 Southern Upland and Eastern Upland zone

Species	Preference index	Frequency %
Saxifraga stellaris	0.38	65
Melica nutans	0.36	36
Pyrola media	0.36	45
Viola lutea	0.35	50
Carex bigelowii	0.28	58

2.0 High Southern Upland and Highland Fringe zone

Species	Preference index	Frequency %
Sedum villosum	0.58	48
Viola lutea	0.38	51
Pimpinella saxifraga	0.33	58
Cardamine amara	0.29	48
Melica uniflora	0.26	35

3.0 Western Mainland zone

Species	Preference index	Frequency %
Scutellaria minor	0.48	33
Carex laevigata	0.42	54
Eleocharis multicaulis	0.36	77
Hymenophyllum tunbrigense	0.35	15
Juncus gerardii	0.34	74

4.0 Northern Isles zone

Species	Preference index	Frequency %
Scilla verna	4.48	84
Ranunculus baudotii	0.64	27
Plantago coronopus	0.61	92
Leymus arenarius	0.57	43
Juncus gerardii	0.35	74

5.0 Western Isles zone

Species	Preference index	Frequency %
Scutellaria minor	0.68	37
Plantago coronopus	0.50	88
Eleocharis multicaulis	0.41	79
Veronica catenata	0.38	14
Catapodium marinum	0.36	19

6.0 Southern Isles zone

Species	Preference index	Frequency %
Umbilicus rupestris	2.09	38
Oenanthe lachenalii	1.72	42
Eupatorium cannabinum	1.33	59
Juncus maritimus	0.92	31
Catapodium marinum	0.77	26

7.0 Caithness and Sutherland zone

Species	Preference index	Frequency %
Ajuga pyramidalis	1.08	39
Subularia aquatica	0.17	46
Calamagrostis stricta	0.13	5
Aira caryophyllea	0.11	75
Potamogeton gramineus	0.10	42

8.0 Buchan zone

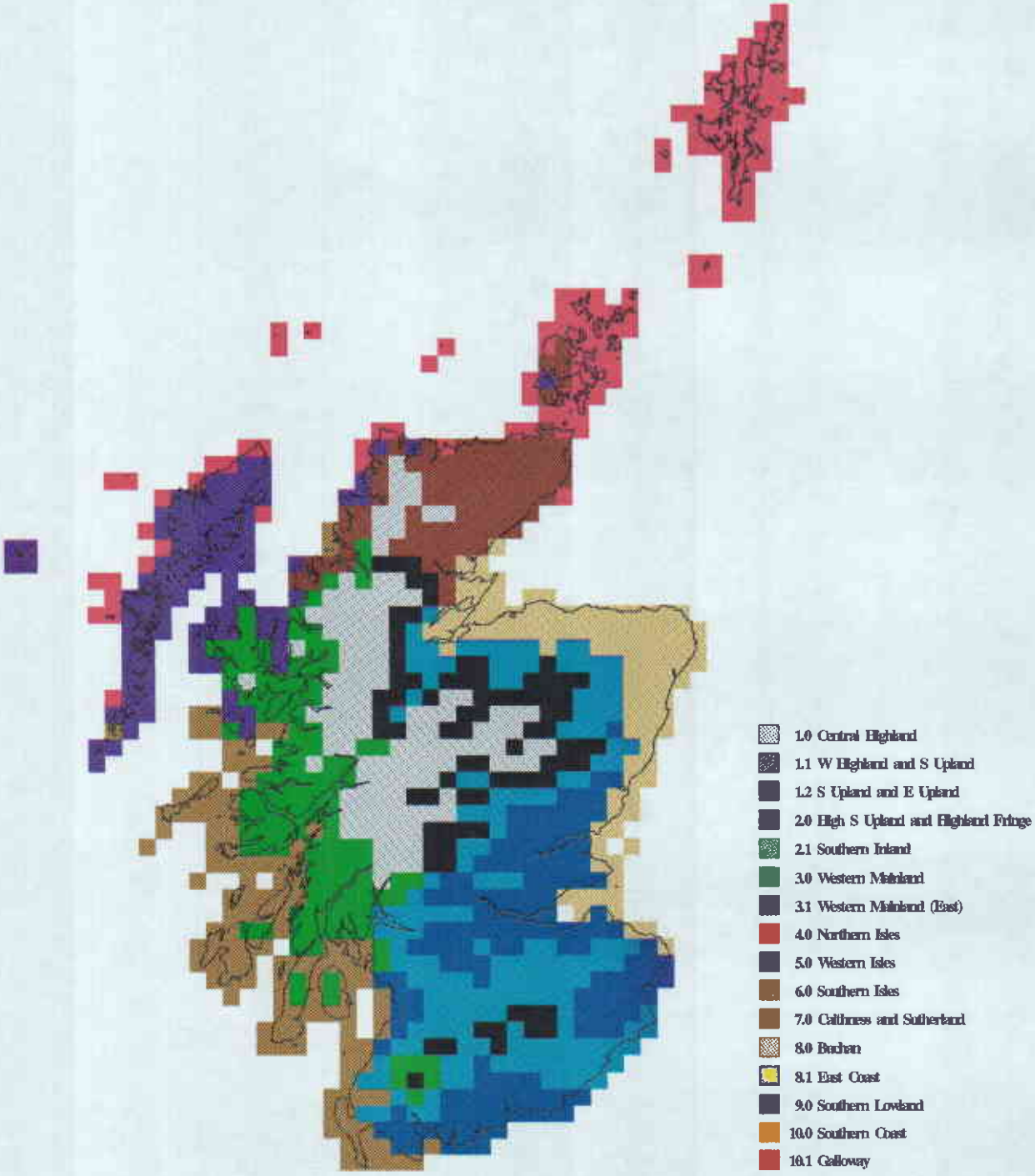
Species	Preference index	Frequency %
Vicia lathyroides	1.54	42
Leymus arenarius	0.98	52
Symphytum tuberosum	0.86	78
Senecio sylvaticus	0.76	79
Cerastium arvense	0.71	41

9.0 Southern Lowland zone

Species	Preference index	Frequency %
Alisma plantago–aquatica	1.69	83
Potamogeton crispus	1.01	66
Malus sylvestris	0.86	57
Carduus crispus	0.79	45
Anisantha sterilis	0.79	45

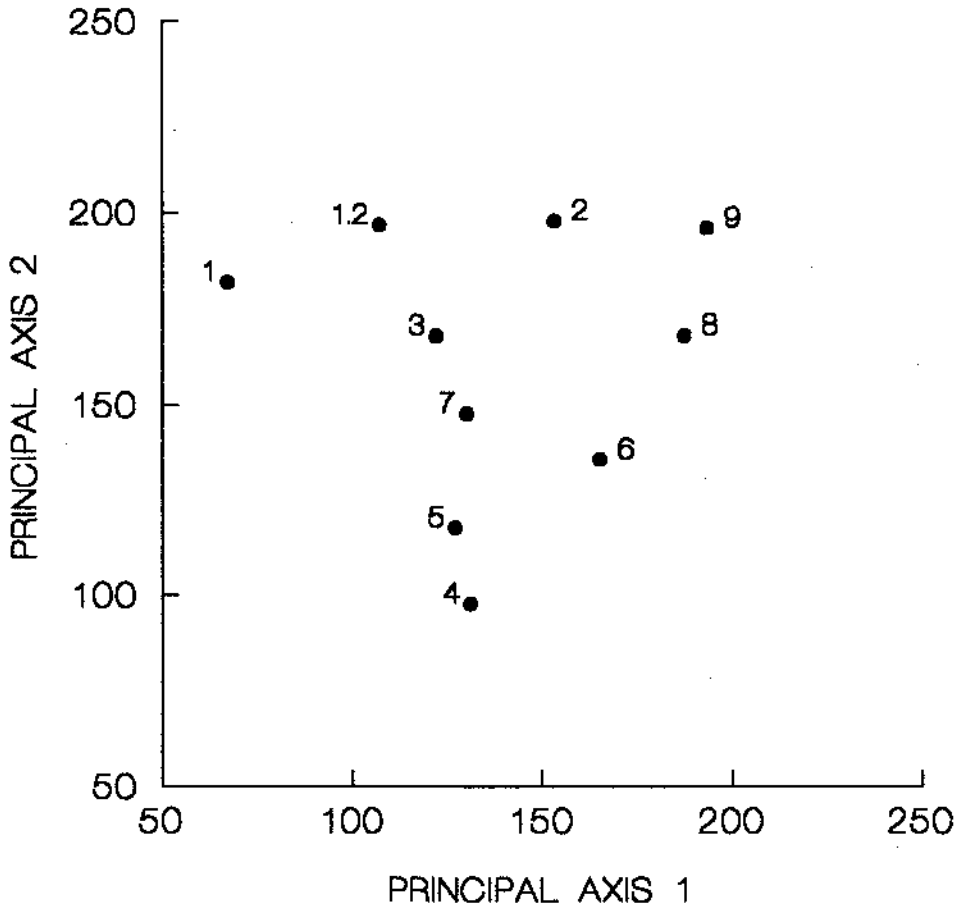
	Main zone									
Vascular Plant (2) zone	1	2	3	4	5	6	7	8	9	10
1	**0.69**	·	0.32	·	·	·	0.011	·	·	·
1.2	0.28	0.34	0.14	·	·	·	0.013	·	·	·
2	·	**0.68**	·	·	·	0.013	·	0.098	0.23	0.0094
3	·	0.044	**0.61**	·	0.0089	0.25	·	·	·	·
4	·	·	·	**0.90**	0.16	·	·	·	·	·
5	·	·	0.0084	0.0099	**0.8**	0.084	0.047	·	·	·
6	·	·	·	·	0.044	**0.71**	·	·	·	0.27
7	·	0.0087	0.045	0.033	·	0.018	**0.89**	·	·	·
8	·	·	·	·	·	·	·	**0.81**	0.023	0.24
9	·	·	·	·	·	·	·	0.0088	**0.83**	0.1

Table of similarity index (S) values.



Vascular Plants (set 2)

VASCULAR PLANTS SET 2



7.6 MOSS ZONES

This classification recognises two zones in the 'Western Mainland' area at the expense of the Southern Coast zone. This reflects the diversity of species in the north and west compared to that in the south and east (see Hill, Preston & Smith 1994 p.23). Otherwise the zones match the overall zones tolerably well.

1.0 Central Highland zone

Species	Preference index	Frequency %
Sphagnum lindbergii	3.13	31
Philonotis seriata	3.12	41
Pohlia ludwigii	3.11	53
Polytrichum sexangulare	2.97	35
Kiaeria starkii	2.78	53

2.0 High Southern Upland and Highland Fringe zone

Species	Preference index	Frequency %
Dicranum spurium	0.24	13
Atrichum tenellum	0.21	12
Grimmia donniana	0.20	41
Orthotrichum striatum	0.12	29
Orthotrichum stramineum	0.10	31

3.0 Western Mainland zone

Species	Preference index	Frequency %
Andreaea alpina	1.08	78
Isothecium holtii	0.90	31
Aulacomnium turgidum	0.89	26
Leptodontium recurvifolium	0.84	27
Dicranodontium uncinatum	0.82	38

3.1 Western Mainland (East) zone

Species	Preference index	Frequency %
Hylocomium brevirostre	0.90	88
Glyphomitrium daviesii	0.65	35
Plagiothecium nemorale	0.61	55
Fissidens celticus	0.59	27
Ulota calvescens	0.55	36

4.0 Northern Isles zone

Species	Preference index	Frequency %
Campylopus brevipilus	1.93	81
Pseudobryum cinclidioides	0.89	27
Sphagnum fimbriatum	0.77	78
Schistidium maritimum	0.69	92
Archidium alternifolium	0.65	65

5.0 Western Isles zone

Species	Preference index	Frequency %
Campylopus shawii	3.70	62
Myurium hochstetteri	3.56	54
Distichium inclinatum	1.29	35
Campylopus brevipilus	1.04	64
Tortula ruraliformis	1.00	57

6.0 Southern Isles zone

Species	Preference index	Frequency %
Tortella flavovirens	0.69	37
Epipterygium tozeri	0.34	6
Schistidium maritimum	0.33	76
Tortula ruraliformis	0.32	39
Eurhynchium speciosum	0.30	8

7.0 Caithness and Sutherland zone

Species	Preference index	Frequency %
Sphagnum fuscum	1.10	63
Brachythecium erythrorrhizon	0.80	4
Sphagnum imbricatum	0.79	59
Bryum violaceum	0.59	19
Bryum klinggraeffii	0.57	22

8.0 Buchan zone

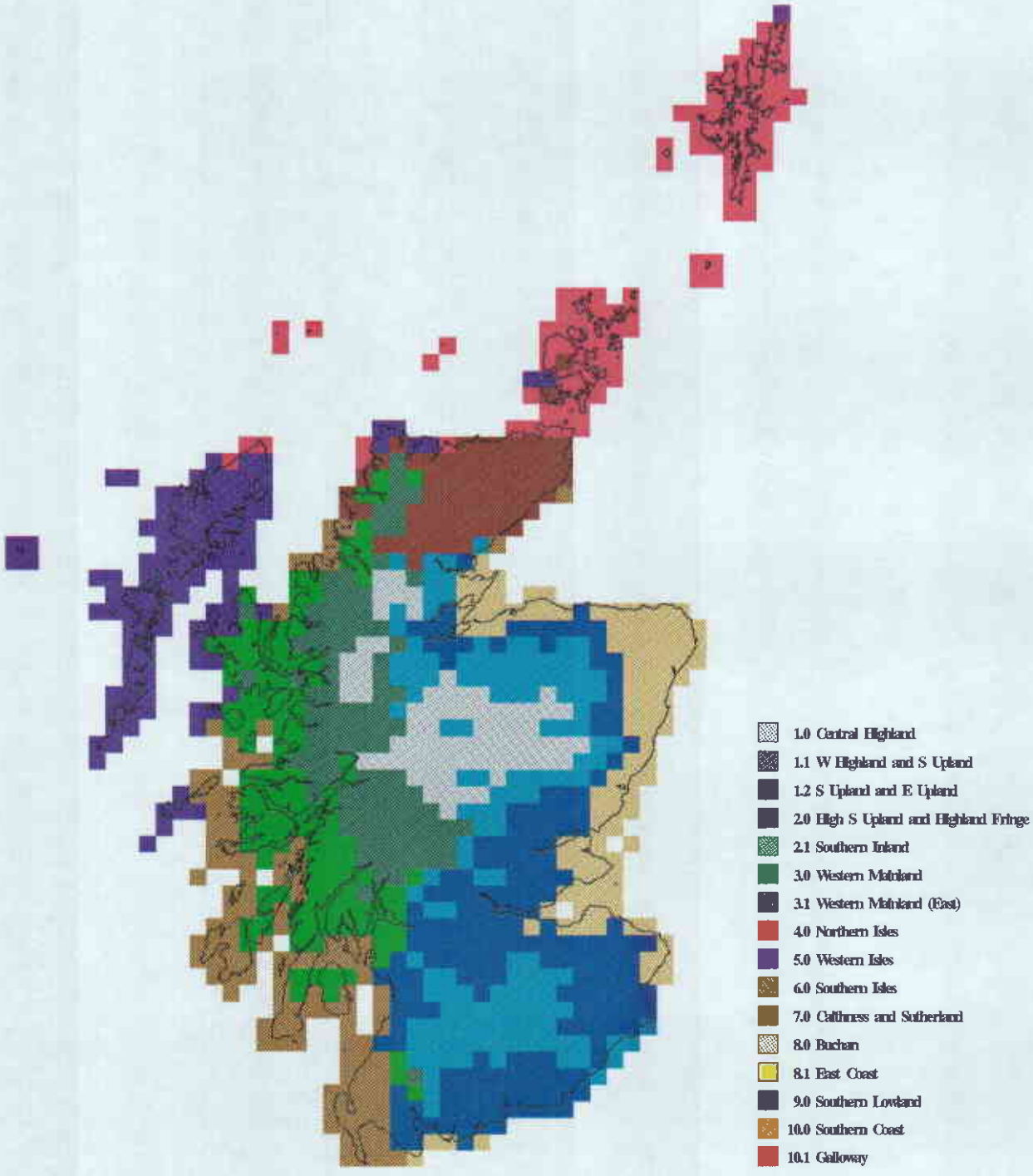
Species	Preference index	Frequency %
Phascum cuspidatum	2.64	67
Desmatodon convolutus	2.60	21
Pottia lanceolata	1.90	28
Fissidens incurvus	1.86	21
Acaulon muticum	1.63	26

9.0 Southern Lowland zone

Species	Preference index	Frequency %
Dicranoweisia cirrata	0.38	84
Tortula papillosa	0.35	29
Brachythecium velutinum	0.35	49
Orthotrichum diaphanum	0.33	56
Amblystegium fluviatile	0.33	26

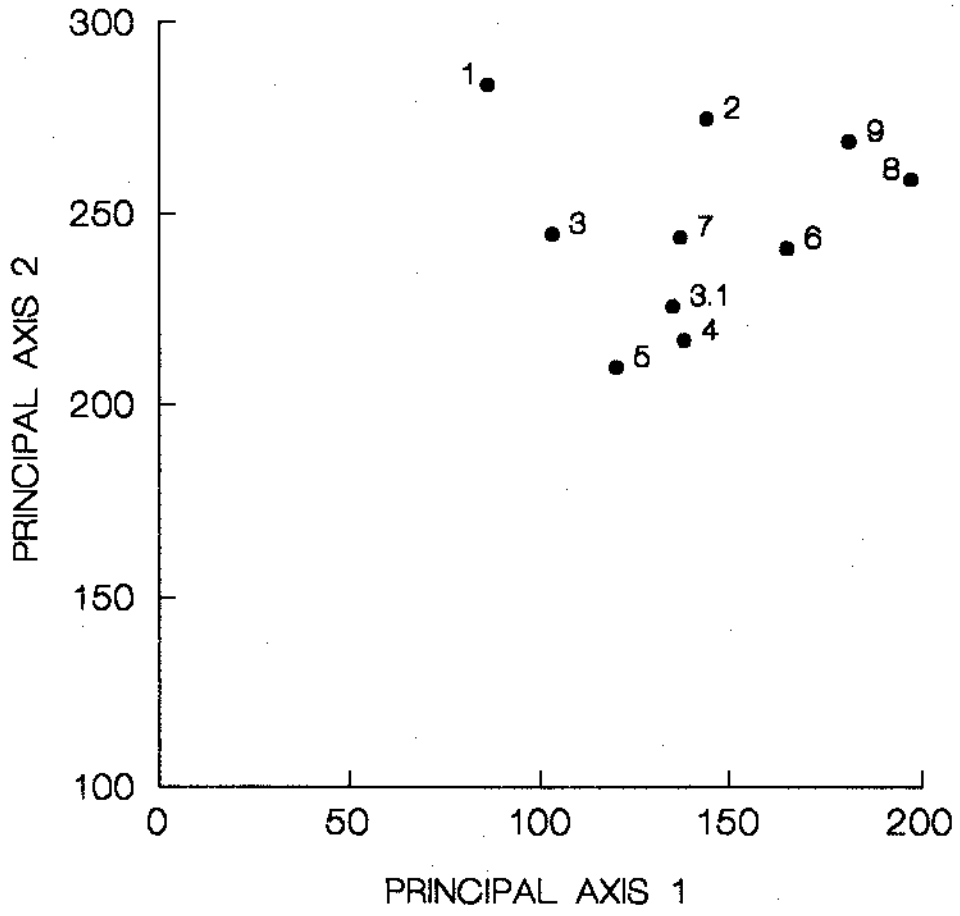
	Main zone									
Moss zone	1	2	3	4	5	6	7	8	9	10
1	**0.77**	0.045	0.0094	·	·	·	·	·	·	·
2	0.025	**0.85**	0.035	·	·	·	0.038	0.026	0.0065	·
3	0.28	0.016	**0.58**	·	·	·	·	·	·	·
3.1	·	0.036	0.49	·	0.017	0.39	0.03	·	0.0067	·
4	·	·	·	**0.95**	0.029	·	0.011	·	·	·
5	·	·	·	0.046	**0.91**	0.047	0.032	·	·	·
6	·	·	·	0.0092	·	**0.65**	0.011	0.01	0.028	0.29
7	0.025	·	·	·	0.012	·	**0.89**	·	·	·
8	·	·	·	·	·	·	·	**0.62**	0.15	0.29
9	·	0.094	·	·	·	·	·	0.17	**0.8**	0.05

Table of similarity index (S) values.


1.0 Central Highland
1.1 W Highland and S Upland
1.2 S Upland and E Upland
2.0 High S Upland and Highland Fringe
2.1 Southern Inland
3.0 Western Mainland
3.1 Western Mainland (East)
4.0 Northern Isles
5.0 Western Isles
6.0 Southern Isles
7.0 Caithness and Sutherland
8.0 Buchan
8.1 East Coast
9.0 Southern Lowland
10.0 Southern Coast
10.1 Galloway

Mosses

MOSSES


300
250
200
150
100
0
50
100
150
200
PRINCIPAL AXIS 2
PRINCIPAL AXIS 1
1
2
9
8
3
7
6
3.1
4
5

7.7 LIVERWORT ZONES

As with the mosses, the diversity of liverworts in the north and west is reflected in the subdivision of the 'Western Mainland' area into westerly and easterly components. The compact Galloway zone is unique to the liverworts but clearly has affinities with the Southern Isles and Southern Coast zones recognised for other groups.

1.0 Central Highland zone

Species	Preference index	Frequency %
Tetralophozia setiformis	3.86	63
Diplophyllum taxifolium	1.65	37
Barbilophozia hatcheri	1.25	67
Moerckia blyttii	1.11	37
Lophozia opacifolia	1.07	37

2.0 High Southern Upland and Highland Fringe zone

Species	Preference index	Frequency %
Barbilophozia hatcheri	0.23	40
Marchantia polymorpha	0.20	64
Porella cordaeana	0.20	36
Ptilidium ciliare	0.18	73
Lophozia bicrenata	0.10	33

0.81

3.0 Western Mainland zone

Species	Preference index	Frequency %
Mastigophora woodsii	1.73	52
Scapania ornithopodioides	1.70	61
Plagiochila carringtonii	1.51	59
Scapania nimbosa	1.48	45
Anastrophyllum donnianum	1.38	44

3.1 Western Mainland (East) zone

Species	Preference index	Frequency %
Drepanolejeunea hamatifolia		61
Harpalejeunea ovata	0.78	69
Plagiochila punctata	0.74	87
Adelanthus decipiens	0.61	44
Aphanolejeunea microscopica	0.57	66

4.0 Northern Isles zone

Species	Preference index	Frequency %
Riccardia latifrons	0.75	67
Kurzia sylvatica	0.69	27
Gymnocolea inflata	0.51	90
Cephalozia leucantha	0.38	57
Lophozia incisa	0.23	95

5.0 Western Isles zone

Species	Preference index	Frequency %
Porella obtusata	0.84	41
Frullania microphylla	0.44	41
Frullania teneriffae	0.42	80
Marchesinia mackaii	0.39	37
Saccogyna viticulosa	0.37	95

7.0 Caithness and Sutherland zone

Species	Preference index	Frequency %
Petalophyllum ralfsii	0.54	3
Cephaloziella hampeana	0.15	47
Anthoceros punctatus	0.10	10
Geocalyx graveolens	0.09	3
Leiocolea alpestris	0.08	40

8.0 Buchan zone

Species	Preference index	Frequency %
Barbilophozia hatcheri	0.41	47
Fossombronia pusilla	0.31	27
Lunularia cruciata	0.30	47
Riccardia palmata	0.27	80
Riccia sorocarpa	0.24	47

9.0 Southern Lowland zone

Species	Preference index	Frequency %
Lophocolea heterophylla	1.60	76
Lunularia cruciata	1.03	68
Metzgeria fruticulosa	0.74	44
Porella cordaeana	0.70	52
Porella platyphylla	0.64	48

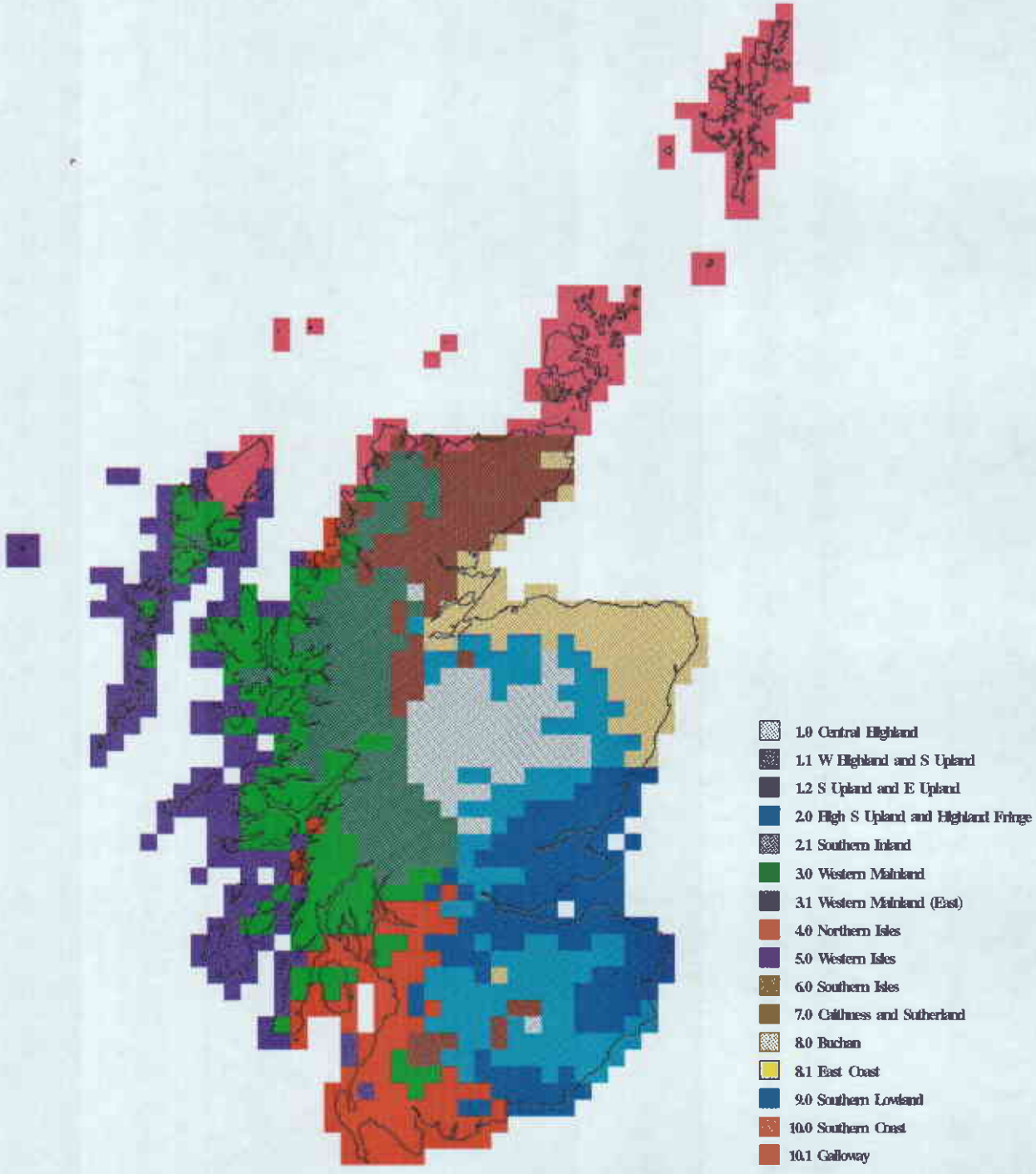
10.1 Galloway zone

Species	Preference index	Frequency %
Phaeoceros laevis	0.43	20
Marchesinia mackaii	0.38	36
Lejeunea lamacerina	0.31	57
Lophocolea heterophylla	0.28	43
Lejeunea ulicina	0.25	57

Main zone

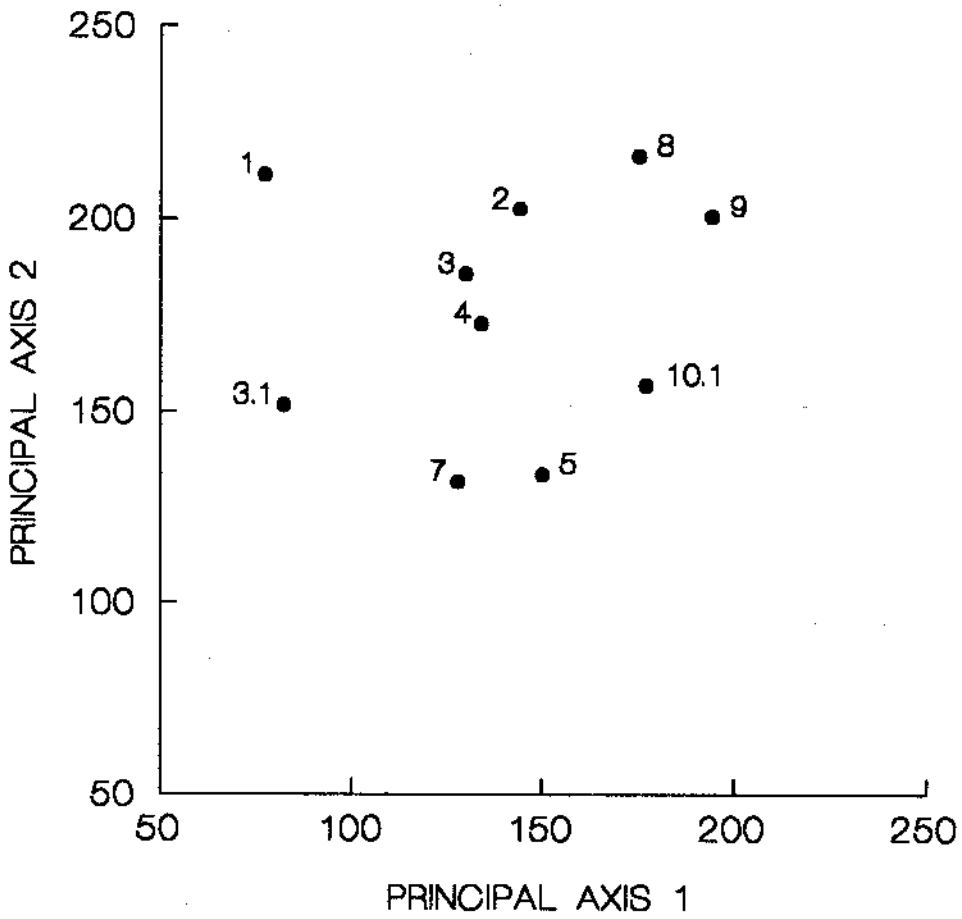
Liverwort zone	1	2	3	4	5	6	7	8	9	10
1	**0.62**	0.15	·	·	·	·	·	·	·	·
1.1	0.42	0.015	0.49	·	0.0091	·	0.043	·	·	·
2	·	**0.73**	·	·	·	·	·	0.046	0.15	·
3	·	0.048	0.49	·	0.17	0.30	0.019	·	·	·
4	·	·	·	**0.91**	0.11	·	0.061	·	·	·
5	·	·	·	·	**0.56**	**0.52**	·	·	·	·
7	0.032	0.15	0.078	·	·	·	**0.73**	·	·	·
8	·	·	·	0.011	·	·	0.025	**0.94**	0.0078	·
9	·	·	·	·	·	·	·	0.0092	**0.73**	0.21
10.1	·	0.04	·	·	·	0.21	·	·	0.27	0.44

Table of similarity index (S) values.


1.0 Central Highland
1.1 W Highland and S Upland
1.2 S Upland and E Upland
2.0 High S Upland and Highland Fringe
2.1 Southern Inland
3.0 Western Mainland
3.1 Western Mainland (East)
4.0 Northern Isles
5.0 Western Isles
6.0 Southern Isles
7.0 Caithness and Sutherland
8.0 Buchan
8.1 East Coast
9.0 Southern Lowland
10.0 Southern Coast
10.1 Galloway

Liverworts

LIVERWORTS


250
200
150
100
50
50
100
150
200
250
PRINCIPAL AXIS 2
PRINCIPAL AXIS 1
1
2
3
4
3.1
5
7
8
9
10.1

8 DISCUSSION

There is a broad similarity between the zones which have been defined for the different species groups. Only sixteen zones have been identified by the analysis of seven different groups, although the details of an individual zone differs from group to group. This is not unexpected in view of the fact that they are basically environmental regions trained by different species groups.

Some of the differences between the zones for different groups appear to reflect biological differences between the species. The subdivision of the 'western mainland' area for both mosses and liverworts into two zones can be attributed to the greater diversity of the bryophytes in the north and west, and the concentration of molluscs in the coastal zone is also reflected in the zones for this group. The coastal breeding birds were not included in the analysis; had they been included one would have expected an even stronger bias towards the coast.

Other differences between the zones are more apparent than real, as they result from the fact that ten zones have to be recognised and each square has to be assigned to a single zone. There is in fact a large degree of overlap between zones identified for different groups. For example, there is one coastal zone in southern Scotland (Southern Coast) in the zones based on all groups, and the Southern Isles zone has some coastal affinities. For molluscs and vascular plants (set 1) there is an Eastern Coast zone (with a few outliers on the west coast) and the west coast is taken up by a narrow Southern Isles zone. For mosses the same areas are covered by southward extensions of the Southern Isles and Buchan zones on the east and west coasts respectively. In diurnal insects (which have many coastal representatives) both Southern Coast and Eastern Coast zones are recognised.

The methods we have adopted are weakest in dealing with the smaller groups, especially in areas where few members of these groups occur. The inland mollusc zones are particularly poor for this reason.

There is considerable scope for developing the methodology we have used in this report, and for extending its application for conservation purposes. It is already clear that some zones are more important than others in the sense that they contain suites of highly characteristic species. The zones identified for all groups no doubt have characteristic species in taxonomic groups which we have not considered. A further analysis of the British and European distribution of the characteristic species of the zones would highlight those zones which were of particular importance in the international context.

9 REFERENCES

Ball, D.F., Radford, G.L. & Williams, W.M. (1983) A land characteristic data bank for Great Britain. Bangor Occasional Paper, ITE, Bangor.

Carey, P.D., Dring, J.C.M., Hill, M.O., Preston, C.D. & Sparks, T.H. (1993) Biogeographical zones: a pilot study. Unpublished report to Scottish Natural Heritage.

Digby, P.G.N. & Kempton, R.A. (1987) Multivariate analysis of ecological communities. Chapman & Hall, London.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. comps (1993) The new atlas of breeding birds in Britain and Ireland: 1988–1991. T. & A.D. Poyser, London.

Hammond, C.O. (1983) The dragonflies of Great Britain and Ireland, ed. 2. Harley Books, Colchester.

Heath, J., Pollard, E. & Thomas, J. (1984) Atlas of Butterflies in Britain and Ireland. Viking, Harmondsworth.

Hill, M.O., Preston, C.D. & Smith, A.J.E., eds (1991) Atlas of the bryophytes of Britain and Ireland. Vol. 1. Liverworts (Hepaticae and Anthocerotae). Harley Books, Colchester.

Hill, M.O., Preston, C.D. & Smith, A.J.E., eds (1992) Atlas of the bryophytes of Britain and Ireland. Vol. 2. Mosses (except the Diplolepideae). Harley Books, Colchester.

Hill, M.O., Preston, C.D. & Smith, A.J.E., eds (1994) Atlas of the bryophytes of Britain and Ireland. Vol. 3. Mosses (Diplolepideae). Harley Books, Colchester.

Kerney, M.P. ed. (1976) Atlas of the non–marine mollusca of the British Isles. Institute of Terrestrial Ecology, Cambridge.

Long, D.G. (1975) The summer meeting, 1974. Caithness. Bulletin of the British Bryological Society **25**, 4–6.

Marshall, J.A. & Haes, E.C.M. (1988) Grasshoppers and allied insects of Great Britain and Ireland. Harley Books, Colchester.

Moss, D. (1985) An initial classification of 10–km squares in Great Britain from a land characteristic data base. Applied Geography **5**, 131–150.

Perring, F.H. & Walters, S.M. eds (1962) Atlas of the British flora. Thomas Nelson & Sons, London.

Sharrock, J.T.R. comp. (1976) The Atlas of breeding birds in Britain and Ireland. British Trust for Ornithology, Tring.

Ter Braak, C.J.F. (1986) Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology **67**, 1167–1179.

Ter Braak, C.J.F. (1988) CANOCO – a FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis, principal components analysis and redundancy analysis (version 2.1). Agricultural Mathematics Group, Wageningen.

10 ACKNOWLEDGEMENTS

The climate data has been supplied by the Climate Impacts LINK Project (Department of the Environment Contract PECD7/12/96) on behalf of the Metereological Office. We are grateful to the British Trust for Ornithology for permission to use the breeding bird data. Mrs Liz Guerin typed and compiled a complicated manuscript at short notice with efficiency and good humour.

Appendix 1

SPECIES USED IN THE ANALYSIS

BIRDS

Accipiter gentilis
Accipiter nisus
Acrocephalus schoenobaenus
Acrocephalus scirpaceus
Actitis hypoleucos
Aegithalos caudatus
Alauda arvensis
Alcedo atthis
Anas acuta
Anas clypeata
Anas crecca
Anas penelope
Anas platyrhynchos
Anas querquedula
Anas strepera
Anthus petrosus
Anthus pratensis
Anthus trivialis
Apus apus
Aquila chrysaetos
Ardea cinerea
Asio flammeus
Asio otus
Athene noctua
Aythya ferina
Aythya fuligula
Aythya marila
Bucephala clangula
Buteo buteo
Calidris alpina
Calidris temminckii
Caprimulgus europaeus
Carduelis cannabina
Carduelis carduelis
Carduelis chloris
Carduelis flammea
Carduelis flavirostris
Carduelis spinus
Certhia familiaris
Charadrius dubius
Charadrius hiaticula
Charadrius morinellus
Cinclus cinclus
Circus aeruginosus
Circus cyaneus
Coccothraustes coccothraustes
Columba oenas
Columba palumbus
Corvus corax
Corvus corone
Corvus frugilegus
Corvus monedula
Coturnix coturnix
Crex crex
Cuculus canorus
Cygnus cygnus

Cygnus olor
Delichon urbica
Dendrocopos major
Dendrocopos minor
Emberiza citrinella
Emberiza schoeniclus
Erithacus rubecula
Falco columbarius
Falco peregrinus
Falco subbuteo
Falco tinnunculus
Ficedula hypoleuca
Fringilla coelebs
Fringilla montifringilla
Fulica atra
Gallinago gallinago
Gallinula chloropus
Garrulus glandarius
Gavia arctica
Gavia stellata
Haematopus ostralegus
Hirundo rustica
Jynx torquilla
Lagopus lagopus
Lagopus mutus
Lanius collurio
Larus canus
Larus ridibundus
Limosa limosa
Locustella naevia
Loxia curvirostra
Luscinia svecica
Melanitta nigra
Mergus merganser
Mergus serrator
Miliaria calandra
Motacilla alba
Motacilla cinerea
Motacilla flava
Muscicapa striata
Numenius arquata
Numenius phaeopus
Oenanthe oenanthe
Parus ater
Parus caeruleus
Parus cristatus
Parus major
Parus montanus
Parus palustris
Passer domesticus
Passer montanus
Perdix perdix
Phalaropus lobatus
Phasianus colchicus
Phoenicurus phoenicurus
Phylloscopus collybita
Phylloscopus sibilatrix
Phylloscopus trochilus
Pica pica
Picus viridis
Plectrophenax nivalis
Pluvialis apricaria
Podiceps cristatus
Porzana porzana
Prunella modularis

Pyrrhocorax pyrrhocorax
Pyrrhula pyrrhula
Rallus aquaticus
Regulus regulus
Riparia riparia
Saxicola rubetra
Saxicola torquata
Scolopax rusticola
Sitta europaea
Sterna hirundo
Streptopelia decaocto
Streptopelia turtur
Strix aluco
Sturnus vulgaris
Sylvia atricapilla
Sylvia borin
Sylvia communis
Sylvia curruca
Tachybaptus ruficollis
Tetrao tetrix
Tetrao urogallus
Tringa glareola
Tringa nebularia
Tringa ochropus
Tringa totanus
Troglodytes troglodytes
Turdus iliacus
Turdus merula
Turdus philomelos
Turdus pilaris
Turdus torquatus
Turdus viscivorus
Tyto alba
Vanellus vanellus

MOLLUSCS

Acanthinula aculeata
Acicula fusca
Acroloxus lacustris
Aegopinella nitidula
Aegopinella pura
Ancylus fluviatilis
Anisus leucostoma
Anisus vortex
Anodonta anatina
Anodonta cygnea
Aplexa hypnorum
Arianta arbustorum
Arion circumscriptus
Arion fasciatus agg.
Arion hortensis agg.
Arion intermedius
Arion owenii
Arion silvaticus
Arion subfuscus
Armiger crista
Ashfordia granulata
Azeca goodalli
Balea perversa
Bathyomphalus contortus
Bithynia leachi
Bithynia tentaculata
Candidula intersecta

Carychium minimum
Carychium tridentatum
Cepaea hortensis
Cepaea nemoralis
Cernuella virgata
Clausilia bidentata
Clausilia dubia
Cochlicella acuta
Cochlicopa lubrica
Cochlicopa lubricella
Cochlodina laminata
Columella aspera
Columella edentula
Deroceras agreste
Deroceras laeve
Deroceras reticulatum
Discus rotundatus
Dreissena polymorpha
Ena obscura
Euconulus fulvus agg.
Gyraulus albus
Gyraulus laevis
Helicella itala
Helix aspersa
Hippeutis complanatus
Lauria cylindracea
Leiostyla anglica
Leucophytia bidentata
Limax cinereoniger
Limax marginatus
Limax maximus
Limax tenellus
Lymnaea auricularia
Lymnaea glabra
Lymnaea palustris
Lymnaea peregra
Lymnaea stagnalis
Lymnaea truncatula
Margaritifera margaritifera
Monacha cantiana
Nesovitrea hammonis
Oxychilus alliarius
Oxychilus cellarius
Oxychilus draparnaudi
Oxychilus helveticus
Oxyloma pfeifferi
Physa fontinalis
Pisidium amnicum
Pisidium casertanum
Pisidium conventus
Pisidium henslowanum
Pisidium hibernicum
Pisidium lilljeborgii
Pisidium milium
Pisidium nitidum
Pisidium obtusale
Pisidium personatum
Pisidium pulchellum
Pisidium subtruncatum
Planorbarius corneus
Planorbis carinatus
Planorbis planorbis
Potamopyrgus jenkinsi
Punctum pygmaeum
Pupilla muscorum

Pyramidula rupestris
Spermodea lamellata
Sphaerium corneum
Sphaerium lacustre
Succinea oblonga
Succinea putris
Theodoxus fluviatilis
Trichia hispida
Trichia striolata
Vallonia costa
Vallonia excentrica
Vallonia pulchella
Valvata cristata
Valvata piscinalis
Vertigo alpestris
Vertigo antivertigo
Vertigo lilljeborgi
Vertigo pusilla
Vertigo pygmaea
Vertigo substriata
Vitrea contracta
Vitrea crystallina
Vitrina pellucida
Zenobiella subrufescens
Zonitoides excavatus
Zonitoides nitidus

VASCULAR PLANT (SET 1)

Achillea millefolium
Agrimonia eupatoria
Agrostis capillaris
Alchemilla alpina
Alchemilla glabra
Alliaria petiolata
Alopecurus aequalis
Alopecurus myosuroides
Alopecurus pratensis
Andromeda polifolia
Anthemis arvensis
Armeria maritima
Artemisia norvegica
Asplenium septentrionale
Aster tripolium
Atriplex laciniata
Barbarea vulgaris
Betula nana
Blysmus compressus
Botrychium lunaria
Bromopsis benekenii
Bromus lepidus
Bromus racemosus
Bryonia dioica
Cakile maritima
Callitriche hamulata sens.lat.
Callitriche stagnalis sens.lat.
Carex caryophyllea
Carex diandra
Carex flacca
Carex hirta
Carex microglochin
Carex muricata subsp.lamprocarpa
Carex nigra
Carex pilulifera

Carex punctata
Carex remota
Carex strigosa
Carex vaginata
Centaurea cyanus
Centaurium littorale
Cephalanthera longifolia
Cerastium alpinum
Cerastium diffusum
Cerastium glomeratum
Cerastium semidecandrum
Chenopodium ficifolium
Chrysanthemum segetum
Chrysosplenium alternifolium
Chrysosplenium oppositifolium
Cicuta virosa
Cirsium arvense
Clematis vitalba
Cochlearia anglica
Coeloglossum viride
Crepis biennis
Crepis mollis
Crepis paludosa
Dactylorhiza majalis
Deschampsia cespitosa
Dipsacus fullonum
Draba muralis
Elatine hexandra
Elytrigia juncea
Empetrum nigrum
Epilobium alsinifolium
Epilobium parviflorum
Epipactis palustris
Equisetum variegatum
Erica cinerea
Erigeron borealis
Euphorbia helioscopia
Euphorbia paralias
Festuca arundinacea
Festuca gigantea
Fragaria vesca
Fumaria bastardii
Galeopsis speciosa
Galium palustre
Galium sterneri
Galium uliginosum
Galium verum
Gentiana nivalis
Glaux maritima
Gnaphalium supinum
Gnaphalium sylvaticum
Gnaphalium uliginosum
Hedera helix
Helleborus viridis
Heracleum sphondylium
Holcus lanatus
Huperzia selago
Iris foetidissima
Jasione montana
Juncus inflexus
Lamium confertum
Lamium purpureum
Lavatera arborea
Lemna gibba
Lepidium campestre

Leucanthemum vulgare
Limonium humile
Linnaea borealis
Linum perenne
Luzula campestris
Luzula pilosa
Luzula sylvatica
Lychnis alpina
Lychnis flos-cuculi
Melampyrum pratense
Mentha arvensis
Moehringia trinervia
Myosotis arvensis
Myosotis laxa
Myosoton aquaticum
Myrica gale
Nardus stricta
Onopordum acanthium
Orchis morio
Orobanche minor
Osmunda regalis
Persicaria lapathifolia
Plantago major
Plantago maritima
Poa nemoralis
Polygala vulgaris
Potamogeton coloratus
Potamogeton natans
Potamogeton perfoliatus
Potamogeton polygonifolius
Potamogeton trichoides
Potentilla anserina
Potentilla fruticosa
Potentilla rupestris
Primula veris
Prunella vulgaris
Prunus spinosa
Ranunculus flammula
Ranunculus peltatus
Ranunculus penicillatus
Ranunculus reptans
Ribes uva-crispa
Rorippa palustris
Rumex acetosella
Rumex hydrolapathum
Rumex pulcher
Rumex sanguineus
Sagittaria sagittifolia
Salicornia europaea
Salix repens
Salvia horminoides
Sambucus nigra
Sanguisorba officinalis
Sanicula europaea
Saxifraga nivalis
Saxifraga tridactylites
Scandix pecten-veneris
Schoenoplectus tabernaemontani
Scirpus sylvaticus
Scutellaria galericulata
Sedum acre
Senecio erucifolius
Serratula tinctoria
Sisymbrium officinale
Sorbus pseudofennica

Sorbus rupicola
Spartina anglica
Spiranthes romanzoffiana
Stachys arvensis
Stellaria holostea
Stellaria media
Stellaria neglecta
Torilis nodosa
Tragopogon pratensis
Trifolium dubium
Trifolium fragiferum
Trifolium micranthum
Trifolium pratense
Triglochin maritima
Tripleurospermum inodorum
Tripleurospermum maritimum
Trollius europaeus
Ulex gallii
Ulmus glabra
Urtica dioica
Utricularia vulgaris
Vaccinium microcarpum
Vaccinium vitis-idaea
Valeriana officinalis
Valerianella dentata
Valerianella locusta
Valerianella rimosa
Veronica alpina
Veronica scutellata
Vicia orobus
Viola odorata
Viola riviniana
Vulpia myuros
Woodsia ilvensis
Zostera noltii

VASCULAR PLANT (SET 2)

Achillea ptarmica
Agrimonia procera
Agrostis stolonifera
Aira caryophyllea
Ajuga pyramidalis
Alchemilla glomerulans
Alisma plantago-aquatica
Allium oleraceum
Alopecurus borealis
Anemone nemorosa
Anisantha sterilis
Anthriscus sylvestris
Anthyllis vulneraria
Arabidopsis thaliana
Arabis alpina
Arabis hirsuta
Arctium minus agg.
Artemisia vulgaris
Asperula cynanchica
Asplenium obovatum subsp.lanceolatum
Atriplex patula
Bellis perennis
Betula pendula
Brassica nigra
Butomus umbellatus
Calamagrostis stricta

Calluna vulgaris
Caltha palustris
Calystegia sepium sens.lat.
Campanula glomerata
Capsella bursa-pastoris
Cardamine amara
Carduus crispus
Carex acuta
Carex acutiformis
Carex atrofusca
Carex bigelowii
Carex buxbaumii
Carex extensa
Carex laevigata
Carex pallescens
Carex saxatilis
Carex sylvatica
Catapodium marinum
Centaurea scabiosa
Cerastium arvense
Cerastium nigrescens
Ceterach officinarum
Chenopodium murale
Cladium mariscus
Conopodium majus
Crambe maritima
Crassula aquatica
Crataegus monogyna
Cynoglossum germanicum
Cytisus scoparius
Dactylorhiza praetermissa
Digitalis purpurea
Drosera intermedia
Drosera rotundifolia
Dryopteris dilatata
Eleocharis multicaulis
Epilobium montanum
Epilobium roseum
Epipactis helleborine
Equisetum palustre
Equisetum pratense
Erigeron acer
Eriophorum latifolium
Erodium maritimum
Eupatorium cannabinum
Frangula alnus
Fraxinus excelsior
Gagea lutea
Galeopsis angustifolia
Galium album
Galium aparine
Galium mollugo
Galium saxatile
Galium tricornutum
Geranium pyrenaicum
Geranium sanguineum
Glyceria declinata
Glyceria fluitans
Glyceria notata
Groenlandia densa
Gymnadenia conopsea
Hammarbya paludosa
Hierochloe odorata
Hydrocotyle vulgaris
Hymenophyllum tunbrigense

Hypericum pulchrum
Hypochaeris radicata
Juncus bulbosus sens.lat.
Juncus compressus
Juncus gerardi
Juncus maritimus
Juncus trifidus
Kobresia simpliciuscula
Lathraea squamaria
Lathyrus sylvestris
Leymus arenarius
Limonium vulgare
Lithospermum arvense
Loiseleuria procumbens
Lolium perenne
Luzula spicata
Lysimachia nemorum
Malus sylvestris
Melica nutans
Melica uniflora
Mercurialis perennis
Narcissus pseudonarcissus
Narthecium ossifragum
Neottia nidus-avis
Nepeta cataria
Nuphar lutea
Oenanthe lachenalii
Ononis reclinata
Ononis spinosa
Ophioglossum vulgatum
Oxalis acetosella
Parapholis strigosa
Parnassia palustris
Pedicularis sylvatica
Petasites hybridus
Phleum alpinum
Phleum arenarium
Phragmites australis
Picris hieracioides
Pimpinella saxifraga
Plantago coronopus
Plantago media
Poa alpina
Poa annua
Polygonatum verticillatum
Polypodium vulgare sens.lat.
Potamogeton crispus
Potamogeton gramineus
Potamogeton pectinatus
Primula farinosa
Pseudorchis albida
Pulicaria dysenterica
Pyrola media
Quercus robur
Ranunculus acris
Ranunculus aquatilis
Ranunculus arvensis
Ranunculus baudotii
Ranunculus bulbosus
Ranunculus fluitans
Ranunculus repens
Rhynchospora fusca
Rumex crispus
Sagina nivalis
Sagina nodosa

Sagina saginoides
Salicornia nitens
Salix fragilis
Salix lapponum
Salix pentandra
Salix purpurea
Saxifraga hypnoides
Saxifraga oppositifolia
Saxifraga stellaris
Scheuchzeria palustris
Scilla verna
Scrophularia auriculata
Scutellaria minor
Sedum villosum
Senecio sylvaticus
Sesleria caerulea
Silene dioica
Silene nutans
Solidago virgaurea
Sonchus arvensis
Spergularia rubra
Spirodela polyrhiza
Stachys sylvatica
Subularia aquatica
Symphytum tuberosum
Tanacetum vulgare
Thymus pulegioides
Trifolium campestre
Umbilicus rupestris
Vaccinium myrtillus
Vaccinium oxycoccos
Vaccinium uliginosum
Valerianella carinata
Verbascum nigrum
Verbascum thapsus
Veronica agrestis
Veronica catenata
Vicia bithynica
Vicia lathyroides
Vicia sativa
Vicia tetrasperma
Viola hirta
Viola lutea
Viola tricolor

MOSSES

Acaulon muticum
Aloina brevirostris
Amblystegium tenax
Andreaea alpina
Andreaea blyttii
Andreaea nivalis
Andreaea rothii
Anoectangium warburgii
Anomodon longifolius
Aplodon wormskjoldii
Atrichum angustatum
Atrichum undulatum
Barbula icmadophila
Barbula sinuosa
Bartramia pomiformis
Bartramia stricta
Blindia acuta

Brachythecium erythrorrhizon
Brachythecium glaciale
Brachythecium mildeanum
Brachythecium reflexum
Brachythecium rivulare
Bryum alpinum
Bryum argenteum
Bryum bornholmense
Bryum caespiticium
Bryum capillare
Bryum gemmiferum
Bryum lawersianum
Bryum pallens
Bryum riparium
Bryum salinum
Bryum sauteri
Bryum torquescens
Calliergon cuspidatum
Calliergon giganteum
Campylium chrysophyllum
Campylium halleri
Campylium stellatum var. protensum
Campylopus brevipilus
Campylopus fragilis
Campylopus introflexus
Campylopus schimperi
Ceratodon purpureus
Cratoneuron filicinum
Cynodontium bruntonii
Cynodontium polycarpon
Cynodontium strumiferum
Cynodontium tenellum
Dichodontium flavescens
Dichodontium pellucidum
Dicranella grevilleana
Dicranella heteromalla
Dicranella rufescens
Dicranella varia
Dicranodontium asperulum
Dicranum glaciale
Dicranum tauricum
Ditrichum heteromallum
Ditrichum lineare
Encalypta alpina
Encalypta brevicollis
Encalypta ciliata
Ephemerum serratum
Eucladium verticillatum
Eurhynchium speciosum
Fissidens adianthoides
Fissidens crassipes
Fissidens incurvus
Fissidens rufulus
Fissidens viridulus sensu lato
Fontinalis antipyretica
Funaria attenuata
Funaria muhlenbergii
Glyphomitrium daviesii
Grimmia anodon
Grimmia atrata
Grimmia decipiens
Grimmia hartmanii
Grimmia laevigata
Grimmia montana
Grimmia orbicularis

Grimmia retracta
Grimmia trichophylla
Grimmia unicolor
Gymnostomum calcareum
Habrodon perpusillus
Herzogiella striatella
Heterocladium heteropterum var. heteropterum
Homalothecium lutescens
Homalothecium nitens
Homalothecium sericeum
Homomallium incurvatum
Hygrohypnum eugyrium
Hygrohypnum molle
Hygrohypnum polare
Hylocomium brevirostre
Hylocomium pyrenaicum
Hypnum mammillatum
Isopterygiopsis muellerana
Isopterygium elegans
Leptodontium flexifolium
Leptodontium recurvifolium
Lescuraea patens
Leskea polycarpa
Leucodon sciuroides
Mielichhoferia elongata
Mnium ambiguum
Mnium hornum
Myurella tenerrima
Myurium hochstetteri
Orthothecium rufescens
Orthotrichum cupulatum
Orthotrichum diaphanum
Orthotrichum gymnostomum
Orthotrichum lyellii
Orthotrichum obtusifolium
Orthotrichum rivulare
Orthotrichum speciosum
Orthotrichum stramineum
Orthotrichum tenellum
Philonotis arnellii
Philonotis calcarea
Philonotis seriata
Philonotis tomentella
Physcomitrium sphaericum
Plagiobryum zieri
Plagiomnium affine
Plagiothecium cavifolium
Plagiothecium denticulatum
Plagiothecium piliferum
Plagiothecium platyphyllum
Plagiothecium ruthei
Platydictya confervoides
Pleuridium acuminatum
Pleurozium schreberi
Pohlia annotina
Pohlia camptotrachela
Pohlia carnea
Pohlia crudoides
Pohlia obtusifolia
Polytrichum alpinum
Polytrichum commune
Pottia bryoides
Pottia davalliana
Pottia starkeana ssp. starkeana
Pseudobryum cinclidioides

Pseudoleskeella catenulata var. acuminata
Pterigynandrum filiforme
Pterygoneurum lamellatum
Ptilium crista-castrensis
Ptychomitrium polyphyllum
Pylaisia polyantha
Racomitrium ellipticum
Racomitrium fasciculare
Racomitrium lanuginosum
Rhizomnium pseudopunctatum
Rhizomnium punctatum
Rhodobryum roseum
Rhynchostegium megapolitanum
Rhynchostegium murale
Rhynchostegium riparioides
Rhytidiadelphus triquetrus
Rhytidium rugosum
Schistidium alpicola
Schistidium apocarpum
Schistidium boreale
Schistidium trichodon
Scleropodium cespitans
Scleropodium tourettii
Scorpidium scorpioides
Seligeria acutifolia
Seligeria trifaria
Sphagnum capillifolium
Sphagnum fimbriatum
Sphagnum lindbergii
Sphagnum magellanicum
Sphagnum majus
Sphagnum molle
Sphagnum palustre
Sphagnum pulchrum
Sphagnum subsecundum sensu lat.
Sphagnum teres
Splachnum sphaericum
Tetraphis pellucida
Tetraplodon angustatus
Timmia austriaca
Timmia norvegica
Tortella densa
Tortella limosella
Tortella tortuosa
Tortula laevipila
Tortula papillosa
Ulota calvescens
Ulota coarctata
Ulota hutchinsiae
Ulota phyllantha
Weissia microstoma var. microstoma
Weissia rutilans
Weissia tortilis
Zygodon conoideus

LIVERWORTS

Acrobolbus wilsonii
Adelanthus decipiens
Anastrepta orcadensis
Anastrophyllum donnianum
Anastrophyllum hellerianum
Anastrophyllum joergensenii
Anastrophyllum minutum

Anastrophyllum saxicola
Aneura pinguis
Anthelia julacea
Anthelia juratzkana
Anthoceros agrestis
Anthoceros punctatus
Aphanolejeunea microscopica
Apometzgeria pubescens
Barbilophozia atlantica
Barbilophozia attenuata
Barbilophozia barbata
Barbilophozia floerkei
Barbilophozia hatcheri
Barbilophozia kunzeana
Barbilophozia lycopodioides
Barbilophozia quadriloba
Bazzania pearsonii
Bazzania tricrenata
Bazzania trilobata
Blasia pusilla
Blepharostoma trichophyllum
Calypogeia arguta
Calypogeia azurea
Calypogeia fissa
Calypogeia integristipula
Calypogeia muelleriana
Calypogeia neesiana
Calypogeia sphagnicola
Calypogeia suecica
Cephalozia ambigua
Cephalozia bicuspidata
Cephalozia catenulata
Cephalozia connivens
Cephalozia leucantha
Cephalozia loitlesbergeri
Cephalozia lunulifolia
Cephalozia macrostachya
Cephalozia pleniceps
Cephaloziella divaricata
Cephaloziella hampeana
Cephaloziella rubella
Cephaloziella stellulifera
Cephaloziella turneri
Chiloscyphus polyanthos var. pallescens
Chiloscyphus polyanthos var. polyanthos
Cladopodiella fluitans
Cladopodiella francisci
Cololejeunea calcarea
Cololejeunea minutissima
Cololejeunea rossettiana
Colura calyptrifolia
Conocephalum conicum
Cryptothallus mirabilis
Diplophyllum albicans
Diplophyllum obtusifolium
Diplophyllum taxifolium
Douinia ovata
Drepanolejeunea hamatifolia
Dumortiera hirsuta
Eremonotus myriocarpus
Fossombronia angulosa
Fossombronia foveolata
Fossombronia incurva
Fossombronia pusilla
Fossombronia wondraczekii

Frullania dilatata
Frullania fragilifolia
Frullania microphylla
Frullania tamarisci
Frullania teneriffae
Geocalyx graveolens
Gymnocolea inflata
Gymnomitrion apiculatum
Gymnomitrion concinnatum
Gymnomitrion corallioides
Gymnomitrion crenulatum
Gymnomitrion obtusum
Haplomitrium hookeri
Harpalejeunea ovata
Harpanthus flotovianus
Harpanthus scutatus
Herbertus aduncus ssp. hutchinsiae
Herbertus borealis
Herbertus stramineus
Hygrobiella laxifolia
Jamesoniella autumnalis
Jamesoniella undulifolia
Jubula hutchinsiae
Jungermannia atrovirens
Jungermannia borealis
Jungermannia confertissima
Jungermannia exsertifolia ssp. cordifolia
Jungermannia gracillima
Jungermannia hyalina
Jungermannia leiantha
Jungermannia obovata
Jungermannia paroica
Jungermannia polaris
Jungermannia pumila
Jungermannia sphaerocarpa
Jungermannia subelliptica
Kurzia pauciflora
Kurzia sylvatica
Kurzia trichoclados
Leiocolea alpestris
Leiocolea badensis
Leiocolea bantriensis
Leiocolea gillmanii
Leiocolea heterocolpos
Leiocolea turbinata
Lejeunea cavifolia
Lejeunea holtii
Lejeunea lamacerina
Lejeunea mandonii
Lejeunea patens
Lejeunea ulicina
Lepidozia cupressina
Lepidozia pearsonii
Lepidozia reptans
Leptoscyphus cuneifolius
Lophocolea bidentata
Lophocolea bispinosa
Lophocolea fragrans
Lophocolea heterophylla
Lophocolea semiteres
Lophozia bicrenata
Lophozia excisa
Lophozia incisa
Lophozia longidens
Lophozia obtusa

Lophozia opacifolia
Lophozia sudetica
Lophozia ventricosa
Lophozia wenzelii
Lunularia cruciata
Marchantia polymorpha
Marchesinia mackaii
Marsupella adusta
Marsupella alpina
Marsupella boeckii var.boeckii
Marsupella boeckii var.stableri
Marsupella brevissima
Marsupella condensata
Marsupella emarginata
Marsupella funckii
Marsupella sparsifolia
Marsupella sphacelata
Marsupella sprucei
Mastigophora woodsii
Metzgeria conjugata
Metzgeria fruticulosa
Metzgeria furcata
Metzgeria leptoneura
Metzgeria temperata
Moerckia blyttii
Moerckia hibernica
Mylia anomala
Mylia taylorii
Nardia breidleri
Nardia compressa
Nardia geoscyphus
Nardia scalaris
Nowellia curvifolia
Odontoschisma denudatum
Odontoschisma elongatum
Odontoschisma macounii
Odontoschisma sphagni
Pellia endiviifolia
Pellia epiphylla
Pellia neesiana
Petalophyllum ralfsii
Phaeoceros laevis
Plagiochila asplenioides
Plagiochila atlantica
Plagiochila carringtonii
Plagiochila exigua
Plagiochila killarniensis
Plagiochila porelloides
Plagiochila punctata
Plagiochila spinulosa
Pleurocladula albescens
Pleurozia purpurea
Porella arboris-vitae
Porella cordaeana
Porella obtusata
Porella platyphylla
Preissia quadrata
Ptilidium ciliare
Ptilidium pulcherrimum
Radula aquilegia
Radula carringtonii
Radula complanata
Radula lindenbergiana
Radula voluta
Reboulia hemisphaerica

Riccardia chamedryfolia
Riccardia incurvata
Riccardia latifrons
Riccardia multifida
Riccardia palmata
Riccia beyrichiana
Riccia canaliculata
Riccia cavernosa
Riccia crystallina
Riccia glauca
Riccia huebeneriana
Riccia sorocarpa
Riccia subbifurca
Saccogyna viticulosa
Scapania aequiloba
Scapania aspera
Scapania calcicola
Scapania compacta
Scapania cuspiduligera
Scapania degenii
Scapania gracilis
Scapania gymnostomophila
Scapania irrigua
Scapania nemorea
Scapania nimbosa
Scapania ornithopodioides
Scapania paludosa
Scapania scandica
Scapania subalpina
Scapania uliginosa
Scapania umbrosa
Scapania undulata
Sphenolobopsis pearsonii
Targionia hypophylla
Tetralophozia setiformis
Trichocolea tomentella
Tritomaria exsecta
Tritomaria exsectiformis
Tritomaria polita
Tritomaria quinquedentata