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INSTITUTE OF TERRESTRIAL ECOLOGY

(NATURAL ENVIRONMENT RESEARCH COUNCIL)

NERC/NCC CONTRACT NO. HF3/03/61

ITE PROJECT NO. 340

SCOTTISH COASTAL SURVEY

MAIN REPORT

A Report on Selected Soft Coast
Sites in Scotland

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MAY 1983

SUMMARY

Background

The mounting pressure of industrial developments on the Scottish coast in the early and mid-seventies, e.g. the building of the Nigg Bay graving dock and the Dunnet Public Enquiry, along with increased recreational use, highlighted the lack of information about a series of important coastal habitats. In general, it was the low-lying, soft coast composed of sand, shingle or mud that was most affected by these changes. Since that time some threats have diminished and new ones have emerged, e.g. the EEC funded Western Isles Integrated Development Programme, and conservation of the Scottish coast is likely to be a continuing problem.

In order to obtain more information about what were thought to be the most scientifically important or vulnerable areas, the Nature Conservancy Council in 1975 commissioned the Institute of Terrestrial Ecology to conduct a survey of selected sites on the Scottish Coast. The objectives of the survey were:

i) To determine the nature and extent of the main habitat divisions and the composition of the vegetation within each of the areas specified by NCC.

ii) To carry out the above investigation in a way that would allow objective comparisons to be made between individual sites.

iii) To determine the presence of rare or localized vegetation types and plant species within each specified site.

iv) To assess subjectively the extent to which sites are currently being affected by human activities of various kinds.

The method of survey was specifically designed by ITE to meet these objectives and can conveniently be divided into two parts;

a) the quadrat survey, and
b) the supplementary survey.

The quadrat survey involved the recording of data (plants, habitats, environment, soil and human activities) from a series of representative areas at each site. However, because this type of extensive survey inevitably has a rather low sampling intensity, i.e. about 0.3% in most sites but up to 3.8% in some smaller ones, it was appreciated this might not adequately serve objective iii), viz. the detection of rare phenomena. In consequence, the supplementary survey was added to meet this specific requirement. A coastal specialist (Dr D S Ranwell) aimed personally to visit all sites in order to locate rare habitats and plants that might not be recorded in the quadrat survey. The results of the supplementary survey are presented in full in the Site Dossiers where they take the form of general site descriptions (Section 2) and as records and annotations in the section on species of interest (Section 5.1.4). Information from the supplementary survey was also used in the preparation of the maps of vascular plant distributions given in Appendix 3. Other information on

specific topics such as field methods, bryophytes, lichens and specifications for the data bank produced by the survey have been prepared as separately bound appendices to the Main Report. A list of appendices and their contents appears in Section 1 of the this report.

Main Report

The Main Report is exclusively concerned with the data obtained in the quadrat survey and the various analyses and interpretations developed therefrom.

Sections 1 and 2

The early part of the report describes the background to the project, i.e. the needs of NCC and how these were taken into account in the design and conduct of the survey. Because of its specific requirement for information on sites, it was the responsibility of NCC to select the areas to be surveyed. This was done in consultation with Regional Staff, who also assisted in the definition of the site boundaries. Over 100 sites were originally considered but this number was reduced to 94 when it was found that some had already been virtually destroyed by human activities, e.g. all sites on the Ayrshire coast. The distribution of the sites actually surveyed is shown in Figure 1 and the names are given in Table 1.

Section 3

This section describes the organization of the project. The field survey phase was spread over three years, from 1975 to 1977. A detailed Handbook of Field Methods (Appendix 2) was prepared at the beginning of the project and improved with increasing experience. At the start of each field season, a training course for prospective survey team leaders was held. Trainees who did not achieve the necessary standards of proficiency were rejected. All team leaders were recruited from ITE permanent staff, with the exception of one scientist from NERC Headquarters in 1977. Also, one post-graduate student, after considerable experience as an assistant, was used briefly in the role of a leader. Casual labour was only employed at field assistant level. By these means a high standard of data collection was maintained.

Section 4

The development of the survey method is described in this section, where the various sampling techniques employed are critically examined. The field trial of the survey methods at Gullane in May 1975 involved a complex stratified sampling technique but this was quickly replaced by a much simpler system that was used for the rest of 1975. At the end of the first year, the method of stratification was shown to have conferred no advantage, indeed, in a few cases it was mildly prejudicial. In consequence, stratified sampling was abandoned in favour of a restricted random sample which was used for the rest of the survey (1976 and 1977). This change is of little immediate significance to the results of the survey but has some implications if additional sampling is envisaged.

An important feature of the organization of the project was that all team leaders were given carefully defined responsibilities for their participation in the work. For example, each team leader had to submit a comprehensive herbarium, both to show that they could identify the common species correctly and also to enable the identity of more difficult material to be checked. The extensive herbarium thus produced is maintained at ITE's Bangor Research Station and is available for consultation. As an additional control of data quality, each team leader was held responsible for checking the transcription of his or her data from field sheets to machine readable form.

Section 5

This section deals with the difficulties encountered in the survey and the limitations that must be placed on the data obtained. Such matters as the choice of sites, their precise boundaries and the influence these decisions had on the outcome of the survey are discussed. The effect of seasonal changes over an extended field season (May to September), sampling intensity and the reliability of the cover data also come under close scrutiny.

Section 6

Finally, in what may be described as the pre-amble to the Main Report, the aims and methods of analyses are discussed in some detail. The interpretation of the numerous data collected in the survey essentially rests on the ability to erect successful classifications for both vegetation and site types. Initially, great difficulties were encountered in the production of a vegetation classification using the currently available methods. An early attempt at a vegetation classification was devised and tested at the Field Course for NCC Staff held at Dunnet in 1978. This classification proved to have a number of unsatisfactory features, the most important being unreliability of the dichotomous key by which it could be generalized, i.e. identification of vegetation types in the field using the key was subject to errors. Subsequent work lead to a satisfactory solution of this problem, resulting in a sensitive and ecologically sound vegetation classification and a completely accurate key (see Section 7). Key accuracy was achieved by a re-allocation procedure and it should be noted that the resultant key has multiple paths, i.e. a given vegetation type may be identified by more than one route throughout the key. The parts of a vegetation type that are isolated by different routes in the key have been termed "forms". In some cases, a form is equivalent to what is often called a "facie".

In general, the site classification presented fewer problems than that for the vegetation. Two apparently contrasting approaches to site classification were considered on theoretical grounds. Both were tried and found to produce essentially the same result. However, one of the analyses, that based on species frequency, showed a more clear-cut geographical distribution of sites in those site types in which within-type variation was least - in this case, Site Types 1 and 2 which mostly occur in the Outer Hebrides. This solution was chosen and is reported on at some length in Section 8.

Section 7

Section 7 marks the beginning of the "results" of the survey. It includes description and ecological interpretation of the vegetation classification. This classification, which is based on 3,847 quadrats from the 94 sites, identifies 28 vegetation types, not including bare ground (166 quadrats) and unclassifiable quadrats (only four in number). The vegetation types have been grouped into seven distinct families which can be further amalgamated into three "orders" - to use the taxonomic analogy. Each vegetation type has been given a descriptive name with both short and long versions (the latter listing the main dominant vascular plants). They may also be referred to by a letter/number mnemonic based on the family name. The arrangement of orders, families and types is as follows:

'Order' 1 - Non-maritime vegetation types with four families.

- Family i) - Colonist, with one vegetation type (C), 217 out of 3,847 quadrats or 5.6%.
- Family ii) - Duneland, with six vegetation types (D1-D6), 1,993 quadrats or 51.8%.
- Family iii) - Grassland with seven vegetation types (G1-G6), 961 quadrats or 25.0%.
- Family iv) - Peatland with three types (P1-P3), 155 quadrats or 4.0%.

'Order' 2 - Types influenced by freshwater with one family.

- Family i) - Marshland, with four vegetation type (M1-M4), 134 quadrats or 3.5%.

'Order' 3 - Maritime vegetation types with two families.

- Family i) - Saltmarsh, with five vegetation types (S1-S5), 180 quadrats or 4.7%.
- Family ii) - Foredune, with two vegetation types (F1-F2), 37 quadrats or 1.0%.

In addition to these "true" vegetation types, a Bare ground (B) category, i.e. no vascular plants present, comprises 166 quadrats or 4.3%. The four unclassifiable quadrats (see above) have been given the mnemonic "U".

Non-maritime vegetation types account for the majority of quadrats (86.5%) recorded in the survey. Even within this order, Duneland vegetation types are by far the commonest, with over half the quadrats (51.8%). One member of the Duneland family, base-rich dune grassland D1, accounts for 28.6% of the total population.

The first and most obvious feature to be noted about the vegetation types is that most of them have a characteristic geographical distribution, e.g. base-rich dune grassland D1 in the west and north and slightly acid dune grassland D2 in the east. The Duneland type D4 and the Grassland types G1 and G2, in the north and west, and the Grassland types G3 and G4, in the east, follow a similar geographical distribution. Other vegetation types are more widespread and this can usually be explained in terms of a particular environmental factor which tends to dominate the more general, geographically linked factors such as climate, sand type and land-use. For example, colinizing communities C and semi-stable dune grassland D3 are related to instability of the substrate simply because this factor tends to dominate the conditions for plant growth wherever it occurs. As far as these two vegetation types are concerned, it seems to matter little whether the substrate contains free calcium carbonate or not (shell sand) or whether the climate is oceanic or continental. Similarly, the members of the Saltmarsh family tend to be widespread because the influence of saltwater inundation dominates all other environmental factors. Some widespread vegetation types are dependent on more specialized habitats such as those found in the vicinity of streams and freshwater bodies, e.g. wet, slightly acid dune grassland D5.

The main aim in the interpretation of the vegetation types is to identify the dynamic relationships or environmental trends that underly the classification. There are diagrams showing the putative relationships of the vegetation types contained within each 'Order' (Figure 3, 4 and 5). In some cases there is good evidence, from a wide range of data, for the suggested relationship between vegetation types, whilst it is more tenuous in others. However, it should be emphasized that the relationships, even the strong, well supported ones, are strictly hypothetical and need to verified experimentally. Many of the relationships and their underlying causes are, however, sufficiently well established to form the basis of a coherent conservation policy or to develop practical management procedures which have a high probability of success. Some relationships are the result of the well-known successional trends in sand dune systems, i.e. increased stabilization of sand and pedogenic processes (see Figure 3), whilst others are the direct result of underlying environmental trends, e.g. height in relation to tidal range and substrate type in saltmarshes (see Figure 5).

Description of the vegetation types follows a common pattern, starting with their derivation in the key and the consequent possibility of different "forms" within the type, i.e. where there are multiple outlets in the key. The most common species recorded in the type are then listed, followed by a discussion of the relationship with other vegetation types. This latter section is usually supported by tables of preferential species (i.e. species which show a frequency ratio of at least 2 to 1 for the comparison being made and with a minimum frequency of 20% in the type to which they are termed "preferential") to enable a floristic comparison to be made between the types concerned. There then follows a series of paragraphs dealing with cover and dominants, soil types, the influence of human activities and land-use, the occurrence of specialized habitats, topographical features and, finally, the geographical distribution of the vegetation type. A map showing the distribution of the type and a table listing the sites in which it occurs is included with each description. Some vegetation types are characterized by having a high probability of containing rare or sensitive species, e.g. damp, base-rich dune grassland D4 or slightly acid, damp grassland G1. Attention is drawn to such features where they are known. Further discussion of relationships or underlying causes may be presented at the end of the type description if it is an interesting or important type.

At the end of Section 7 there are a series of two-way tables showing the species composition and cover relationships of the different vegetation types. The arrangement of these tables is based on an ordination of vegetation types (order across the top of the table) and a classification of species (order down the side), the object being to obtain the best possible blocking of entries in the body of the table, i.e. analogous to traditional phytosociological tables.

Section 7 is completed by a set of instructions for the use of the dichotomous key for the identification of the vegetation types. Because of size limitations on the Main Report, the key itself is bound in a separate cover. This is also convenient for field use. Again, it should be noted that this is a multi-path key, i.e. a given vegetation type may be derived by one or more pathways through the key. In practice the number of pathways varies from 1 to 13. There are a total of 105 steps in the key with between 5 and 10 indicator species defining each step. The number of steps that have to be negotiated before reaching the appropriate vegetation type varies from 2 to 10. It should be emphasized that, unlike most keys of this kind, the vegetation type key presented here is completely free from misclassification. Providing the population definition is properly observed, i.e. it should only be applied to samples recorded on soft coast in Scotland, its use for the allocation of new samples to the established framework should be error free.

Section 8

Section 8 of the report deals with the site classification, starting with the derivation of the site classification which defines 14 site types. Each site type has been given a name based primarily on its geographical distribution but also on the the habitats it contains. Sometimes this latter part of the name refers to the dominant habitat, e.g. ST1 - West Coast Hebridean, Machair type, or it may refer to the presence of a characteristic habitat, even though this may occupy quite a small proportion of the site, e.g. ST7 - North-west Coast, bog type. As is already obvious from the previous sentence, the types may also be referred to by a mnemonic (ST1-ST14). The following is a list of the names and mnemonics, showing the number (in brackets) of sites allocated to each type.

ST1 - West Coast, Hebridean, Machair type (13 sites)
ST2 - West Coast, Hebridean, dune type (20 sites)
ST3 - North and West Coast, truncated type (7 sites)
ST4 - Northern Isles type (5 sites)
ST5 - North and West Coast, acid heath type (7 sites)
ST6 - North Coast, bayhead, well drained type (2 sites)
ST7 - North-west Coast, bog type (3 sites)
ST8 - North-west Coast, montane type (2 sites)
ST9 - East Coast, main type (14 sites)
ST10 - West Coast, acid, dwarf shrub type (7 sites)
ST11 - Hebridean Saltmarsh type (1 site)
ST12 - East Coast, truncated type (6 sites)
ST13 - East Coast, Firth type (6 sites)
ST14 - East Coast, estuarine shingle type (1 site)

Unlike the vegetation classification, no attempt has been made to arrange the various site types into higher orders or families. Nevertheless, there is an inherent structure to the site classification and this is largely manifest through a marked geographical distribution of types, i.e. site types ST1-ST8, ST10 and ST11 have a predominantly western or northern distribution, whilst ST9 and ST12-ST14 are eastern. The geographical basis of site types is evident from the first division in the site classification, i.e. ST1-ST8 are separated from ST9-ST14. The two exceptions to the western and northern versus eastern split, ST10 and ST11, can both be explained by the presence of exceptional habitats; peat bog in the case of ST10 and saltmarsh in the case of ST11. It is these features that initially cause ST10 and ST11 to be segregated with the eastern types. Several other divisions in the site classification also have strong geographical affinities. The net result is that five site types, with a total of 53 sites (56%), can be described as having a discrete geographical distribution - ST1 (13 sites), ST2 (20 sites), ST4 (5 sites), ST9 (9 sites) and ST13 (6 sites). Three site types have widespread geographical distributions, ST3 (7 sites), ST5 (7 sites) and ST10 (7 sites), giving a total of 21 sites or 22% of the population. For each of these widespread site types there is a logical explanation as to why geographically independent factors have had a dominant role in their classification. For example, ST3 is characterized by instability and truncation (limited extent of the site in a landward direction) and the peaty element in ST10 is the result of the type of landform on which these sites have developed. The remaining six site types all have less than five sites in them, so it is difficult to be certain about their geographical affinities, but the likelihood is that they are also discrete. The geographical basis of the site classification has important implications for conservation because it means that localized pressures, e.g. further development of the east coast estuaries, could virtually destroy a given type.

For some site types there is evidence of parallel western and northern as opposed to eastern development. The best example of this feature is observed for sites that are either truncated or, for some other reason, a high proportion of the site has remained unstable. The site types involved are ST3 - North and West Coast, truncated type (7 sites), which contains the northern and western representitives, and ST12 - East Coast, truncated type (6 sites), which contains the eastern equivalents. The common factor for these types is the presence of a significant proportion of unstable or semi-stable vegetation types, e.g. B, C and D3. As already noted, these are widespread vegetation types which seem to be determined by substrate instability rather than more general factors such as climate and chemical composition of the sand.

The next part of Section 8 deals with methods and types of data that were employed to interpret the site classification and identify its underlying causes. The main problem in this type of investigation is the confounding of factors. Survey data are rarely like those produced by designed experiments because there are no proper controls and the factors cannot be varied orthogonally in order to measure their effects. Even simple comparisons between classes may be weakened by their being different numbers of observations, e.g. ST1 with 20 sites as compared with ST11 and ST14 with one site each. In surveys, the various observable factors, e.g. climate, soil and even land-use, are often highly correlated but this does not mean that they are necessarily causally related. As a result, the range of combinations available for study may be strictly limited. In the case of the Coastal Survey, climate, sand type (i.e. the proportion of free calcium carbonate in the form of shell fragments) and land-use are thought to be the most important factors. The problem is that all three factors are highly correlated. The west and north of Scotland is dominated by an oceanic climatic regime, whilst in the east, the climate is more continental (dry and cold). Unfortunately, sand type follows roughly the same distribution, with shell rich sand is the west and north and siliceous sands in the east. There are a few localized exceptions and these provide the only evidence enabling the relative importance of these two factors to be inferred. The somewhat tenuous conclusion is that climate and sand type are of roughly equal importance in determining the structure of the site classification but that, independent of topographic factors, the latter may be dominant. Similar problems exist in the case of land-use, with the traditional crofting system in the west and north being a rather different from the more modern agricultural regime in the east where there is also a forestry influence. The same sort of western and northern, as opposed to eastern, pattern also exists for public pressure. In general, it is easy to observe the distribution of the various factors but it is more difficult to determine their real effect on the status of sites in the site classification.

Section 8.3 describes the overall characteristics of the site classification in terms of geographical distribution, indicator and preferential species, vegetation types, site boundaries, landforms, climate, land-use and soil types.

The main part of Section 8 is taken up by site type descriptions for the 14 site types. These descriptions adopt roughly the same pattern as those for the vegetation types but are slightly more formalized through the use of a standard series of headings. Much emphasis is placed on comparing and contrasting various features of the site types, such as the relative amounts of the vegetation type, species frequency, cover, landforms, soil types, boundaries and land-use. A map showing the distribution of sites is included with each type description.

Section 8 is completed by a set of instructions for the use of the site key which is followed by the key itself. The site key is much simpler than that for the vegetation types, consisting of 13 steps with 10 indicators per step. Each step is paired with a sheet of maps showing the geographical distribution of sites involved in that division.

Section 9

Despite the fact that it was excluded from the original contract specification for the Scottish Coastal Survey, a good deal of soil information was obtained in the course of the survey. In order to use these data properly it was found necessary to construct a simple classification of soil types. Section 9 of the report describes how this was done and gives outline descriptions for the 33 soil types thus defined. As with the vegetation classification, it was found to be useful to amalgamate the soil types into series (analogous to the vegetation type families). These were five in number, with names and mnemonics as follows:

Series 1 - Deep Sandy Soil with eight types (DS1-DS8)
Series 2 - Peaty Soils with five types (PS1-PS5)
Series 3 - Sandy Cobble Soils with seven types (CS1-CS7)
Series 4 - Thin Soils with ten types (TS1-TS10)
Series 5 - Beach Deposits with three types (BD1-BD3)

Within each series the types are numbered, as near as possible, in developmental order, i.e. usually according to the state of maturity of the soil profile. Thus, in the Deep Sandy Soil series, DS1, DS2 and DS3 are virtually pure mineral sands with no profile development and DS6, DS7 and DS8 are more mature types with a substantial proportion of humus incorporated in the profile to a depth of 40cm or more. DS4 and DS5 are intermediate. The same principle applies to the other series, except that the Thin Soil series is largely ordered according to depth, i.e. TS1 is the deepest and TS9 and TS10, the shallowest. As might be expected, the Deep Sandy Soils series are numerically dominant, occupying no less than 73% of the quadrats recorded.

Both the descriptions of the vegetation and site types (Sections 7 and 8) contain numerous references to the soil classification. Considerable interest lies in the degree of correlation between the vegetation and soil types. Thus, Table 6, at the end of Section 9, summarizes the extent to which the vegetation types and soil types are associated, using Fisher's Exact Test to attach significance levels to the observed values of coincidence between vegetation and soil. Some vegetation types are limited to quite a narrow range of soil types and there are a number of highly significant correlations, e.g. base-rich dune grassland D1 with soil types DS5, DS6 and DS7 which together account for 89.2% of quadrats allocated to this vegetation type.

Sections 10 and 11

Finally, the last two sections of the Main Report are devoted to acknowledgements and a list of references.

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1 INTRODUCTION

1.1 Background

Sand dune systems along with associated sand and shingle spits, and saltmarshes, are currently more affected by man's activities than most other terrestrial ecosystems. For millennia, man has made use of sand dune areas; witness the Mesolithic shell middens. Subsequently, since the Neolithic agricultural revolution, he has grazed his animals there. In more recent times, on dune systems where there are no common rights, agriculture has encroached close to the shore. In some cases, rough grazing has continued, but, where arable crops are grown, the changes to the flora and topography have sometimes been catastrophic, e.g. the Bornish Blowout (Seaton, 1968). On the west coast of Scotland, the crofting system of agriculture involves both grazing and arable use of the sand dune system.

Near centres of population, mainly in the south of Scotland, the sand dunes have been used for recreation, especially the construction of golf courses, e.g. Turnberry, and St Andrews. Recently, with increased mobility of human populations, the recreational pressures have spread to even the most remote places. The discovery of oil and gas in the North Sea has led to coastal areas being affected by industrial developments. The coast provided sites for oil platform fabrication yards in the early stages of the North Sea oil boom. More recently, suitable places for the landfall of undersea pipelines and the associated treatment works, which need to be close to where the pipeline reaches the shore, have been much in demand. Some of these industrial developments are on a massive scale, e.g. Nigg fabrication yard which has one of the largest graving docks in Europe, and irrevocably alter the terrain, destroying wildlife interests in the process.

The ease of extraction of coastal sands and gravels has resulted in their use for building and agricultural purposes. With the advent of large scale industrial developments, what was a minor disturbance may now result in severe damage to or destruction of a dune system. Although the extraction of suitable sand and gravel deposits of glacial origin from further inland will cause local disturbance, the long term effects are likely to be less detrimental than on the coast. Besides affecting the wildlife, loss of sand from the coastal fringe may result in reduced agricultural production, and problems with coastal erosion in the short and long term.

The Nature Conservancy, and its successor the Nature Conservancy Council (NCC), faced with these changes and developments, found themselves often with very little information on the sites under pressure. Therefore, they decided to commission a survey of coastal sites to enable them to carry out their charter functions. The objectives of this survey were as follows:-

(i) To determine the nature and extent of the main habitat divisions, and the composition of the vegetation within each of the areas specified by NCC.

(ii) To carry out the above investigations in a way which will allow objective comparisons to be made between individual sites.

(iii) To determine the presence of rare or localized vegetation types and plant species within each specified site.

(iv) To assess subjectively the extent to which each site is currently being affected by human activities of various kinds.

To attain these objectives, a detailed programme of field work was devised to collect information on the flora, limited features of the fauna, and various environmental parameters. The details of this programme are described in Section 4, with an indication of how the project evolved in the light of experience during the first field season.

At the beginning of the project, in early 1975, it was suggested the results could be presented as three main end-products.

(i) A field handbook describing the methods used.

(ii) Instruction for NCC staff in the appraisal of sites by the method adopted in this survey.

(iii) Results of the survey as they relate to both individual sites and comparisons between sites. These will include the following :-

(a) Summaries of information for each individual site, including species lists of vascular plants, bryophytes and lichens, together with estimates of the frequency and cover. The proportions of major habitat types on each site will be determined and, where possible, maps will be provided to indicate their within-site distribution.

(b) Analysis and description of the variation between sites in terms of floristics and main habitat types.

(c) Subjective assessment of the extent to which each site is currently being affected by human activities of various kinds.

The above headings, both objectives and end-products, are taken from Appendix A to the contract (an outline project plan) prepared in summer 1975.

As the project evolved and contacts were made with NCC staff, thoughts on the presentation of the work also developed. With an extensive quadrat survey, in which the average sampling intensity was less than 1%, the detail provided could only be slight and largely unsuited to mapping of vegetation types or habitat types (requirement (iii) (a) above), unless the site happened to be remarkably uniform - a characteristic for which sand dunes are not noted. Thus, the production of detailed maps showing the distribution of these features will not be possible with the amount of information available.

The final submissions to NCC will be as follows.

(1) The Main Report which covers the whole project; aims, methods, analysis and results. Particular emphasis is placed on a classification of vegetation types and its interpretation (Section 7) and on a similar classification of site types; the geographical distribution of the types and between-site comparisons (Section 8).

(2) Ninety-four Site Dossiers comprising essentially (iii)(a) and (c) of the end-products outlined above.

(3) A series of appendices to the Main Report.

(i) Appendix 1 - Vegetation Types and Key.
This appendix was to have contained detailed descriptions of the vegetation types as defined from the field survey data, along with the dichotomous key for their identification. However, this report has been abandoned for the present, partly through lack of demand, but also because a more comprehensive account of the vegetation types than was originally envisaged is presented in the Main Report. In practice, Appendix 1 would have contained roughly the same text as Section 7 in the Main Report but this would have been supplemented by all the tables, maps and diagrams that were used in the interpretation of the vegetation types. The original thinking behind Appendix 1 was to provide more detail than could be presented within the confines of the Main Report and, being under one cover along with the key, it would also have served as a field guide. If there is sufficient interest in NCC, Appendix 1 could still be produced at some later date - without a great deal of effort.

(ii) Appendix 2 - Handbook of Field Methods.
This handbook is a comprehensive instruction manual covering all activities involved in the quadrat survey, from sampling methods and map preparation, to details of procedures used in the field. It includes a section on how the survey can be extended to record additional quadrats on existing sites or to cover entirely new sites.

A course for NCC staff was run at Dunnet and Strathy (survey sites 62 and 59) on the north coast of Scotland in June and July 1978. The participants were instructed in the methods used to collect the field data and were then shown how additional quadrats and sites could be identified using preliminary versions of the vegetation and site keys.

(iii) Appendix 3 - Species Distribution Maps for Vascular Plants.
A series of maps showing the distribution of vascular plant species (in alphabetical order) in the 94 sites covered by the survey in such a way that they can be compared with published information. A foreword to the maps gives details on species identification and lists the taxonomic authorities used. Symbols on the maps and accompanying tables of site names give information on the source of the records. These maps and tables provide a useful cross referencing system with the Site Dossiers. Because of the sheer bulk of this appendix, the maps and accompanying tables have been transferred to microfiche.

(iv) Appendix 4 - Species Distribution Maps for Bryophytes.
This appendix takes exactly the same form as Appendix 3 but deals with the bryophytes recorded in the Scottish Coastal

Survey.

(v) Appendix 5 - Species Distribution Maps for Lichens.
This appendix is equivalent to Appendices 3 and 4 but is for lichens.

(vi) Appendix 6 - Bryophytes in the Scottish Coastal Survey.
This is a separate account of the bryophytes recorded in the survey. It comprises sections on methods, the distribution of species, a classification of bryophyte assemblages, a comparison between the bryophyte and vascular plant classifications and an account of bryophytes in relation to the site classification. It is supplemented by a series of maps and tables similar to those that would have appeared in Appendix 1 had it been produced. Indeed, Appendix 6 can be used to assess the usefulness of producing Appendix 1 in its full form.

(vii) Appendix 7 - Lichen Flora of Scottish Coastal Sites.
A report on the lichens identified from the Scottish Coastal Survey. There is also a supplement (under a separate cover) which was prepared as further identifications became available.

(viii) Appendix 8 - Data Specification.
A precise description of all the data obtained in the Scottish Coastal Survey and subsequently translated into machine readable form, their coding, the logical structure of the data bank and how and where it is held.

1.2 Use of Findings to NCC

1.2.1 Conservation.

The development of an effective and readily defensible conservation policy for the soft coast of Scotland requires a good basis of information on the amount of resource involved, its range of ecological variation and its geographical distribution. Although some information about individual sites already exists, it is very difficult, or impossible, to use it to provide the type of conspectus that is needed to to make decisions at this strategic level. The ultimate aim must be the production of a coherent rationale allied to a list of sites, in some sort of order of priority, which NCC will then attempt to conserve by one or other of the various means open to them. The means of conservation include declaration as a National Nature Reserve (NNR), notification as a Site of Special Scientific Interest (SSSI) or other less formal measures, depending on the priority, pressures and the possibilities that exist.

The main aim of the Scottish Coastal Survey was to meet this need for a widescale survey of the coast. Whereas the decision on an overall policy for the conservation of the coast of Scotland is largely the responsibility of Territorial Headquarters, the details of how this policy is to be implemented must obviously lie at a Regional level. In order to do their work, Regional Staff must know their own sites in more detail as well as understanding how they relate to the total range of sites. Again, the type of information produced by the Scottish Coastal Survey should contain sufficient detail to satisfy most of these needs.

At a still lower strategic level, Regional Staff (mainly Assistant Regional Officers (ARO) and Wardens) are responsible for site management - using the term "management" in its broadest meaning. The type of activity referred to here is direct management of NNR's, advice to landowners and the deflection of pressures from important or vulnerable parts of individual sites. At this level, the information provided by the Scottish Coastal Survey is perhaps less useful, although the overall picture is still highly relevant. This is the point where NCC staff may need to supplement the existing information for themselves by extending the sample obtained in the original survey and possibly incorporating new types of information as required. The original survey having set up the framework, a great deal of flexibility is now possible. The only data that must be recorded in order to provide a link with the existing body of information is the flora, i.e. a list of vascular plants for the 25 sq m quadrat.

1.2.2 Development of Site Evaluations

The type of information obtained by the Scottish Coastal Survey is in no way a substitute for site evaluation. Only a small part of the supplementary survey, e.g. the effects of human activities, borders on evaluation and is to some extent based on subjective judgement. The main effort of this survey has been to obtain a uniform body of objective, reproducible information with as high a degree of accuracy as possible. Much of this information could, however, be used as the factual basis from which site evaluations are in part generated. In 'A Nature Conservation Review' (Ratcliffe, 1977), a series of criteria for site assessment and selection are defined. Some of these criteria are obviously outside the scope of the survey information, e.g. potential value, intrinsic appeal. Being based largely on value judgements, these must remain the prerogative of the conservationist actually making the assessment. In the case of other criteria, e.g. typicalness, extent, diversity, naturalness, rarity, fragility (possibly) and position in ecological/geographical unit, there is a great deal of information contained in the survey data that could be used to assist in assessment. Typicalness stands out as possibly being the single most important criterion in site assessment, the one that is arguably most difficult to derive, and the one to which a widescale survey and suitable analysis can best provide the answer.

The philosophical basis of site evaluation is clearly a matter for NCC to decide for themselves. However, when it comes to implementation, the Institute of Terrestrial Ecology (ITE) may be able to assist NCC in getting the best out of the available information.

1.2.3 Basis for Future Activities

The records from the Scottish Coastal Survey constitute a vast amount of information stored in machine readable form. Because it is so readily accessible, any research organization would find it a useful starting point for further work on the coast of Scotland. An obvious future development would be for NCC to obtain more detailed information on sites already recorded, perhaps with the aim of producing vegetation maps. Similarly, the survey could be extended to cover sites not included in the original survey. Alternatively, it might constitute the starting point for more detailed ecological or physiographical studies of sites on the Scottish Coast. Analysis of environmental data could lead to work on site management, whilst the soil and auger hole data could stimulate investigation into the post

Pleistocene history of soil development on dunes and the relationship to the raised beaches which occur in many of the survey sites.

The use of surveys to provide "a basis for monitoring" has often been proposed, even in connection with the Scottish Coastal Survey. However, it is difficult to combine the number of sample observations required to make estimates of reasonable precision with the rather smaller number of fixed quadrats needed for the accurate measurement of change. Furthermore, the variables to be recorded for the detection of change would need to be specified in advance of the initial survey. Extensive survey of the kind used in this Scottish Coastal Survey may be valuable in helping to define the necessary stratification for the monitoring of change, and should certainly provide information on the variability of the target population.

1.3 Role of NCC in the Project

NCC made the first and critical decision affecting the design of the project when they chose the sites to be surveyed. The fact that the survey was to be site orientated had a major effect on everything that was done subsequently. The total population of soft coast sites in Scotland has never been determined, so it is not known how the 94 selected sites relate to the whole. It is thought that most large sites have been included but not all small ones. Some bias is evident through the neglect of small sites in areas where large sites are available and their inclusion in other areas. Figure 1 shows the distribution of the 94 sites selected by NCC and Table 1 lists their names.

NCC also decided on most of the site boundaries. These were usually determined by various members of their staff (Regional Staff and Chief Scientist Team), but in exceptional cases, where little was known about the site in question, boundaries were drawn by ITE staff using maps and aerial photographs (when available).

NCC also undertook to arrange access to the sites for the field survey teams. As a matter of courtesy, field team leaders usually introduced themselves to the local farmers and crofters before going on to the sites.

The relationship between ITE and NCC staff developed as the project progressed. Local ARO's often joined the field teams at work and came to understand what the work involved. At the project management level, there was a free interchange of views and ideas, which enabled both sides to see the development of the project. Regional Officers were able to comment on interim reports and prototype Site Dossiers, so that, hopefully, ITE can report on the project in a manner that will be of maximum assistance to NCC staff. The enthusiasm for the work shown by NCC staff on the "Dunnet Course" was a morale boost for ITE staff concerned, who believe the NCC staff also benefitted. It is hoped that use of the survey will not end with the formal report. If what has been done is to be used to full effect, NCC will be asking ITE questions about the work for some time to come, as well as themselves filling in detail, where required, by additional survey.

Figure 1 Map of 94 sites selected by NCC

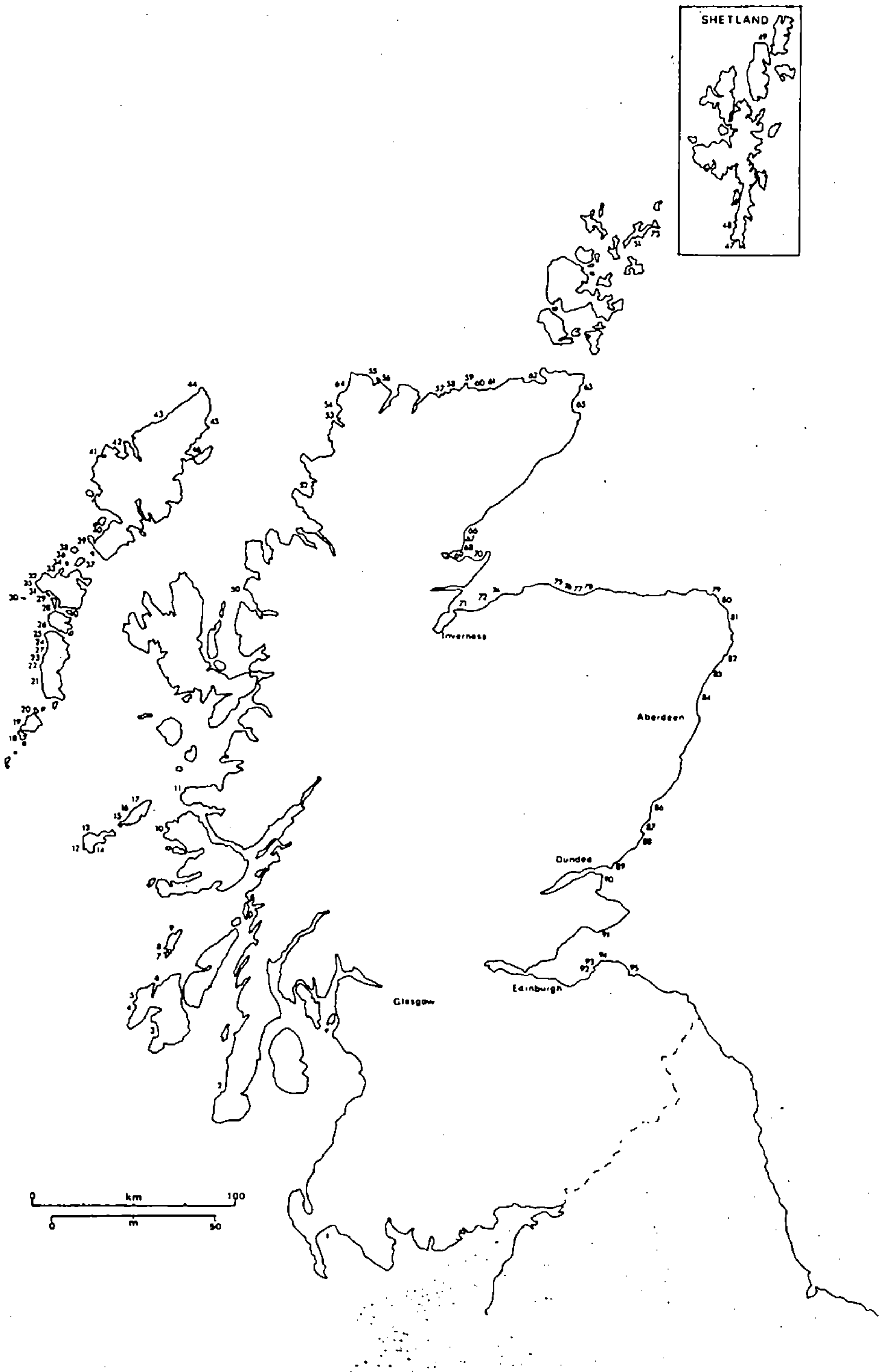


Table 1 - List of the 94 Sites Selected by NCC (key to Figure 1)

1 Torrs Warren
2 Macrihanish Dunes
3 Laggan Bay
4 Kilchoman Dunes
5 Saligo Bay
6 Gruinart
7 Oronsay
8 Garvard
9 Kiloran Bay
10 Calgary Dunes
11 Sanna
12 West Tiree
13 Ballevullin
14 Hynish Bay
15 Crossapol and Gunna
16 Totamore Dunes
17 Gallanach
18 Vatersay
19 West Barra
20 North Barra
21 Daliburgh
22 Ormiclate
23 Howbeg
24 Stilligarry (North)
25 Loch Bee
26 Borve
27 Stilligarry (South)
28 Baleshare
29 Kirkibost
30 Monach Isles
31 Paible
32 Hosta
33 Vallay
34 Leathann
35 Balranald
36 Robach
37 Berneray
38 Pabbay
39 Northton
40 Luskentyre
41 Uig
42 Valtos
43 Barvas
44 Europie
45 Tolsta
46 Tong
47 Quendale
48 Scousburgh
49 Breckin
50 Redpoint
51 Holland
52 Achnahaird
53 Oldshore More
54 Sheigra
55 Durness
56 Faraid Head
57 Bettyhill
58 Farr Bay
59 Strathy
60 Melvich
61 Reay
62 Dunnet
63 Freswick
64 Sandwood
65 Sinclairs Bay
66 Ferry Links
67 Coul Links
68 Dornoch
69 Clashmore
70 Morrich More
71 Whiteness
72 Culbin Bar
73 Overbister
74 Findhorn
75 Lossiemouth
76 Spey Bay (West)
77 Spey Bay (Central)
78 Spey Bay (East)
79 Fraserburgh
80 Strathbeg
81 St Fergus
82 Cruden Bay
83 Forvie
84 Don to Ythan
86 St Cyrus and Montrose Links
87 Lunan Bay
88 Arbroath
89 Barry Links
90 Tentsmuir
91 Dumbarnie
92 Aberlady
93 Gullane
94 Yellowcraig
95 Tyninghame

NB Sites numbered 1-95, no site 85 surveyed.

2 DESCRIPTION OF THE PROJECT

2.1 Requirements of NCC

As already discussed in the previous Section (1.2), the main requirement of NCC is for a widescale survey, investigating the range of ecological variation in sites occurring on the soft coast of Scotland. A uniform set of data, covering all the major sites with a potential for conservation, will enable equitable inter-site comparisons to be made and also assist in the process of site evaluation. The type of ecological information produced by a widescale survey can be useful to NCC at various strategic levels, possibly down to the general management of individual sites (again using management in a very broad sense). Detailed management of sites will, however, often require still more and different types of information than can be incorporated into a widescale survey, and here the existing survey can provide the basis for the necessary investigations. It is clearly impossible for NCC to obtain and hold extremely detailed information on everything they might conceivably need to know at some time in the future. Even for one habitat, however important or threatened, this is out of the question - and there are many other habitats competing for attention. The only practical solution is for information to be carefully structured on a "need to know" basis, allied with the means to obtain further information at short notice. Preliminary, widescale survey is seen as providing the foundation on which other investigations are built as the demand arises.

In addition to having a sound ecological understanding of sites, the pragmatic approach of practical conservation also requires some knowledge of the pressures to which individual sites are subject. For example, it is often necessary to initiate conservation measures for sites under pressure, whilst marginally "better" sites, which are not currently threatened, can be kept under surveillance. The Scottish Coastal Survey had the additional aim of providing information on directly observable pressures, e.g. agriculture and recreation. Other pressures, e.g. the intentions of landowners or planning applications, are obviously beyond the scope of survey but are normally detected by the activities of NCC Regional Staff.

In order to meet the requirements set out above, the survey was divided into two distinct parts which, for convenience, have been called the quadrat survey and the supplementary survey. Further information was obtained from other sources such as maps, aerial photographs and other previously published material. The major part of the resources available to this project was, however, expended on the quadrat survey.

2.2 Design of the Quadrat Survey

The background to the project (Section 1.1) and the requirement of NCC (Sections 1.2 and 2.1), as expressed in the terms of the contract (Section 1.1), determined the design of the quadrat survey. Originally, the quadrat survey was called "the objective survey" (and the supplementary survey was called the "subjective survey") and, in a sense, this name represented what was actually done more accurately; a quadrat is merely a sampling device, but the word "objective" describes the general approach. Unfortunately, both "objective" and "subjective" are emotive words. Their use has become somewhat debased and they were subsequently abandoned for use in this context.

Quite simply, the quadrat survey is based on an unbiased sampling procedure, allied with the collection of useful ecological information of a type that can be obtained in the course of a single visit using a standardized method. Information collected in this way has well-defined properties, including reproducibility and the ability to estimate quantities with a specifiable degree of accuracy. This ability ensures the suitability of the survey data for a wide range of interpretive methods. These issues are discussed in more detail in Section 4 of the report.

The main emphasis of the quadrat survey was on vegetation. This very traditional approach is justified by the fact that, in our present state of knowledge, vegetation is probably the best means of differentiating between different ecosystems. The reasons for this belief are discussed at some length in Section 6.1. Other information on the environment, e.g. slope, aspect, soil characteristics and the presence of various habitats, and some faunal features, e.g. macro-fauna, were also recorded. Their inclusion in the survey is based on feasibility, rather than anything else, i.e. can they be recorded effectively by a one visit survey?. Fortunately, soil and macro-fauna, in the shape of the herbivores, are both major ecological factors. The collection of information on other features such as micro-fauna or climate are clearly difficult or impossible within this type of survey.

2.3 Design of the Supplementary Survey

The supplementary survey was included in the project to fulfil objective (iv) of the contract: to assess subjectively the extent to which each site is currently being affected by human activities of various kinds. The survey also aimed to add information to the vascular plant species list for each site and, in particular, to hunt for rare or localized communities and species (objective (iii) of the contract).

In an attempt to achieve a reasonably uniform treatment of what is essentially a rather subjective approach, only one person was engaged on the supplementary survey. This part of the survey had to be done by an experienced coastal ecologist because the terms of the contract put heavy emphasis on the ability to interpret current dune features in respect of past and present land-uses.

An extensive survey, with a relatively low sampling intensity of less than 1%, is very effective at recording the common, widespread vegetation types and plant species and also gives a reliable estimate of their amount and distribution. The information collected by the quadrat survey is mainly aimed at producing an account of the commoner vegetation types and allowing unbiased comparisons between individual sites to be made (objectives (i) and (ii) of the contract). However, extensive survey cannot be expected to provide the comprehensive site species lists for vascular plants required by NCC. An experienced botanist can selectively search the rarer habitats, e.g. strandline, freshwater edge and transition zones in general, and add considerably to the total plant records for a site. As its name suggests, the supplementary survey was used to supplement the species list produced by the quadrat survey.

When presenting a mass of rather terse, factual information about individual sites, which constitutes the main contents of the Site Dossiers, it is desirable to first "set the scene" for the reader. This is best achieved by a general site description which also incorporates a conspectus of the entire range of sites. Again, this can only really be done by one person, and another aim of the supplementary survey was to gain the necessary synoptic view of the sites under investigation.

The main outlet for the information collected in the supplementary survey is the Site Dossiers. Each of these documents includes a general site description and notes on "species of interest". Species recorded in the supplementary survey, but not in the quadrat survey, are included in the site species list at the end of each dossier (indicated by (S)). Although not used in the more formal analyses, i.e. the site and vegetation classifications, species recorded in the supplementary survey are incorporated into the species distribution maps (see Appendix 3)

2.4 Other Sources of Information

To augment and help interpret the information collected in other parts of the project, existing published and unpublished accounts of the sites have been consulted.

Reports of visits to the sites by members of both ITE and NCC staff prior to this project, along with published data, have been used to augment the lists of vascular plant species for some of the sites. By comparing these earlier reports with the information obtained from the survey, it has been possible to comment upon some of the changes that have taken place during the intervening time. In fact, in some cases, these earlier reports have provided the main contribution to the general site description. Problems have arisen when the earlier reports relate to site boundaries other than those used in the current survey or where the exact location or extent of the work has not been properly specified. In some cases, it has not been possible to resolve these problems satisfactorily.

Other types of published data, e.g. climatic maps, geological maps, topographical maps, etc., have been used in an attempt to explain the underlying causes for the observed range of variation between the sites surveyed (see Section 6.5).

3 ORGANIZATION OF THE PROJECT

3.1 Quadrat Survey

In order to complete the field work involved in the quadrat survey part of the Scottish Coastal Survey in the time available, it was necessary to use many surveyors. A total of twenty-four ITE staff and nineteen casual labour assistants were employed at various times to make up the field teams. Of these ITE staff, only seven had commitments to the project which extended beyond brief periods of field work (usually of no more than three weeks duration) and subsequent checking and verifying of the data they had recorded. To ensure timely completion, the maintenance of a high standard of field work when involving so many people and to minimize the disruption to other ITE projects, a very high level of organization within the project was necessary.

The planning and scheduling of each of the three field seasons was done by one person, whose task it was to supply all the equipment and information required by the field teams, and to make all the necessary travel and accommodation arrangements and bookings.

The field work was spread over three summer seasons 1975 to 1977 (May to September), in which time 94 sites were surveyed with a total of almost 4,000 quadrats. The field work was divided as follows:-

1975 - 28 sites (Moray Firth and most of the north coast)

1976 - 40 sites (Outer Hebrides, remainder of north coast and east coast)

1977 - 26 sites (Orkney, Shetland, Inner Hebrides, south-west and south-east coasts)

At the beginning of each field season, a training course in survey methods was held and all ITE staff involved in the quadrat survey during the coming field season were obliged to attend. This course was designed to produce survey team leaders, a role which carries a number of well-defined responsibilities. All the courses were held on sites which were included in the survey and the data collected (always under careful supervision) forms part of the quadrat survey. The following sites were used for training purposes: 1975 - Gullane and Tyninghame (part), 1976 - Tentsmuir (part) and 1977 - Torrs Warren. Gullane was also used as the test site for field methods and sampling (see Section 4.2).

All training was done with close reference to a Handbook of Field Methods (Appendix 1), the original version of which was written before the survey commenced. The Handbook has subsequently been updated and improved each year of the survey, in the light of experience and the comments of surveyors. The initial part of the training course concentrated on the method of survey; from navigating and locating samples on the ground, through how to complete the four types of record sheet, to the checks that are made before moving on to the next quadrat. When it came to the survey itself, each survey team leader was responsible, not only for his or her own work, but also for that of the field assistant who normally collected everything except the plant records, but under constant supervision from the leader. Team leaders have, therefore, to be experienced in all aspects of the work and this experience can only be gained by first doing the work themselves. In fact, learning the field methods is not difficult and, after the first few days, most training can be concentrated on botanical recording. During the training course, all prospective survey team leaders were expected to become proficient at identifying the plants commonly found on the Scottish Coast. Obviously, it was not possible for the surveyors to be taught all the species they might encounter in advance. The main emphasis in training was to build up experience so that surveyors could deal with the general run of quadrats efficiently, but would also know how to approach the problem when difficulties occurred. It was just as important for recorders to know when they could not identify species in the field, carry out the necessary documentation and collect specimens, than it was to record species that could be immediately identified.

Not all staff who underwent training were subsequently used as survey team leaders. Failure to reach the required standard was always connected with botanical recording. Except for some slight problems with navigation, no other part of the survey method proved difficult to learn. The ability to produce the required standard of botanical recording was largely a matter of previous experience (care and diligence were also important) and no shortcuts in obtaining this experience were found to be possible.

As a result of the training courses, a good standard of botanical recording and the proper collection of herbarium specimens were maintained throughout the survey. A high degree of uniformity between individuals was also achieved in the recording of the (unavoidably) more subjective parts of the data, e.g. estimates of cover, grazing intensity and soil profile features. Survey team leaders had a continuing responsibility for the data they collected. They checked all their own field sheets against species lists printed out by the computer in order to eliminate various sources of error, and were responsible for answering all queries relating to their work. As far as possible, the identity of species submitted as herbarium specimens was communicated back to surveyors together with comments and advice on their work. A good deal of feedback was generated so that surveyors learnt by their mistakes.

Most of the sites were surveyed by at least two field teams (a field team consists of a survey team leader plus assistant) working as a co-ordinated group under the supervision of an experienced member of ITE staff, usually a member of one of the teams. Only three sites were recorded by a single field team, and, on each occasion, an experienced member of ITE staff either formed part of that team or was close at hand to supervise the work.

The handling of the data and specimens collected by the field teams was done at various ITE stations. The data on the record sheets were photocopied, coded and punched on to paper tape at Merlewood and then checked by the field recorder before being sent to Bangor for computer analysis and storage. The vascular plant specimens were mounted and sent to Bangor within a few days of their collection so they could be dried and treated with a biocide to preserve them. The herbarium specimens were later examined and the identifications used to correct the field records. This stored herbarium forms a comprehensive reference collection of the plants recorded during the quadrat survey. The combined bryophyte and lichen field collections were sent to Colney where they were dried and separated. Some of the specimens were later examined at Colney, e.g. most of the lichens, but the majority of bryophytes were sent to Edinburgh for identification. The soil samples were dried at Merlewood and are now stored at Bangor where some further investigations have been conducted.

3.2 Supplementary Survey

To provide as consistent an approach as possible to the essentially subjective supplementary survey, the work was done by one person, Dr D S Ranwell.

Although no strict field procedure for each site visit was used, as in the quadrat survey, certain features of the sites were consistently noted. These included strandline developments and oil deposits on the shore, height of the coast dune, stocking and grazing intensities, recreational activities, human occupation and use (past and present) and general topographical and habitat features. Together with these notes, lists were made of the vascular plant species and their associes seen on each site.

The survey consisted of a perambulation of each site from various access points to include the shoreline and localized habitats such as freshwater bodies, edge communities etc. The information was dictated in the field into a tape recorder and subsequently typed and structured into the general site descriptions found at the beginning of each Site Dossier.

It was not possible for Dr Ranwell to visit all the 94 sites during the three years of this survey. In fact, only 72 of the sites were covered by the supplementary survey:-

1975 - 25 sites (North coast, Moray Firth and east coast)

1976 - 25 sites (Outer Hebrides)

1977 - 22 sites (south-west coast, south-east coast, Inner Hebrides and Orkney)

In 1977 brief re-visits were made to six of the north coast sites to check for major changes in land-use.

Of the 22 sites not covered by the supplementary survey, 11 were visited by Dr Ranwell between 1969 and the commissioning of the Scottish Coastal Survey. For these sites, the earlier reports have been used to write the general site descriptions. Of the remaining 11 sites, all but 4 have been briefly visited by Dr Ranwell at some time in the past. Although no detailed reports were made during these visits, the knowledge of the site has enabled Dr Ranwell, using the results of the quadrat survey, documentary records and Ordnance Survey maps, to write the general site descriptions. Where possible, the descriptions of the sites not seen by Dr Ranwell personally have been written with the assistance of members of the quadrat survey field teams who visited those particular sites.

The proportion of the area of each site covered by the supplementary survey varies greatly between sites. On some sites only a few hours were available for the visit, whilst, on others, a complete day or more was allocated. This disparity has resulted in a very detailed coverage of some sites and a less than desirable coverage on others. In view of this inconsistency, no valid detailed comparisons between sites, e.g. number of plant species on each site, can be made from the data collected by the supplementary survey. In some cases, the number of species found on a particular site will merely be a reflection of the time and effort expended on the supplementary survey of that site. Therefore, all detailed comparisons between sites should be made using only the quadrat survey data, which provide the necessary uniformity.

4 SURVEY METHODOLOGY

4.1 Development of the Methodology

The methods of survey employed in the Scottish Coastal Survey were based on previous experience of widescale survey in connection with the Conservation Review and from a survey of semi-natural woodlands in Britain carried out by staff of the Merlewood Research Station. The general approach to ecological survey and the type of methods involved are set out in Bunce and Shaw (1973), using examples taken from the semi-natural woodland survey. The four underlying principles of the method may be summarized as follows.

(1) Sampling - the use of an unbiased sampling procedure. Without this, reproducibility of data cannot be ensured and no valid comparisons can be made. The three main requirements of an unbiased sampling procedure are that:

(a) the population is properly defined;

(b) the precision achieved by the sample is determinable; and

(c) the sample is free from unknown bias, i.e. random or systematic sampling must be used.

Sampling methods are discussed in greater detail in Section 4.2.

(2) Standardization - the derivation of a set of rules and procedures which can be communicated from person to person and implemented with the minimum exercise of subjective judgement. This type of approach is essential if uniformity and reproducibility of data are to be ensured; for only then can valid comparisons be made. The adoption of standardized procedures has long been accepted in other investigative methods, e.g. experimentation, and the same principles apply to survey, although an equal degree of control is difficult to achieve. An outline of field methods is given in Section 4.3 and details are given in the Handbook of Field Methods.

(3) Choice of Measures - a careful decision concerning the type and amount of data to be collected. The choice of measures is based on four main considerations:

(a) that the data carry information relevant to the problem in hand;

(b) that the necessary information is carried in as few measures as possible;

(c) that the data are easy to record accurately; and

(d) that comparable information can be obtained for all members of the population.

The choice of measures and allied matters are dealt with at some length in Section 6.

(4) Analysis - the use of formalized analytical techniques in order to investigate, specifically or generally, the information that survey generates. Ecosystems are so complex that mere presentation of isolated facts or informal attempts at synthesis do not usually provide an adequate solution to the type of problem faced by the conservationist. This activity may even become an end in itself. Analytical techniques, from the most simple, e.g. calculating means, to the more complex, e.g. ordination or classification, seek to simplify a complex situation, as represented by the field data, and reveal the underlying pattern. Without this type of summarization, interpretation is reduced to making ad hoc decisions based on a restricted examination of the facts or on intuition. An experienced ecologist may have sound intuition, but this type of evidence is not always easy to defend in the outside world. The results of analytical techniques, as applied to data, are more easily defended, enabling a level of probability to be defined for tests of significance and for estimates. This type of approach places conservation on a similar footing to other competing activities.

Aims of analysis are dealt with in greater detail in Section 6 together with some discussion of analytical methods.

As the above considerations were closely debated from the outset, the whole of the quadrat survey methodology was designed to meet the most stringent requirements of an unbiased survey method. In all major respects the design was successful. Some minor shortcomings and limitations are discussed in Section 5.

4.2 Methods of Sampling

The method of sampling employed in the survey underwent a process of evolution, extending from the design stage up to the end of the first field season (1975). From both a theoretical and practical point of view, it is important to make clear why certain methods of sampling were adopted, why some were less successful than others and what, if any, implications these decisions have for the user (NCC).

The most common criticism, that phytosociologists level at random or systematic sampling, is that it is less efficient, i.e. it takes more samples and more time than an approach in which samples are selected to be representative of their "type". In a limited sense this criticism is perfectly valid. The advantage claimed for subjective sampling is that it permits sufficient samples to be taken in each "type" without over- or under-sampling any of them. By contrast, all non-stratified methods of random or systematic sampling sample a given "type" in direct proportion to the total amount of that "type" present; common "types" are over-sampled and rare "types" under-sampled or missed altogether. This comparison is, of course, an over-simplification and begs the question as to how one knows what "type" is being sampled before it has been recorded (and also perhaps analysed). In this case, it is necessary to have an outline scheme of classification in mind, often derived from a thorough pre-sampling reconnaissance, against which to select the necessary samples. After the initial sampling and analysis of the data (perhaps using numerical analysis), the classification may be modified in the light of experience and further samples taken to obtain more detail or fill in gaps.

This process of successive approximation (Poore 1956), may be regarded a reasonable one for erecting a classificatory framework. The main danger is that of circularity of argument, i.e. subjective sampling according to an initial (hypothetical) structure will tend to confirm that structure, and information to the contrary will be unwittingly excluded. The only true validation of a classification which has been derived from subjective sampling is to test it on randomly or systematically selected samples drawn from the same population - does it identify such samples correctly? For various reasons, this test has never been done in a formal manner, even though the means of doing so, using appropriate statistical methods, is now available.

The other problem with traditional phytosociological methods lies in the manner with which they deal with so called heterogeneous samples, transitions and other aberrant situations, i.e. usually by ignoring them. Indeed, this is one of the main functions of selecting samples subjectively - to sample only homogeneous quadrats, to avoid transitions and obviously aberrant quadrats, e.g. the results of disturbance. It is not disputed that such entities exist and that, in some senses, they are less interesting to the ecologist than "genuine communities", but a rigorous definition is difficult to find. In uniform habitats, homogeneous stands are in the majority, but in other areas, e.g. uplands, the opposite may be the case. Applying the same rules of homogeneity to a uniform and non-uniform habitat, the latter may be regarded as largely unclassifiable. In order to overcome this problem, and because homogeneity is a function of area, the usual procedure is to reduce the quadrat size drastically, using the species/area curve as a guideline. Obviously, the question as to whether a particular sample is homogeneous or not or when to change quadrat size (or even shape) introduces a serious element of uncertainty into a procedure that was, up until this point, reasonably acceptable on pragmatic grounds to fulfil the limited function of producing a classificatory framework. It is also important to note that, although a phytosociologist may not be interested in transitions, disturbed and other heterogeneous communities, the practical conservationist cannot afford to ignore them. Transitions may be just the places where change is taking place, e.g. the drying out of a site due to drainage or re-establishment of an abandoned arable area. Similarly, certain types of disturbance which produce communities that are not usually recognized in a phytosociological classification may support rare or threatened species, and this knowledge is important to the conservationist.

The main reason why heterogeneous quadrats are avoided in traditional phytosociology is that they are difficult to classify. They often contain complex, and even conflicting, species assemblages for which it is difficult to identify character species and fit them into any form of tablework. Indeed, most numerical methods have difficulty with such quadrats, although the better methods will at least succeed in isolating them in a reasonably logical manner.

The above preamble on phytosociology and the implications of subjective as opposed to objective sampling are necessary background to an understanding of the evolution of sampling methods in the quadrat survey. The question of heterogeneous quadrats, transitions and the like is easily solved. Numerical methods of classification have the ability to deal with the problem and therefore, throughout the survey, no quadrat was rejected in the field because of its species complement, however unusual it might be (in fact, four quadrats were rejected after preliminary analysis, see Section 7.3). Admittedly, at the end of the day, the most peculiar quadrats are isolated as just that. They cannot be regarded as vegetation types and there is very little to be said about them, simply because of the paucity of information about them. Other unusual quadrats are repeated a number of times and must, therefore, qualify as vegetation types even though they are not conventionally recognized as such. Their exact status may be very uncertain, i.e. are they stable or rapidly changing (?), but because they exist (or rather, existed at the time when they were recorded) at several locations they can hardly be ignored. By definition, these are the "rare" vegetation types, although it should not be argued that this automatically means that they are of particular conservation interest.

The original method of sampling tested for use in the quadrat survey was intended to overcome some of the disadvantages of unrestricted random sampling by the use of stratification. For example, if 90% of an area was occupied by vegetation type A and 10% by type B, a random sample of 10 quadrats would, on average, produce 9 samples of type A and 1 sample of type B. A stratified random sample of the same area would treat type A and type B as separate strata, and, if the two strata were equally variable, would take 5 samples from each. The efficiency of the stratification would, of course, depend on the validity of the a priori distinction between the two types, but, on average, might be expected to be an improvement over the efficiency likely to be obtained by unrestricted random sampling.

The original assumption was that good quality aerial photographs would be available for all the sites. From these photographs it would be possible to identify a large number of distinctive habitats (strata). The original plan was to recognize eight open (areal) strata (coast dune, inland dune, dry slack, wet slack, saltmarsh, former cultivated sand, plantation and other areas) and four linear strata (strandline, stream, loch edge and other). These were to be delineated on the aerial photographs and then subjected to random sampling, with about 5 quadrats in each stratum.

The first setback was that good aerial photographs were not available or, at least, not readily available, so the same stratification was attempted with 6 inch maps (1:10,000 and 1:10,560), using the symbols and contours contained on these maps to delineate the strata. It should be emphasized that the aim was not to identify all these strata with a high degree of accuracy (the internal variability of the strata being unknown anyway) but merely to produce a stratification that would improve the distribution of samples.

One of the survey sites (Gullane - site 93) was chosen as the test for this method of stratified random sampling. On the ground it was immediately obvious that the method had failed, and that, far from obtaining a distribution of samples that was better than an unrestricted random one, the distribution was much worse. Some of the smaller strata were very uniform while other larger strata were very variable indeed, and there was no obvious pattern that could be effectively harnessed for sampling purposes.

Clearly the stratification was too complex and the only possible course of action was to simplify it greatly. This simplification was achieved by reducing the number of strata to five (three open and two linear) as follows.

(1) Coast dune - defined as being all that area within 50m of high water (marked on the 6 inch map).

(2) The rest - defined as being the rest of the site landward of the coast dune stratum (more than 50m from high water mark).

(3) Saltmarsh - defined as being any areas below high water (HWMST) marked by Ordnance Survey as being marsh (OS are rather inconsistent about this).

(4) Strandline - a linear stratum defined as being high water marked on the map.

(5) Water edge - a linear stratum defined as streams and the edge of lochs and other water bodies marked on the OS map.

Sampling was done on a series of transect lines with restricted random origins running approximately at right angles to the shore. The original reason for using transects was that navigation was done using aerial photographs, not maps (see above). Sampling on lines located from fixed features by compass bearing would ensure that surveyors did not navigate by photo-interpretation of the vegetation and thereby run the risk of biasing the sample. When the change was made to maps, the transect system was retained because of supposed navigational difficulties on sand dunes. In practice, such fears were unjustified on the vast majority of sites. The length of transect line traversing each of the open stratum was measured as was the length of the linear strata. Random points along the sections of transect relating to each stratum were determined and marked on the maps. Only the saltmarsh stratum was treated differently and this was subjected to a random sample. The sampling intensity for the five strata was as follows.

(1) Coast dune - 6 samples (restricted randomization 2x3 on transects)

(2) The rest - 24 samples (restricted randomization 4x6 on transects)

(3) Saltmarsh - 8 samples (completely random, not on transects)

(4) Strandline - 6 samples (random on linear stratum)

(5) Water edge - 6 samples (random on linear stratum)

This scheme gives a possible maximum of 50 samples per site if all strata are present.

The term "restricted randomization", used above in relation to the coast dune stratum, means that the length of transect crossing this stratum was divided into two parts and three samples were randomly located in each half. Similarly with the rest, the length was divided into four parts with six random samples in each. The aim of a restricted randomization is to ensure good coverage without forgoing the statistical necessity of random sampling. This system was used for 26 out of the 28 sites surveyed in the first year (1975). The remaining two sites were subjected to random sample because of their small size and difficult shape.

During the first winter (1975/76), the sampling system was thoroughly reviewed and various tests conducted on the data collected so far. The result of these investigations showed that there was little advantage in the use of a stratification. The value of the stratification depends mainly on the relative variability of the coast dune and the rest strata, and there appeared to be no consistent pattern upon which to base a useful stratification. Saltmarsh was an effective stratum, where it was possible to identify its presence from maps in advance.

The two linear strata of strandline and water edge were useful in the sense that they ensured a number of samples were placed in habitats which would be poorly represented in a random sample. However, as both saltmarsh and the linear strata are usually minor components of the site, it is questionable whether they should receive special attention in a widescale survey - increased sampling intensity can only be achieved at the expense of something else. The linear strata are a particular problem as they are often not well served by the standard quadrat, i.e. because of its size and shape. Really, both linear strata require specialized investigation of a type that is not compatible with a widescale survey.

The other question investigated by means of the 1975 data, was whether large sites require a bigger sample than small ones. In other words, are large sites more variable than small ones? Sampling in 1975 made no allowance for size; it depended purely on how many of the 5 possible strata were present. Again, as with the stratification, no consistent pattern could be found and there was no evidence that variability was a function of size.

The only positive finding about the sampling methods used in the first year concerned the use of transects. On two sites with an unusual shape, i.e. distance along the coast was short and distance inland long, the number of transects was too small and the resulting sample was more clumped than was desirable.

As a result of these investigations, the sampling method was modified for the remainder of the survey. Because the stratification could not be shown to serve any useful purpose - indeed, it created a number of complications - it was abandoned. The use of transects was also discontinued for the reason given above. Using 6 inch maps, the navigational problems originally anticipated with aerial photographs were virtually non-existent and transects were not required. Only a few large sites with very out of date maps, e.g. site 70 Morrich More, presented any problems. Over the question of whether large sites were more variable than small ones, a cautious attitude was adopted, particularly because this was a one visit survey. It was not found possible to sample in direct proportion to size because of the size range involved (Barry Links = 993 ha to Cruden Bay = 16 ha, or a ratio of about 60:1), and this would not have been desirable anyway. The method described below results in a progressive scale of sampling intensity.

The method of sampling adopted was a restricted random one, using sampling units of 15ha and a standard sampling intensity of two samples per unit. This sampling intensity (=0.27%) was maintained for all sites over 225ha, in other words, a minimum of 30 samples per site. For sites less than 225ha the sampling intensity was increased to three, four, five, etc. per unit in order to give a minimum of 30 samples. The exact procedure, with a worked example, is given in Handbook of Field Methods (Appendix XIII). The advantages of this method of sampling are that it is easy to apply and gives a good, relatively uniform coverage of a site regardless of size. It also provides a starting point for mapping vegetation types and other recorded features. The overall intensity of sampling was mainly determined by the practical consideration of the total number of samples that was possible in the time available. From the point of view of comparing sites, using the site classification, 30 samples are almost certainly adequate even for the most variable site. As a basis for producing accurate vegetation maps of sites (one of the original requirements of NCC), it is obviously rather poor except for very uniform sites - if such exist. The total number of quadrats recorded in the entire survey was 3,847.

It should be noted that, although all sites were originally allocated a minimum of 30 quadrats, several finished with less than 30 quadrats actually recorded (the lowest was 16 quadrats). This loss of samples is the direct result of quadrats being abandoned in the field. The rules which govern this decision, to be taken by the survey team leader, are given in the Handbook of Field Methods. The three most common reasons for a quadrat being abandoned were inaccessibility, erosion and a crop that would be damaged by the surveyors. The last of these is numerically the most important. Abandoned quadrats are not a total loss because the reasons for their rejection contain some information about the site, e.g. what proportion of the site was affected by agriculture and what crops were involved.

Finally, in view of the theoretical advantages of stratified sampling, why were both attempts at stratification a failure? The answer is quite simple, that it was not possible to determine where the variation on a site occurred in advance of actual sampling. Maps were of little use and, having seen many sites on the ground, it is difficult to imagine that aerial photographs would have been much better without considerable time spent checking in the field. The question then arises, would all the time and effort spent working out a stratification result in a commensurate increase in efficiency of the sample? Alternatively, is it better to spend the time recording more quadrats with no stratification? A straightforward answer to this question is not possible; it really depends on the nature of the variation, the availability of prior information, e.g. aerial photographs, and the exact aims of the survey. If mapping is a main aim, then time spent studying aerial photographs and the use of ground control could be rewarding.

4.3 Field Methods

The fundamental principle of the field methodology is the use of a standardized procedure which every field worker knows and follows (see Handbook of Field Methods for details). The randomly selected sample points were marked on 6 inch to 1 mile maps. Having found the appropriate area of a site, a suitable fixed point, e.g. corner of a field, which was shown on the map, was located on the ground. This was the starting point for navigating to the quadrat location, by pacing along a compass bearing.

On arrival at the sample location, the quadrat was laid out, and four field sheets filled in by the two field workers forming the team. The Plant Record sheet, which was recorded additively, was arranged to keep the records from the six zones (1, 4, 25, 50, 100, and 200 sq m) of the quadrat separate. There was also a section for recording other features such as bare ground, water, bryophytes, lichens and artefacts. Cover estimates were made for vascular plants and the additional cover categories within the central 25 sq m of the quadrat. A collection of bryophytes and lichens was also made from this part of the quadrat. In the 50, 100 and 200 sq m quadrats the presence only of vascular plants was recorded. This sheet was completed by the ITE staff member, whose assistant usually recorded the remaining three sheets.

On the Environmental/Habitat Record sheet were sections covering various features of topography, vegetation structure, animal signs, tidal litter, human disturbance and water bodies. The completion of this record sheet required some measurements, e.g. slope and aspect, but most of the data were attributes for which the presence or absence of various features was recorded.

A soil pit was dug at the centre of the quadrat, from which were recorded soil attributes in four 10cm zones from 0-40cm depth, along with soil smears. A profile diagram was drawn and annotated, and three soil samples collected from 5, 15 and 30cm depth. An auger hole was bored to 2m depth, unless soil conditions, e.g. the presence of shingle or rock, or reaching the water table prevented this depth being reached. Any features in the bore hole were drawn on a diagram, and sand and water table depths, if found, were recorded.

Finally, a sketch map and section diagram of the plot were drawn. The holes were filled in and the site left as neat and tidy as possible.

At the end of the day, the field sheets were checked, soil, bryophyte and lichen samples stored, and any unknown plants that had been collected were identified as far as possible before pressing in the herbarium, making sure there was an adequate cross reference between herbarium and field sheets.

4.4 Herbarium

At a time when the existence of species and habitats is threatened by human activities, it may seem strange for a collection of pressed plants to be made at all. The reason lies in the large scale of the project which necessitated the use of many different field staff, some with limited experience in plant identification, and the aim of attaining the highest possible standards of field botany. Nevertheless, plants were not collected unnecessarily and special care was taken not to collect orchids and other rare species.

Individual field workers were required to produce a collection of "voucher specimens", to show what they meant by a particular species name, when it appeared on a field sheet. Besides the voucher specimens, all plants over which there was some doubt as to their identity, e.g. seedlings, depauperate or damaged specimens, or plants belonging to difficult taxonomic groups, as well as truly "unknown" specimens, were put into the collection for subsequent identification in the laboratory. The bulk of the collection, therefore, consists of common plants with a sprinkling of less familiar ones. There is a small residue of specimens which remain unidentified, a few of these because the quality of the specimen was too poor to attempt identification.

Many of the field botanists had little previous experience of survey work, so it was necessary to define these procedures carefully and make them as foolproof as possible, so as to ensure that plant identification errors were kept to a minimum.

The collected plants have been used in a number of ways. For example, many surveyors found their collections useful for later identifications, especially after their specimens had been verified. In the analysis of the data, the herbarium has been used for checking dubious records and for ensuring the validity of the site species lists. The specimens will be retained to answer any queries that arise. They are important evidence for the distribution of species in Scotland, where many plants are at or near their northern limits. The survey provided some new records for Scotland.

The nomenclature used throughout has, as far as possible, been that of Clapham et al. (1962). Details of the way individual genera and species have been treated are supplied with the introduction and explanatory text to the Distribution Maps (Appendix 3). For the few plants not mentioned in Clapham et al. (1962), mainly garden escapes, we have used Chittenden (1951). In identifying the plants, every available source has been consulted. Some identifications made in the field have perhaps placed too much reliance on books other than Clapham et al., if one can judge by the use of some non-standard nomenclature which matches a certain well-known set of illustrations! Other floras used include Butcher (1961), Keble Martin (1965), Philips (1977), Ross-Craig (1948-74) and four specialist books by Chancellor (1966), Hubbard (1968), Hyde et al. (1969) and Jermy and Tutin (1968).

It was considered an impossible task to identify plants to subspecific level, where these have been described. It would have been necessary to collect many more specimens to check or even make identifications. The problem of getting a high standard of plant identification was great and, in some instances, it has been necessary to group species which, with better material, would have been separable. These grouped species have been used for all analytical and mapping purposes and a list of amalgamations, and the reasoning behind them, is given in the introduction to the species distribution maps. However, where specimens of these species have been collected and subsequently identified, positive identifications will be given in the species lists in the Site Dossiers. Even so, there will be a residue of records which will be subject to doubt and, where these are used or presented, the likelihood of error will be indicated.

4.5 Data Handling

From the outset it was recognized that virtually all the data produced by the quadrat survey would be converted into machine readable form for computer analysis.

The problem starts with the collection of data in the field. The four types of record form (see examples in Handbook of Field Methods) were carefully designed to:

(a) assist the field surveyor to record accurately; and

(b) be used directly, i.e. no need to make fair copies or abstracts, for converting the data into machine readable form (punching on to paper tape).

The only significant departure from normal practice was the writing of species names directly on to the plant record sheet instead of using a check list. In the field, this is by far the most efficient and accurate method of recording these data (particularly where there is such a potentially large species list) and the only disadvantage is that the field sheets have to be coded prior to punching. All the other field sheets were designed, as far as possible, as check lists, but with the total list being subdivided into logical units conveniently arranged on the form.

As already noted (Section 3.1), each survey team was led by a permanent member of ITE staff and that person was held responsible for all the data (even those collected by the field assistant) for all quadrats assigned to them. In the case of the plant records, each team leader had to check that a computer print-out of the data agreed with their field sheets. There were also special provisions in the data handling to deal with incorporation of herbarium specimen identifications (see also Section 4.4) into the data bank.

As well as the normal manual checking, i.e. checking of field sheet against computer print-out, all data were subjected to a series of logic checking programs on the computer. The data were successively amended by reference to the field sheets until all tests were passed.

The net result is a series of data files containing virtually all the information (the only exceptions being comments and soil smears) collected in the quadrat survey. The computer files (the data bank) all have a precisely defined, and relatively simple, structure and can be interrogated by anybody in possession of information about this structure. A full data description and specification are given in Appendix 6. Data security is ensured by holding several copies of the data bank on both magnetic (magnetic tapes and discs) and non-magnetic (paper tape) media.

4.6 Analytical Methods

The whole of Section 6 of this report is devoted to a fairly detailed account of, first, the aims of analysis, and second, an account of the methods actually used. The following paragraphs merely seek to describe the general approach to analysis, as far as possible, in non-technical terms.

Analysis is itself a rather forbidding word, but the basic concepts are invariably relatively simple. Most useful analysis is directed at calculating such familiar statistics as means, ranges, probabilities and proportions in various categories. The overall purpose is to summarize a large number of separate observations, to simplify them and try to extract laws about relationships, generate hypotheses and make predictions.

The analytical cornerstone of the Scottish Coastal Survey, and of most other surveys, is classification. In this case, the method of classification used is called indicator species analysis (ISA). It is a numerical method of classification and, because the analysis involves a large number of (relatively simple) calculations, it is conveniently done on a computer. All this is of very little significance to the practical user compared with knowing why classification has been used. Classification is merely the process of putting like with like, so that a given number of entities may be reduced to a smaller number of classes, thereby achieving a marked degree of simplification. It is then possible to investigate the internal properties of the classes and the differences between classes, and draw general conclusions about them more easily than by contemplating the original individual entities. This type of situation is analogous to an experiment in which the treatments are equivalent to the classes and the replicates are the entities that make up a class. The only difference is that, in an experiment, the classification structure is deliberately imposed by the experimentor. The general approach to drawing conclusions and making predictions based on the observations is similar.

Classification, consciously or unconsciously, enters just about every aspect of the mental process, as every observation we make, however trivial, must automatically be compared against some sort of reference set. It is only when problems become increasingly complicated that we first lose the ability to remember the reference set, and then find difficulty in even deriving an effective one. Often we need external help by writing down or, by other means, recording the reference set, e.g. a flora. Next we may feel the need of a method of accessing the reference set, e.g. a key, and, in the last resort, we may require some more formal procedure of actually deriving a reference set, e.g. a method of classification.

The other main technique used to analyse data produced by the Scottish Coastal Survey, which needs some explanation, is ordination. It is not quite so easy to give a simple account of ordination as it is for classification. However, as the name "ordination" suggests, it is concerned with the process of putting a number of entities in order and a familiar example would be arranging a number of people according to their height. This is obviously not the only way these people could be arranged; they could also be ordered according to their weight, and it would then be possible to draw a plot or graph of weight against height. In this example, height and weight would almost certainly be related, but one might equally well introduce age and eye colour, or innumerable other possibilities, to the investigation. The same graph of one variable against another could be produced, but the number of permutations would swiftly outrun the ability to assimilate the relationships. A method of ordination examines all the inter-relationships between a large number of features; it finds out which are related to which and then produces a series of orderings of the entities according to combinations of closely related features. Again, using the example of the people, one ordering might be a composite of height, weight and age and a second might be according to eye colour alone. The dual interests in the results of ordination are in the features which are related and in the orderings of entities produced.

Turning now to the real object of our interest - vegetation - a quadrat (the entity) contains a number of species (the features of that entity). Given a series of such quadrats, it is obvious that one can ordinate them. The interest to the ecologist is, first, which features (species) are related to which or, in other words, what are the species associations, and, second, how the entities (quadrats) are ordered. The ordering of quadrats can be examined to investigate ecological trends. This can be done by a knowledge of groups of species that are determining a given ordination, or by seeing how various environmental factors, e.g. pH, soil moisture, rainfall, temperature, grazing intensity, are related to the different orderings (or to axes of the ordination). Examination of such relationships can be done by graphical methods or, more formally, by correlation

The combination of classification, ordination and a whole series of other more familiar methods of analysis provides a powerful means of investigating a set of data with the size and complexity of that produced by the Scottish Coastal Survey.

Details of the methods used can be found in the technical literature. For indicator species analysis the main references are Hill et al. (1975) and Hill (1977), and for reciprocal averaging ordination (the particular method of ordination used for the Coastal Survey data), Hill (1973 and 1974).

5 DIFFICULTIES AND LIMITATIONS

5.1 Choice of Sites

Thoughts about nature conservation in Scotland have been centred on sites and conservation areas, at least since the publication in 1947 of "National Parks and the Conservation of Nature in Scotland" Cmd 7235. In 1949 this Command Paper was followed by "Nature Reserves in Scotland" Cmd 7814 which suggested sites for nature reserves and outlined their boundaries. The Nature Conservancy and its successor the Nature Conservancy Council have used these publications to form the basis of their National Nature Reserves and Sites of Special Scientific Interest in Scotland. It is, therefore, natural that NCC should have requested a site orientated survey which, in fact, includes a number of sites mentioned in Cmd. 7814 .

It is because of this background that there is no unambiguous definition of the population of soft coast sites from which the Scottish Coastal Survey sites have been drawn. An added complication arises from the contribution to the list of sites by various members of NCC staff, who each have their own ideas about the sites for which they want information. The choice may range from every site in a region to a selection based on existing SSSI's. Whilst the list of sites studied probably covers most of the range of variation, it is by no means certain that the findings of the survey can be extrapolated to all other coastal sites in Scotland. Extrapolation is most likely to be valid for large sites and least likely for small ones, as very few small sites were included in the original sample. Besides bias caused by geographical distribution of sand, e.g. the north-western fiord coast has few areas with blown sand, there are relatively few surviving sites from the south-west of Scotland. The reason for this bias is a restriction placed on the sample, namely that golf courses should not be included in the survey. The Ayrshire coast, being close to large residential areas, has golf courses along most of its length, and these have been constructed as close to the sea as possible. As a result, it has not been possible to examine the fragments of semi-natural vegetation left within the golf courses. This information might have been useful in tracing the distribution of plants which extend their range up the west coast of Britain into the Hebrides. The problem has not been so acute elsewhere in Scotland, so that adequate coverage has been possible.

5.2 Determination of Site Boundaries

At the beginning of the project, NCC undertook to provide the boundaries to the sites they wished to have surveyed. These boundaries were determined by various members of NCC staff. Some of the boundaries given were those of existing SSSI's, some were made with good personal knowledge of the sites, whilst others relied on published or file reports and a limited familiarity with the area in question. The different approaches used to determine the boundaries have led to inconsistencies between the surveyed sites. Attempts to lessen these inconsistencies have been made by providing NCC with 6 inch maps on which to draw the boundaries and by a subsequent rationalization of these boundaries by a member of the ITE project team, experienced in the assessment of soft coast areas. In some cases the original boundaries have been extended to follow, where possible, a feature on the ground, e.g. fence line, river or track. An attempt has been made to ensure that each site encloses all the area of blown sand. Nevertheless, it is known that some boundaries do not include all the sand whilst others extend on to peatland and bog. Certain areas on the sites were excluded from the survey at the request of NCC. These were golf courses, forestry plantations (except for a few exceptional cases, e.g. site 75 Lossiemouth), cultivated land, farm and croftland, and built-up areas.

The result of delimiting the sites by man-made features has increased the difficulties of inter-site comparisons. Some east coast sites are been limited by agriculture which has encroached right up to the coastal dune, although the limit of blown sand is much farther inland. In other sites on the east coast, a large portion of the blown sand is now afforested. On the west coast, the extent of cultivated croftland varies from none on some islands to about 50% (as estimated by the number of quadrats abandoned for this reason) at Paible (site 31) in North Uist.

Whilst it is the site that is normally the centre of interest to NCC, it would be useful to try to understand to what extent site differences are determined by anthropogenic factors. One approach to understanding this aspect would be to re-analyse selected parts of the data. The quadrats to be investigated could be defined using environmental criteria such as a minimum depth of blown sand, presence of saltmarshes, peatland, grazing or public pressure. Those without the desired character would be deliberately excluded from analysis. In this way it would be possible to make more equable comparisons between sites. This type of approach has not been used in the preparation of the current report.

5.3 Geographical Limitations

Certain geographical limitations to the data set have been mentioned in Section 5.1. There, is of course, the major limitation of the survey being restricted to Scotland so that the vegetation and site keys cannot be used in England and Wales. Whilst the keys might work reasonably well on sites in the north of England, this would certainly not be the case in southern England. Many plant species found on dunes reach their northern limit at about the Solway Firth, e.g. Euphorbia paralias. The number of possible species increases southwards, with lusitanian species occurring in the south-west of England and continental species in East Anglia and the south-east of England.

The apparent lack of scientific criteria to define the population of sites could cause problems if it was decided to extend the Scottish Coastal Survey to include England and Wales. However, such problems could be minimized by retrospective study of the Scottish coast to determine how the selected sites relate to the whole population.

5.4 Effect of Seasonal Changes

5.4.1 Vegetation Changes

The main field season for the quadrat survey lasted from the beginning of June to the middle of September. In 1976 and 1977, the training courses were held in late May, a time at which few plants had developed flowering shoots. Late June is probably the best time for the study of the dune flora but with so many sites to survey it was clearly impossible to limit the field work to such a short period. Most plants underwent considerable development during the field season and it was necessary to be able to identify them in all stages. A few species appear briefly for a week or two and disappear, the vegetation rotting as quickly as it grew, e.g. Parnassia palustris. Some dune annuals are winter green, growing during the winter to complete flower and seed production by late spring. Cerastium semidecandrum is an early flowering plant which may well have been under-recorded as a result. Fortunately, most methods of vegetation classification are robust enough not to be seriously affected by the omission of such species. Although, as a combined result of the quadrat and supplementary surveys, the site species lists are thought to be fairly comprehensive, there may be some systematic differences due to seasonal variation in species complement.

More important from the point of view of making the site comparisons, are the differences in the weather from year to year which affected the performance of some species. It is thought that the Orchidaceae, particularly the marsh orchids, have varied in abundance in response to wetness both at the time of survey and in the previous growing season. The summer of 1976 was one of the wettest on record in the Hebrides, while mainland Britain was experiencing drought. This wet period coincided with the survey of the Outer Hebrides, and the marsh orchids were prolific there. However, later in the same season survey activities switched to the north and east coasts where the weather had been warm and dry, and few marsh orchids were recorded. One site, Strathy, was recorded during this period and then re-visited (in connection with the NCC training course) in June 1978, when the display of orchids was quite spectacular. The weather of 1976 was so extreme that, when surveying some sites on the east coast in September, even clover was difficult to identify because the leaflets were dropping off through the drought. The three field seasons had different weather and because, for logistic reasons, the survey had some geographical pattern, minor systematic variation may have been introduced into the data.

In addition to the presence or absence of species due to season, the cover of an individual species will change as the season progresses. This is one of the main reasons why the cover data have not been used in formal analysis (see Section 6.2).

5.4.2 Habitat Changes

Changes in vegetation structure allied to those of cover are also evident, particularly in the tall herbs and grasses which over-winter at ground level yet grow a flowering shoot of over 1m high.

Apart from the ubiquitous rabbit, which is active all the year, certain farming practices may mean that the dunes are either winter or summer grazed or that the animals may change with the season, e.g. sheep at one season and cattle at another. A winter grazed site still showing the evidence in early June may have lost all trace by

September when the vegetation has regrown. The evidence for grazing activities presented should be interpreted in the knowledge that it represents a sample taken at a particular time in the year. Even rabbit populations are known to have fluctuated violently during the course of the survey in relation to the prevalence of myxomatosis which showed marked local variation.

In mobile dune areas and along the shore, dramatic changes can be wrought by a single storm. Longer term changes of erosion or accretion may have happened since the map used for the survey was made. These occurrences accounted for some quadrats being abandoned.

5.4.3 Soil Changes

There will inevitably be day to day changes in soil moisture with short term rainfall, even to the extent of water ponding temporarily in slacks. In 1976, the sand became so dry on east coast sites that it was difficult to use an auger in the top 75-100cm. This difficulty is reflected in the soil data recorded at that time.

More important in a survey of this kind are the changes in the water table. The depth to the water table was measured to investigate correlations with slack vegetation. The water table may change by as much as 1m in a season so that interpretation may prove difficult. For example, a water table at a depth of 1m in early June may be at 2m by the end of August. Care must therefore be taken to check the depth against the season.

5.5 Limitations of Sampling Intensity

The standard sampling density of two samples per 0.15 sq km (1 sample per 7.5 ha) was arrived at through the necessity of surveying 94 sites in three years. The rate of working for a field team was known so it was possible to determine how many quadrats could be completed in three field seasons. The limited number of quadrats possible meant that the survey was extensive rather than intensive. The greater the number of quadrats on a site the more precisely can the boundaries of vegetation types be determined and then placed on a map. The density of sampling was inadequate to attempt detailed mapping on all but the most uniform site - if such exists. Most sand dune systems are a mosaic of habitats forming a relatively fine pattern which is inevitably difficult to map accurately without a large number of samples.

The detection of rare habitats and species will improve with an increased sampling intensity regardless of which of the two surveys (quadrat or supplementary) is considered. The discipline and close scrutiny of the quadrat survey, where every plant is recorded, often ensure that diminutive species are found. Nevertheless, there is an element of chance in finding rare species.

5.6 Limitations of Cover Data

The method of estimating cover for vascular plants and the various cover categories, such as bare sand, rock, bryophytes, lichens, etc., is described in the Handbook of Field Methods. Much effort was expended in making these data as uniform as possible. The Handbook contains guidelines (they are not quite firm enough to be called rules) as to how the cover estimates should be made. The training course also placed considerable emphasis on this aspect of the method, including tests of the different surveyors' ability to produce comparable estimates when assessing the same quadrat. Results were compared and the ensuing discussion helped surveyors to unify their approach. The level of comparability achieved on the training course was good, but whether this level of performance was maintained by individual surveyors on their own in the field is difficult to determine. A more objective method of estimating cover, using a smaller 0.25 sq m quadrat (estimating the cover for all species with [5% cover in 16 replicates within the 25 sq m quadrat), was tried in the early trials of the field method but was abandoned because of the time taken. As it was never intended to use cover in the more formal analyses (see Section 6.2), merely as interpretive information, relatively low precision is of little consequence.

As far as the whole survey is concerned, the mean cover values for site or vegetation types can be used with confidence to make comparisons. The cover values for individual sites should be treated with caution, as they usually represent the work of only two surveyors who could, by chance, both be biased in a particular direction. For detailed comparisons, the cover values produced by the method used in the survey can not be relied upon. However, as emphasized above in Section 5.4.1, individual cover values at a particular point in time have little meaning so this cannot be regarded as a significant limitation. In extensive surveys, like the Scottish Coastal Survey, the use of better methods of estimating cover is not really justified.

6 AIMS AND METHODS OF ANALYSIS

6.1 Classification

The philosophical background to classification has already been covered in Section 4.6. It now only remains to decide on the subject matter for classification and the type of information on which it should be based; in other words, classification of what and what type of classification?

The answer to these questions lies in the main objective of the survey; to compare sites and determine the extent of habitat types and vegetation types within sites (see Section 1.1). As far as subject matter is concerned, two classifications are clearly required.

(a) A vegetation classification.

(b) A site classification.

The ecologist is usually more familiar with the first of these, but it can be argued that both are merely convenient points on a continuous scale which starts with individual plants and ends where the units involved are too big to be useful. In the case of the Scottish Coastal Survey, a site is, by definition, a useful unit for classification (see Section 4.2). The fact that sites are not of fixed size has little bearing on the matter. For the vegetation classification, a 25 sq m quadrat (a fixed size) is taken as being the unit of classification. For some purposes it could have been smaller and for others bigger, and 25 sq m has been chosen as a convenient compromise.

It is also a useful aid to the interpretation of vegetation types to produce a species classification, i.e. defining groups of associated species. This has been done for the Coastal Survey data and the results are shown in the two-way tables (species x vegetation types) in Section 7.7. Only the commoner species are included in this classification, i.e. all those with an overall frequency of 10 or more in the 1 sq m quadrat size. The smallest quadrat size of 1 sq m was recorded specifically with a species classification in mind. The small size of the sample area means that it provides a stringent test of whether two species will grow in close proximity to one another. This is the basic concept of associated species.

The term "vegetation classification" is self-defining as to both the subject matter of the classification and the type of information upon which it is based. In the case of site classification, only the subject matter is implicit, and the type of information used could be almost anything that was relevant, e.g. climate, soil, management, ownership, scenic value, cost, etc. Although vegetation classification is sometimes regarded as an end in its own right, its origin and most general application is really that of ecological classification. In other words, plants are being used as a source of information about the whole ecosystem, i.e. the plants, the animals, the environmental complex and their interactions. The arguments for using vegetation as an index to the ecosystem as a whole have been summarized by Bunce and Shaw (1973) as follows.

(a) By virtue of its direct dependence on environment, vegetation can be regarded as providing a sensitive, integrated measure of the entire complex.

(b) As vegetation is the primary producer, upon which nearly all other organisms, directly or indirectly, depend, it must contain a great deal of information about the rest of the biosphere.

(c) Suitable measurements of macro-vegetation are comparatively easy to obtain because of its size and the comparative absence of major taxonomic problems.

(d) Because of the integrating properties and relative permanence of vegetation, the time dimension can largely be ignored in the collection of data.

The only other obvious way of classifying ecosystems is through measures of the environmental complex which is assumed to drive the ecosystem. This approach has some theoretical advantages, particularly if the main interest is in the potential ecosystem rather than the actual one. Thus, environmentally, a cornfield could be identified in terms of its equivalent natural ecosystem or at any stage in between. The difficulty of constructing an effective environmental classification lies mainly in the problem of obtaining the information upon which it is to be based. The collection of environmental data may become more feasible in the future, but at the present time the use of vegetation offers the best solution to ecosystem classification and one that is particularly well suited to the needs of NCC.

6.2 Basis of the Vegetation Classification

Although it is called the vegetation classification, it has already been established that ecological classification is the main aim and that vegetation is merely a convenient method of achieving this objective. Obviously a vegetation classification must be based on information about plants but there is a range of possibilities as to exactly what measures are to be used. The following paragraphs describe what measures were used and why.

Firstly, the information used in vegetation classification was limited to vascular plants; bryophytes and lichens were deliberately excluded. The main reason for this decision was that a classification which required the identification of these rather specialist groups would be undesirable. Sand dune bryophytes are usually rather small species, which are difficult to identify in the field, and lichens are intrinsiaclly difficult to identify and may require resort to chemical tests. A vegetation classification that could not be used in the field would be of less use to NCC than one which can. Fortunately, restricting the basis of classification to vascular plants has very little effect on its powers of resolution or accuracy (see also Appendix 6 - Bryophytes in the Scottish Coastal Survey, Section 5.1). The relatively large number of species present in most vegetation data results in a considerable degree of information redundancy, i.e. a number of species are contributing the same, or very similar, information. In most vegetation classifications it would be possible to reject half the species at random and still produce essentially the same classification. It is only in the very species-poor vegetation types that bryophytes and lichens have the possibility of making a significant contribution. Even this contribution can be virtually ruled out in the coastal habitats because most species-poor types occur in specialized habitats, e.g. pioneer dune, saltmarsh, strandline. These habitats support species with very narrow environmental tolerances which immediately characterize the vegetation type because they occur nowhere else.

Secondly, the information used in the vegetation classification was limited to presence or absence of species; the use of quantities such as frequency or cover (the latter was actually recorded in the field) was deliberately avoided. The choice between the use of qualitative or quantitative data in vegetation classification, is a recurring problem; and is a problem which is often unecessarily laboured. Measures of the relative information content of qualitative and quantitative data have been developed (e.g. Williams and Dale 1962). They usually show that a high proportion of the information is contained in the qualitative element but, as far as the practical ecologist is concerned, this is a rather sterile approach. The main issues are:

(a) what type of classification is required; and

(b) what types of data is it practical or efficient to collect in the field?

If a classification which reflects the grazing potential of various types of vegetation is the objective, then clearly quantities of species (ideally biomass) would be highly relevant. On the other hand, if all that is required is a rather general ecological classification, then simple species lists with no quantitative qualification will almost certainly suffice. This is not, of course, a universal rule, for even with general ecological classification, if the total range of variation is narrow, quantitative information may become necessary. If there is a rule to follow, it is that, unless there is any prima facie reason to suppose otherwise, qualitative information should be used. Quantitative information is always more time-consuming to collect, e.g. frequency, cover or biomass, than qualitative. Estimates of cover, as carried out in the Scottish Coastal Survey, are not suitable for formal analysis because they are not sufficiently reproducible, despite the care that was taken to ensure a uniform approach. A key based on cover data would be open to an undesirable degree of subjectivity in its use. A more reproducible method of recording cover was tried in the early stages but abandoned because of the time it took.

In fact, the balance of argument was even more strongly against the use of quantitative measures as a basis for classification in the Scottish Coastal Survey. The main reasons for rejecting the use of quantitative data in this particular application (but it probably applies equally to many others) can be summarized as follows.

(i) The relative quantities of various species change quite markedly over the season (a long field season had to be adopted to get the work done). It even has a minor effect on the presence/absence of certain species (see Section 5.4.1).

(ii) In certain habitats, cover can change markedly overnight, e.g. as the result of a minor sand blow.

(iii) Grazing intensity has a major effect on cover. Details of the grazing regime, e.g. periodicity and type of animal, are also important.

In other words, many quantitative features must be regarded as being unstable in the short term which makes them difficult to measure in any meaningful way. Also, there is no reason to suppose this kind of instability is directly related to the underlying ecology. It is, therefore, considered that the use of quantitative measures would merely introduce a confusing element into the type of basic ecological classification that is required. In practice, the range of vegetation types covered by the survey is so great that there would seem to be no possibility of quantitative information being required to give additional differentiation. Evidence will be presented later (Section 6.3), that a vegetation classification based on purely qualitative information can produce finer, ecologically significant divisions than can be interpreted with ease.

Turning now to the matter of scale, the use of a 25 sq m quadrat for the vegetation classification was an arbitrary decision based on general observation of coastal vegetation and on what it was thought would be convenient. A smaller quadrat size, e.g. 0.25-1 sq m, would have been quite satisfactory for the machair vegetation - heavily grazed, species-rich, fine patterned and very uniform. However, this size would have been most unsatisfactory for tussocky marram dune vegetation where the pattern is much larger, i.e. a small quadrat could either fall on or between the tussocks. At the other extreme, a large quadrat increases the chance of including heterogeneous samples. Although objective sampling requires the acceptance of heterogeneous quadrats (unless tests of heterogeneity are used to reject such samples afterwards) and numerical methods of classification deal with the majority in a sensible manner, they are to be avoided wherever possible. The compromise quadrat size of 25 sq m is large enough to sample the coarser patterned types well and yet not so large as to produce a high proportion of heterogeneous samples.

It will be recalled (see Section 4.3 or the Handbook of Field Methods) that a nested quadrat system consisting of six sizes (1, 4, 25, 50, 100 and 200 sq m) was used in the Scottish Coastal Survey and that species were recorded additively. As stated above, data derived from the 25 sq m quadrat were used as the basis of the vegetation classification. The smallest, 1 sq m, quadrat was introduced in order to provide a means of species classification (see Sections 6.1 and 6.4). The largest 200 sq m quadrat was recorded to produce as comprehensive as possible total species list for each site. Subsequent analysis has shown that this was an extremely efficient method of gathering records for the less common species. The 200 sq m quadrat data have been used to construct the species distribution maps (Appendix 3) which link with the annotated species list given at the end of each Site Dossier. The other quadrat sizes serve two main purposes, first, to enforce an element of discipline into the searching of the quadrat for species (this makes a very big contribution to the quality of the field recording) and, second, to ensure that the Scottish Coastal Survey can be made compatible, in terms of quadrat size, with most previous and future vegetation surveys which may, for various reasons, use a different quadrat size. Finally, a series of quadrat sizes provides a means of studying heterogeneity, either by means of the species/area curve or by other methods. No such analysis has been attempted for the present report.

This then is the theoretical background to the derivation of the vegetation classification but, in practice, things did not work out so smoothly. As soon as the plant records for all three years of the survey had been fully corrected and the majority of herbarium specimens identified and entered into the data, a preliminary vegetation classification was prepared. A site classification based on vegetation type frequency was also produced (see Section 6.3 below).

Keys to both classifications were prepared from the analysis along with an outline interpretation of the vegetation and site types thus defined. The results of this work were taken to the training course for NCC Staff held at Thurso in July 1978. Two of the sites covered by the original survey (Dunnet and Strathy) were re-sampled to provide practical training in field methods for the participants. The results of the survey were examined using the two keys and it immediately became apparent that there were serious deficiencies in the vegetation classification. This, in turn, had some effect on the site classification because it depended on the vegetation types derived from the vegetation key. Fortunately, the site key was shown to be extremely robust and the effects were minimal.

Closer examination of the vegetation type key revealed that it had an error rate of about 12%, approximately half of which resulted in serious (and extemely conspicuous) errors, i.e. the allocation of a quadrat to a totally inappropriate vegetation type. Most errors were in connection with bog, marsh or semi-aquatic vegetation or quadrats in which there were trees or shrubs forming a superimposed layer over the ground vegetation. Disturbed quadrats of various types were also subject to error.

The problem lies not in producing a good computer classification but in providing an accurate dichotomous key with which to generalize this classification. In general, the type of mistake made by the key was fairly obvious, i.e. the user was left in no doubt that the answer was wrong, but the problem was how to correct it. As with most taxonomic keys, it is not difficult to find at which stage things went wrong and "fix it" but the need for this sort of rectification is most undesirable in what is supposed to be an objective classification.

Mistakes in the key have an entirely logical explanation; they are the so called "misclassifications" produced in ISA (see Hill et al. 1975, pages 601-602). A misclassification is a quadrat which does not contain the right complement of indicators to agree with its total species composition. In the computer analysis, the total species composition, as expressed by its ordination score, is permitted to override the indicators. Subsequently, when the key is used, the ordination score is not known and the quadrat is allocated according to its indicators. Thus, all misclassifications (in the strict sense used in ISA) are allocated to the opposite side of the key to that in the original computer classification. This is not necessarily a serious matter. If there are reasonably similar quadrats on the other side of the division, as there frequently are, the offending quadrat will almost certainly be allocated to a reasonable type, although this is obviously not an optimum procedure. Only when there are no remotely similar quadrats on the other side of the key does a really disastrous allocation occur.

It is not proposed, in this report, to give an exhausive description on how the problem of key accuracy was investigated. This will be the subject of a scientific paper in the near future. However, it is necessary for the user to know the outcome. First, the key accuracy was greatly improved by minor improvements to the way ISA works. Modifications were made to the method of weighting species, to the method by which indicator species are selected, and, finally, to the method by which the exact point of division is chosen. The combined effect of these improvements was to approximately halve the number of misclassifications, but it is doubtful if the serious mistakes were reduced in the same proportion.

Because some divisions in ISA only need a few indicators to produce an accurate key, whilst others need many, a new version of the method was produced which permitted the number of indicators per division to be varied according to the ease or difficulty of that division. It is easy to measure difficulty of division, so this selection of the indicators was done automatically. The net result is a more accurate key with the minimum number of indicators so as to make it efficient for the user.

In early August 1978, this was thought to be the final solution to the vegetation classification problem - the most accurate classification that could be produced with existing methods. Soon after this, the possibility of a different approach was appreciated. Although this approach incorporates a new principle, i.e. new to ISA, that of re-allocation, it only involves a minor change to the internal rules by which ISA operates. When dealing with misclassifications, the modification required is to ignore the ordination score and permit the misclassifications to be allocated according to their indicators. The dichotomous key now allocates quadrats in exactly the same way as the computer analysis and is therefore completely accurate. The penalty - and of course there must be one - is that for a given number of divisions the computer classification is not optimal; within-type heterogeneity is higher and there is a greater tendency to fragmentation of types. However, a simple remedy is possible, by allowing the ISA to over-divide and then recombining the result, using the types to replace individual quadrats in the analysis. Over-division ensures within-class homogeneity, whilst recombination both reduces the number of types to a reasonable number again and rectifies any fragmentation. Recombination was carried out in exactly the same way as for the site classification, using species frequency within the types (transformed to pseudo-species) in a second ISA.

In theory this classificatory strategy - a polythetic divisive method allied with a means of re-allocation - has much to commend it. Not only does it produce a completely accurate key but it is also likely that the classificatory framework is marginally improved. As far as the user is concerned, the only difference is that the dichotomous key is now multi-path, i.e. a given type may be reached by several different routes through the key. This is not an uncommon feature of taxonomic keys, e.g. the Equisetaceae in Clapham et al., 1962. Nothing of the recombination process, except the end result, is evident to the user.

6.3 Basis of the Site Classification

As has already been emphasized, the site classification and the various analyses derived from this are considered to be the most important products of the Scottish Coastal Survey. These analyses define the range of variation of sites on the soft coast of Scotland and provide the means of making objective site comparisons.

In this version of the report, the site classification deals with the sites exactly as defined by NCC, i.e. with no boundary modifications. As has already been discussed in Section 5.2, the determination of site boundaries was done on a rather <u>ad hoc</u> basis, by a number of people with rather different outlooks, and this factor has inevitably contributed, in some degree, to the structure of the site classification. However, systematic differences between sites resulting from land-use are almost certainly still more important, so that the full range of habitats normally associated with soft coasts is rarely present in a given site. Sites in eastern Scotland are usually most affected, often being reduced to a narrow strip of coast dune, the inland part of the system having been extensively modified by agriculture or golf course construction. As already noted, most sites in south-west Scotland have had much of their conservation interest destroyed by such activities, and are not included in the survey. By contrast, some sites in western Scotland (particularly the Outer Hebrides) retain the full range of dune habitats, from foredune to the "blackland" beyond, more or less intact. However, they are affected to some extent by crofting activities (grazing and shifting cultivation). In other words, some differences between sites result from the choice of boundary and/or the effects of land-use, whilst others represent fundamental differences in the ecosystem, i.e. those governed by climate and soil.

It should be emphasized that the above paragraph is not intended as a criticism of NCC's approach to defining site boundaries. Although nowhere has it actually been expressed, this selection was done on a logical basis. First, most sites conform roughly with the extent of semi-natural habitat. This criterion has worked quite well where there is a clear distinction between semi-natural and greatly modified habitats, e.g. in eastern Scotland, but less well where there is greater continuity of the former, e.g. the Outer Hebrides. The second criterion, that has probably been more consciously applied by NCC in defining boundaries, is that of producing usable conservation or administrative units. Hence the splitting of some continuous sites and, not infrequently, the retention of some sort of buffer zone round what is considered to be the "prime" site.

Because, for a number of reasons, conservation of dune systems is more important than certain other habitats that occur within the sites as defined, there are sound arguments for carrying out a separate analysis of sites based only on those samples which have sand as their substrate. This analysis could be done very easily by using information collected from the soil pits and auger holes that were recorded for each quadrat. Basically, the analysis would permit between-site comparisons to be made free from the possibly confusing influence of the non-sandy habitat. However, in the absence of any reaction from NCC when this suggestion was made in the preliminary (1978) report, no further attempt has been made to follow this line of analysis.

Having earlier discussed at some length, in Section 4.2, the advantages and disadvantages of a priori stratification (which produced so many problems that it had to be abandoned), screening of samples according to substrate type is an example of a posteriori stratification. The main advantage of such an approach is that the stratification can be based on reliable information collected during the survey. A posteriori stratification is seen merely as an analytical device. In its present context, it does not affect the efficiency of the sample but, if further sampling were envisaged, it could be directed to this purpose.

With regard to the type of data on which to base the site classification, two distinct methods were considered:

(a) Species frequency.

(b) Vegetation type frequency.

The basic problem is that of summarizing the quadrat data so that they best express the properties of sites. For each site, a variable number of quadrats (the actual range is 16-108) have been recorded for presence of vascular plants. The cover data were not considered suitable for the main analysis because the precision of the estimates was low but there were other reasons as well (see Section 6.2).

Option (a), species frequency, is the obvious one of using the estimate of percentage frequency derived from the quadrats recorded. Thus, if species A occurred 8 times in 32 quadrats its frequency would be 25%. This type of data summarization is conventionally used to produce a composite that represents a site. It is a simple method of summarization and one that requires very little modification of the original data. However, as the basic assumption of classification using vegetation is that certain species grow together and others do not, it is interesting to note that this information would appear to be destroyed by using species frequency. For example, if species A and B both have a frequency of 50%, this statistic does not indicate whether they occur in the same 50% of quadrats, or a totally different 50%, or somewhere in between these two contrasting possibilities.

On the other hand, option (b), vegetation type frequency, is an obvious means by which information on species association can be retained. Here the approach is to classify each quadrat by its species complement and then use the relative quantities of these vegetation types to represent the site. Compared with the use of species frequency, this is clearly a more extreme form of data summarization; each quadrat is reduced to a single entry to the site data instead of each species making a contribution. Vegetation type frequency has (as far as we know) never previously been used to classify sites.

How do these two apparently contrasting types of data summarization differ, and which is the best? At the end of the second field season (autumn 1976) the question was investigated using the data from the 68 sites surveyed at that time. Rather than produce two classifications and try to compare them (it is not easy to compare the similarity, or otherwise, of two classifications), the initial investigation was conducted using ordination techniques. Reciprocal averaging ordinations were calculated for sets of site data produced by the two methods of summarization and then the correlations between the first five axes for each were calculated. Remarkably, the two ordinations were similar. The correlations between matched pairs of axes were 0.92, 0.92 and 0.74 for the first three axes, with further very highly significant correlations between axes 4x5 and 5x4 for method (a) and (b) respectively. This result indicates that the two apparently contrasting methods of data summarization are essentially the same.

On purely theoretical grounds (because it is likely to retain more information), method (a), species frequency, is to be preferred to (b). However, a number of practical considerations favour method (b), vegetation type frequency. The main advantage of this basis for site classification is that it is easier to envisage a site as being composed of varying quantities of a series of vegetation types than it is to think about species frequency, which, despite its proven efficiency, is a somewhat inscrutable statistic. Also, when it comes to preparing quadrat data for application to the site key, it is easier for the user to calculate vegetation type frequency than species frequency by hand.

With these considerations in mind, classifications based on the two methods were now produced. In the case of (a), species frequency, the percentages were transformed into four pseudo-species (see Hill et al., 1975) with limits of 25, 50, 75 and 100%. For (b), twenty-eight vegetation types (plus one extra type for bare ground) were recognized. Here, six pseudo-species were used with limits of 1, 5, 10, 20, 50 and 100%. The outcome of these two classifications was examined by plotting them on maps of Scotland and studying the distribution of types. As expected, the two classifications were remarkably similar, the exception being the Outer Hebrides where there was a marked geographical distribution of types using species frequency. This feature was far less clear-cut using vegetation type frequency. As it is extremely unlikely that a marked geographical distribution would be produced by chance, it must be concluded that the former is almost certainly the superior classification. The most likely explanation for this outcome is that species frequency is a more efficient method of data summarization. This conclusion is further supported by evidence from the ordination investigation described above, where it is clear (from ordination plots) that between-site variation in the Outer Hebrides is low compared with the rest of Scotland. In other words, this is just the situation in which information loss could become important.

The next step in this methodological investigation was to increase the number of vegetation types recognized in an effort to reduce the information loss. A second classification using fifty-two vegetation types for summarization (b) (again, plus one extra for bare ground) was calculated. The number of vegetation types used here must be regarded as excessive and well beyond the limit of what is customarily identified in the field. In the resulting classification, the distribution of types in the Outer Hebrides was very much more clear-cut than that produced using only twenty-eight vegetation types, but still not quite as good as that produced using species frequency. The simple conclusion is that, with more vegetation types, more information is retained. But what can be done about the proliferation of vegetation types? Clearly if they assist in differentiating between sites, they must be significant, even though their significance is hard to appreciate by looking at species lists. The obvious solution would be to use a rather coarse vegetation classification for the normal purpose of identifying vegetation, and looking at it in the field, and a finer version (produced by subdivision of the coarse version) for site classification.

Further investigation, using the full set of data, in the winter of 1977/78 and the testing of preliminary site and vegetation classifications at the training course for NCC Staff the following summer, reinforced the importance of the greater accuracy and finer resolution that could be achieved by using species frequency. As a result of this and other considerations, it was decided to revert to species frequency as the basis for the site classification, thereby forgoing a certain amount of user convenience. The advantages and disadvantages of a key based on species frequency can be summarized as follows.

1. Advantages:

   (a) the method of summarization results in minimum information loss;

   (b) it does not require a lot of complicated juggling with numbers of vegetation types to produce a good classification in areas of low between-site variation; and

   (c) the resulting key should be more robust.

2. Disadvantages:

(a) interpretability - it is more difficult to think in terms of site types being composed of species frequencies than it is of vegetation types ; and

(b) the mechanics of using the site key are more difficult - the user has to calculate % species frequency rather than % vegetation type which, by hand, is more difficult.

Not much can be done about disadvantage (b); it is the price the user has to pay for accuracy. As far as disadvantage (a) is concerned, it should be emphasized that species frequency need only be used to feed the key. The view that the user gains some insight into the classification from the actual use of the key is much over-rated. Indeed, it can be argued that too much attention to the key can be positively misleading; it is all too easy to arrive at a simplistic interpretation of the key through failing to appreciate that the set of indicators defining a given division must be qualified by all divisions that have gone before. In practice, it is quite easy to interpret the first two levels of division but after that interpretation becomes increasingly difficult. Failure to appreciate the true nature of the process often leads to questions such as why certain indicators, or even groups of indicators, are repeated in different parts of the key and how a species can become an indicator to a subdivision of a division for which previously it was indicative by its absence. Such questions all have eminently logical answers but, for the practical user, it is probably better to accept the keys on trust and rely on the descriptions of within- and between-class characteristics for most of the interpretation. This is, to a large extent, analogous to what happens in a flora, i.e. the characters used in the keying-out process do not give a clear picture of the species concerned. A much more useful approach to the interpretation of the site classification is to describe what vegetation types, or proportions of vegetation types, they contain. Because the classifications based on species frequency (the actual basis of classification) and vegetation type frequency are so similar, this method of interpretation is certain to be very revealing (see Sections 8.3.3 (Table 4) and 8.4).

6.4 Basis of the Species Classification

As already explained, the purpose of a species classification is to understand the species associations. This understanding is of considerable assistance in interpreting the vegetation classification and, to a lesser extent, the site classification. A species classification can be used to investigate heterogeneity in the vegetation types. It would also be useful in any studies of rare or local species, for example, to see which other species are commonly associated with them.

The basis of the species classification is the data collected from the smallest 1 sq m quadrat. The underlying model, upon which ISA is based, is not really suitable for inverse classifications, i.e. classification of species by the quadrats in which they occur, so an alternative method had to be found. In this case, the combination of reciprocal averaging ordination (using the axes scores to calculate a matrix of Euclidean distance) and minimum variance clustering proved to be a perfectly satisfactory solution. The results of the species classification are discussed in Section 7.7.

6.5 Relationship with the Environment

Relationships between the vegetation and site classifications and various environmental features are an important means of interpretation for both levels of classification. Information on environmental features has been obtained from a number of sources.

(a) Directly from the quadrat survey itself, e.g. slope, aspect, a range of soil profile attributes and auger hole data, such as sand and water table depth together with management features such as cultivation and grazing pressure.

(b) Indirectly from the quadrat survey, including the soil samples that were obtained from quadrats. A sub-sample of these have already been analysed for loss on ignition. Other analyses such as pH, free calcium carbonate and mechanical analysis could be done if resources permit.

(c) From other sources such as OS maps, e.g. measures of altitude, slope and fetch, or climatological data, e.g. rainfall, mean temperature, wind-run, insolation, humidity, etc.

These data have been used in various ways (usually by calculating class means and ranges) to assist in the interpretation of both the vegetation and site classifications. Whilst this type of investigation cannot establish causal relationships, it can yield working hypotheses and identify particular factors for further study.

6.6 Other Analyses

A whole range of other analyses have been completed in order to produce the type of data summaries that should be useful to NCC staff. These summaries take a variety of forms including tables, histograms, diagrams, maps, etc. Some of these analyses, particularly those connected with the site classification, are included in the Main Report. Others appear in the various appendices and, in particular, in the Site Dossiers.

7 VEGETATION CLASSIFICATION

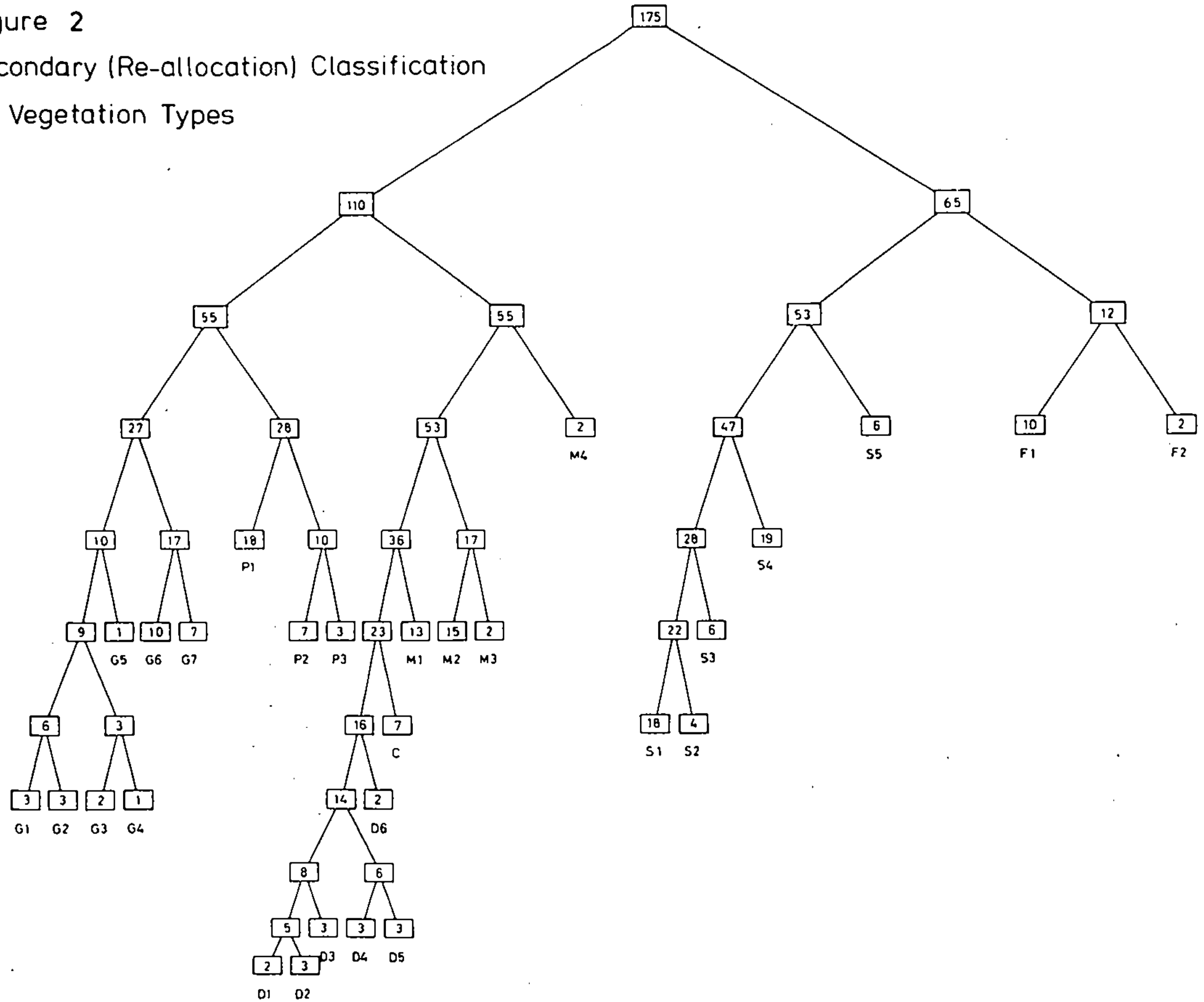
7.1 Introduction

The derivation of the vegetation classification and the problems involved have already been discussed at some length in Section 6.2. This section contains a description of a new "version" of ISA that completely eliminates the possibility of mis-allocation in the synthetic key which can be constructed from the analysis. It is argued that the theoretical basis of this method - a polythetic, divisive method combined with a means of re-allocation - is sound and should lead to useful results. There now follows a description of how this method was applied to the Scottish Coastal Survey data and with what result.

The first stage in producing the vegetation classification, was to submit the data to ISA, using the version with a modified ruling concerning the allocation of misclassifications. This analysis was allowed to run to ten levels of division at which there are potentially 2 to the power 10 (1,024) classes. However, due to premature termination of some parts of the hierarchy, only 175 primary classes were isolated. These classes were very variable in size, containing from 1 up to 938 quadrats, but their most important property should be that of reasonable homogeneity, i.e. all the members of a class should be similar within fairly close limits. In general, a high level of homogeneity was achieved in the 175 primary classes, the only exceptions being a few small, and therefore relatively unimportant, classes composed of rather aberrant or disturbed quadrats. Nothing really sensible can be done with such quadrats and, whatever procedure is followed, they tend to become isolated with their own kind which is all that can be expected or desired. The whole of the primary classification is shown in the form of a hierarchical diagram in Figure 6 (in four parts - Figure 6 shows the top levels of division and Figures 6A, 6B and 6C the three main stems of the hierarchy).

It will be recalled that, because of the changed ruling by which misclassifications are allocated according to their indicator scores (as occurs when the classification is implemented by the key) rather than the ordination score, it is necessary to allow the primary classification to over-divide. In this context, the term "over-divide" means that too many classes for practical use are produced (175 is obviously too many). This over-division is necessary because the changed ruling with respect to misclassifications tends to lead to greater within-class heterogeneity for a given level of division. For example, in the primary classification the first level of division (step 1 in the key) separates most of the saltmarsh quadrats from the rest. However, there is a small residue of misclassifications which, in conventional ISA, are allocated to the saltmarsh types on the basis of their ordination score. On closer examination, these turn out to be pure stands of Salicornia spp., i.e. extreme pioneer saltmarsh, with no other species present. Salicornia is not used as an indicator because it is not sufficiently common in the saltmarsh types as a whole to be a good discriminating factor. In conventional ISA such samples will misclassify when the key is used to generalize the classification. The ordinary key will direct these particular quadrats into the non-maritime vegetation types. No remotely sensible outcome is now possible and they constitute a source of serious (if rather

Figure 2
Secondary (Re-allocation) Classification
of Vegetation Types



obvious) misclassification. In the modified version of ISA, the pure Salicornia quadrats are initially (step 1) allocated to the non-maritime group but the second level of division (step 2) immediately isolates them by a "second stab at", or a "clean-up" of, the first division. The key now works with complete accuracy but it has taken two levels of division to achieve the same results as one level in conventional ISA.

The next stage in the process was to calculate species frequency for the 175 primary classes. This was, in turn, transformed into pseudo-species (for details see Section 8.1). As with the site classification, the pseudo-species were five in number using 20% frequency classes, i.e. 1=,20%, 2=20-40%, 3=40-60%, 4=60-80% and 5=80-100%. These data were then re-submitted to ISA (in pseudo-species formulation) and again run to ten levels of division. Although level six was considered to be the standard cut-off level, at which most classes were interpreted, some classes had to be taken to a lower level. Others either terminated at a higher level or it was considered expedient that they should be terminated on the basis of size (number of quadrats) and within-class variation. The secondary or re-allocation classification is shown in hierarchical form in Figure 2.

In general, the classification produced in the re-allocation stage is of little direct interest or use to the practical user of the vegetation classification. Neither is the key produced by the re-allocation process required because this analysis is merely used to determine which classes isolated by the primary classification are sufficiently similar to be pooled. The primary classification key thus becomes a multi-path key, in which a given vegetation type may be identified by more than one route through the key (see Figures 6, 6A, 6B and 6C). After careful examination of the re-allocation analysis it was decided to recognize twenty-eight vegetation types, i.e. 175 primary types became amalgamated to produce 28 secondary types. In practice, the 28 secondary types are composed of from 1 to 19 of the primary types. In terms of the key itself, the number of paths by which the constituent parts of a given type are determined varies from 1 to 13. As a general rule, the common vegetation types - which in a non-stratified, objectively sampled survey attract a large number of samples - consist of relatively few primary classes and have a limited number of pathways in the key. Conversely, less common vegetation types tend to be badly fractionated by the primary classification (this is mainly because they are so heavily outnumbered by the common types) and these consist of a large number of primary types and have numerous pathways in the key. The only exceptions to this trend are the extreme (uncommon) vegetation types, i.e. those which are composed largely of species that do not commonly occur in other vegetation types. These tend to be isolated intact early on in the primary analysis, as it is desirable they should be. The use of a low downweighting function in ISA accentuates this feature, isolating the more extreme types at a high level in the hierarchy. In the analysis described here, a zero downweighting function was used.

Despite having dismissed the secondary classifications as far as the practical user is concerned, it does, however, have some extremely useful features, i.e. other than its main function of providing the means of re-allocation for the too numerous primary classes. The most important feature is that the classification hierarchy (see Figure 2) gives quite a clear, well-balanced picture of the structure of the population (cf. the complex primary classification). The reason for this is that the process of calculating class properties, on which the secondary classification is based, produces a significant simplification of the data. In particular, there is a degree of standardization over the range of variation so that the various parts have more equal weight. The mechanism for this is that common vegetation types occur in large primary classes and uncommon types in small classes. The substitution of class means for the original quadrats that make up a primary class gives each class unit weight in the secondary classification. As a result the bias of contrasting quantity is largely removed and the range of variation can be treated more equably by the ordination part of ISA. In a sense, this process transforms the original data in such a way that they resemble the type of data produced by a stratified sampling procedure in which the number of samples is related to the range of variation.

In comparatively simple sets of data, in which the variation is fairly uniform and can be accounted for in relatively few dimensions, this sort of transformation is not necessary to the achievement of a reasonable understanding of a classification produced by ISA. In the present survey, the classification of bryophyte assemblages (see Appendix 6) was interpreted and the types placed in families without assistance from a secondary classification. Moreover, it is doubtful if much improvement would have been effected by the use of a re-allocation procedure. Similarly, the soil classification described in Section 9 of this report was accomplished in a single step. For some reason, for which there is no immediately obvious explanation, the data on which the vascular plant classification is based appears to be a good deal more complex than those for bryophytes or soil profile characteristics.

Despite the comparative difficulties of interpreting pseudo-species, i.e. quantities of species within a class, the indicator species used in the secondary classification also provide some very useful clues as to the nature of the population structure by means of an ecological interpretation. For example, the first division of the secondary classification is determined by Holcus lanatus (0%+), Anthoxanthum odoratum (0%+), Carex nigra (0%+), Potentilla erecta (0%+), Rumex acetosa (0%+), Ranunculus repens (0%+) and Luzula campestris (0%+) as negative indicators and Armeria maritima (40%+), Puccinellia maritima (0%+) and Glaux maritima (20%+) as positive indicators. There is no mistaking the interpretation of the species defining this division as other than a split into non-maritime (-ve) and maritime (+ve) vegetation types. Similarly, the next division of the non-maritime types, determined by Potentilla erecta (40%+), Molinia caerulea (20%+), Calluna vulgaris (20%+), Erica cinerea (0%+), Carex panicea (20%+), Nardus stricta (20%+), Carex nigra (20%+), Eriophorum angustifolium (20%+) and Anthoxanthum odoratum (20%+) as negative indicators and Cirsium arvense (0%+) as the single positive indicator, is clearly a division relating to acidity and base-richness of the soil. In fact, so clear-cut is the secondary classification that it is possible to use the main stems of the hierarchy as the basis of the families in which to place the twenty-eight vegetation types (see Figure 2).

Reading from left to right in the hierarchy shown in Figure 2 there are seven such families. The figures in the boxes in this diagram are the numbers of primary classes involved in each division, i.e. commencing with 175 primary classes.

1. Grassland - 7 types G1 - G7 (961 quadrats)

2. Peatland - 3 types P1 - P3 (155 quadrats)

3. Duneland - 6 types D1 - D6 (1,993 quadrats)

4. Colonist - 1 type C (217 quadrats)

5. Marshland - 4 types M1 - M4 (134 quadrats)

6. Saltmarsh - 5 types S1 - S5 (180 quadrats)

7. Foredune - 2 types F1 - F2 (37 quadrats)

To this list must be added one other "vegetation" type, not shown in Figure 2, and this consists of all samples where no vascular plants were recorded in the 25 sq m quadrat.

8. Bare ground - 1 type B (166 quadrats).

It should be noted from the above list of vegetation type families that just two of them make up 77% of the population - Duneland types with 1,993 quadrats (52%) and Grassland types with 961 quadrats (25%). The Colonist family, with a single type, is the next most important with 217 quadrats (6%), bringing the total to 82%. None of the other families, all of which occupy rather specialized habitats, exceeds 5% of the population, so it is clear where the efforts towards understanding coastal vegetation types should be directed.

The key by which the vegetation types can be identified is, of course, completely accurate, in the sense that it exactly reproduces the classification produced on the computer. The key has a total of 105 steps and there are 106 outlets for the 28 vegetation types. As has already been noted, there are from 1 to 13 outlets for different vegetation types. The number of steps in the key before a type is identified, i.e. an outlet is reached, varies from 1 to 10 (more usually 8-10) and at each step there are from 5 to 10 indicators that need to be checked to calculate the indicator score for that step. The indicator species are listed in two columns, negative on the left and positive on the right, with the species names in alphabetical order (not according to their power to discriminate between the two sides of the division). Below this, the division threshold score is given in the form of score X or less (negative side) or X + 1 or more (positive side). A dashed line leads to a new step number or an outlet in the form of a vegetation type code name or mnemonic (see Section 7.2).

At the end of the primary classification, at which point there are 175 types, there is little doubt that within-class variation is quite low. However, it is inevitable that re-amalgamation to produce 28 vegetation types does re-introduce some heterogeneity. The number of vegetation types used is purely arbitrary but utility of the classification demands that these be as few as possible without losing ecologically significant differences. To what extent this compromise between simplicity and sensitivity has been achieved can only be ultimately determined by the user. Where a vegetation type has several outlets in the key it is quite common that some of these are systematically different in an ecological sense; rather like the sub-species of a species, to use a taxonomic analogy. The different outlets of a type are usually referred to as "forms" and are identified by their step number and sign, i.e. -ve or +ve. In types where an ecological difference is known to exist, and the nature of the difference is understood, it is discussed in the type description. The classic example of this is Colonist type C. Originally this was to have been called the "Coastal dune" type because, viewed in its entirety, this is what it appeared to be. However, on closer examination, it transpired that only one outlet in the key defines what might be described as typical coast dune vegetation. This outlet is step 75 (-ve) which, in fact, contributes 153 out of the 217 (71%) quadrats allocated to the type - hence the overall properties of the type. All other outlets are to some degree atypical of coast dune vegetation, the most extreme examples bearing no resemblance whatsoever. Nevertheless, there is a common factor between the various forms of C that ISA has apparently been able to identify on the basis of species composition, and this is disturbance. In the genuine coast dune type, surface instability and wind are the disturbing factors, albeit a natural form of disturbance. In other outlets, there is also disturbance, mainly in the form of cultivation but it also involves such things as tracks, dumping, rabbits, fire, etc., in fact anything that can destroy, or partially destroy, the vegetative cover. The information in the floristic data upon which ISA bases this unexpected but curiously logical result is not so much the presence of disturbance species, although there are a range of these present, but more the absence of certain species, i.e. those species that have been eliminated (temporarily?) by the disturbance. Again, the common factor between the genuine coast dune quadrat and the disturbance situation is that the number of (common) species is low. There may be an added selection of disturbance species present but, because these are so variable, they do not provide a reliable means of identifying this condition. Interestingly, Duneland type D3, semi-stable dune grassland, has a similar intrusion of about 25% of rather aberrant quadrats. The aberrant quadrats of D3 are isolated by step 69 (-ve), which, in fact, is the "nul" path through the key, i.e. the path taken if no indicator species are present. Again, this is a disturbance phenomenon, where missing species are the common factor. These two examples will be discussed in more detail later in this section.

In general, a vegetation classification, with the characteristics described above, provides a very good account of the common vegetation types on the sites surveyed, i.e. the Duneland, Grassland and Colonist types. Where it is less sensitive is with the vegetation types that occupy marginal habitats and, in particular, the Peatland and Marshland types. The problem here is two-fold; insufficient quadrats to define the types and somewhat biased, or even incomplete, information on the range of variation. The types that make up these two families would probably be rather unsatisfactory when considered in the context of a wider investigation of their particular habitat type. Despite the rather small sample of brackish habitats, the Saltmarsh family is probably reasonably satisfactory as the species composition and range of variation in this habitat are much more limited.

Finally, before proceeding to full descriptions of the vegetation types, it is necessary to explain how interpretation of the types was approached. The survey method (see Handbook of Field Methods) included the collection of a wide range of information to assist in understanding both the site and vegetation types. This information can be divided into six main categories.

1. Floristic data - species frequency, cover and dominance of vascular plants, frequency and cover of bryophytes and lichens. Included in this category are data on non-vegetative cover, e.g. sand, rock, etc. There is also some information on vegetation structure, e.g. height and quantity of the main life-forms.

2. Biotic data - frequency of grazing animals such as sheep, cattle, rabbit, etc., as evidenced by droppings and other signs of their presence. There are also estimates of grazing intensity.

3. Land-use and human disturbance data - information on various types of land-use such as fences, wall, paths and a wide range of other artefacts including cultivation.

4. Environmental data - information on aspect, slope, elevation, distance from sea, etc.

5. Soil data - information on soil types (see below).

6. Distribution data - maps of distribution of vegetation types within sites and also their distribution round the Scottish coast also provide valuable information on the various vegetation types.

The only one of these categories that really needs further explanation is the soil data. Because edaphic factors are thought to be so important in understanding coastal vegetation and because summaries of individual soil characteristics, e.g. substrate type, colour, wetness, etc. at a particular depth, proved to be singularly uninformative, it was found necessary to produce a simple soil classification. This classification is based on attribute data recorded for a relatively shallow soil pit (up to 40cm deep) dug at the centre of each quadrat. Soil samples were also taken but these have not been worked on at the present time. Section 9 of this report contains an account of how the soil classification was produced and is followed, in turn, by a description of the various soil types and a table showing their relationship with the vegetation types (Table 6). These are the soil types that are referred to in the vegetation type descriptions.

7.2 Nomenclature

Thus far the vegetation types have only been referred to by their family name and a letter/number mnemonic derived from this, e.g. D1, G3, M2, etc. However, even with familiarity, this system does not provide a ready mental picture of the vegetation type referred to - something that most ecologists seem to require. In order to try and assist the user a series of brief, descriptive names have been derived using what is thought to be the most characteristic feature of the type in question. However, it should be emphasized that any name short enough to be of general use is at best an oversimplification for what is, by its very nature, a complex entity. The naming of vegetation types by dominants, traditional in British ecology, is not only a great simplification but it may also be ecologically misleading. Many dominants are wide ranging species, relatively insensitive to environmental conditions (which is why they are wide ranging in the first place). In other cases, dominance may be a rather ephemeral feature or it can be be largely an artifact as a result of human activity, e.g. the effects of grazing and burning. For these reasons we reject the use of dominance as the sole basis for nomenclature but prefer instead to use a combination of habitat, growth form and structure and edaphic characteristics, followed by a list of the most common dominants in the type. Some attempt has been made to keep the names consistent but this has proved to be quite difficult with some of the less common types.

The best approach when using numerical classification is to use the names only as convenient labels. The name itself cannot be relied on to describe the type in such a way that it can be immediately identified in the field. Accurate identification can only be achieved by use of the key (or similar device), although experience of the classification will quickly lead to familiarity with the commoner vegetation types. Care should, however, be taken not to jump to conclusions on the superficial evidence of appearance, i.e. dominant species and structure, of a sample for it is the total species complement that determines the type. It is very easy to get over-confident and fail to observe what is really there or use the key itself carelessly. In our view, "instant" recognition of coastal vegetation types, i.e. identification without careful recording of species allied with some formal method of using this information, according to a sensitive ecological classification is a near impossibility - such is the inherent complexity of the problem.

As far as naming the types in the text of this report is concerned, the convention that has been adopted is to give the family name a capital letter, e.g. Bare ground or Duneland, whilst the names of the types within the family are represented in lower case throughout but they always appear with their mnemonic, e.g. semi-stable duneland D3, acid, wet grassland G7. There are therefore two ways of specifying a given vegetation type, e.g. base-rich duneland D3 or Duneland (type) D3, colonizing community C or Colonist (type) C, where the inclusion of the word "type" is optional. In context, a vegetation type may also be referred to by its mnemonic alone, with or without the prefix "type", e.g. D4 or type D4.

The extended vegetation type name can also be supplemented by a list of the three most important dominants, i.e. the three species which most commonly occur with a cover of 10% or more. A list of dominants is appended to the name in order of importance but if the overall frequency of the species in the type is less than 50% then the name is enclosed in brackets "()". For example, semi-stable dune grassland D3 is dominated by Ammophila arenaria, which is a dominant in 57.3% of quadrats and has an overall frequency of 70.5%, followed by Festuca rubra (51.8% and 82.2%) and Poa pratensis (8.1% and 76.8%). Thus these three species appear after the type name for D3 with no brackets. By contrast, acid, damp grassland G2 has the dominants Festuca rubra (53.5% and 74.7%), Festuca ovina (23.2% and 49.5%) and Anthoxanthum odoratum (21.2% and 76.8%) and here Festuca ovina is enclosed in brackets because its overall frequency is less than 50%.

7.3 Introduction to Vegetation Type Descriptions

Figure 2 shows the hierarchy produced by the secondary (re-allocation) classification, from which the vegetation types and families of types are derived. The families are numbered from left to right on this diagram and the types within families are treated in like manner. Although the order of types within a family can usually be used as the basis for the type descriptions (the exception to this is the Duneland family), the families themselves do not occur in a convenient order (indeed, there is no reason why they should). It has, therefore, been necessary to deal with the families in a different order. The main reason for this is that, for at least part of the classification, there are strong successional relationships between the types and families. Even where the relationship is not successional, there are usually underlying environmental trends, such as increasing wetness of the soil or acidity, and it is convenient to follow this in describing the types.

Following the taxonomic analogy, it has been possible to amalgamate the seven vegetation type families into three higher level groups based on the type of habitat which they occupy. The three "orders", as they might be termed, are constituted as follows.

1. Non-maritime types - Bare ground, Colonist, Duneland, Grassland, Peatland.

2. Types influenced by freshwater - Marshland.

3. Maritime types - Saltmarsh and Foredune.

A diagram showing the putative relationship between the families and types within them accompanies each of these three orders (Sections 7.4, 7.5 and 7.6).

First of all, to clear up one loose end, there were four quadrats in the survey that were so extraordinary that they were considered to be unclassifiable (they are marked on the maps in the Site Dossiers as "U" - unclassifiable). There is little virtue in discussing them in any detail but, just to illustrate the point, i.e. just how peculiar a quadrat has to be to be unclassifiable, there follows a rough description of the four quadrats. One (Breckin, quadrat 9) was on the shallow edge of a loch with only one species present, Potamogeton filiformis. Another (Sheigra, quadrat 36) was in a boulder field near to the shore with Sedum rosea as the only species present. The third (Spey Bay Central, quadrat 13) occurred in a riverine situation, with the unusual combination of Polygonum cuspidatum, Symphytum tuberosum, Impatiens glandulifera and Calystegia sepium as the only species present. The last unclassifiable quadrat (Tyninghame, quadrat 9) was located on a rubbish dump and contained only one barley seedling (Hordeum sp.) and a potato plant (Solanum tuberosum). If applied to the key, all these quadrats would work their way through to Duneland D3 (step 69 (-ve)) on a succession of zero indicator scores. This would not have been a wholly unsatisfactory result because, as will be seen later, a number of quadrats segregated by this route are also somewhat aberrant but to a much lesser degree than those described above.

7.4 Non-Maritime Vegetation Types

Figure 3 shows the putative relationships between the families and types. Firm relationships are indicated by double, solid lines, rather less well established relationships by single, solid lines and speculative relationships by broken lines. The inclusion of an arrow indicates that the relationship is thought to be at least partly successional and the arrow points in the direction in which the change is thought to occur. The supposed factor, or factors, underlying the change are also indicated on the diagram.

The diagram has been constructed from a range of evidence, species composition and ordinations based on species composition being one important source. Both frequency and cover of species provide useful evidence, as does other related information about bryophytes, lichens, bare sand and certain specialized cover types, e.g. water or saltmarsh mud. Because the relationships contained in the vegetation classification are so complex (cf. bryophyte and soil classifications), it has been necessary to do a whole series of ordinations, progressively excluding parts of the full range of variation in order to "unravel" the true relationships. This has been particularly important in gaining some understanding of the types within the Duneland (D) family and their relationship with the Grassland (G) family. As has already been noted, these two families comprise over 75% of coastal vegetation.

In addition to being numerically most important, the Duneland and Grassland families can be said to occupy the non-specialized habitats, where management and land-use are likely to have the most effect. They are also located where such activities are most likely to occur, i.e. most arable land-use takes place in areas where the more stable parts of the Duneland family or the Grassland family are the dominant vegetation type.

Other sources of evidence as to the relationship of the vegetation types include the soil classification (pedogenesis is the basis of dune succession). The geographical distribution of vegetation types round the Scottish coast is also an important means of interpretation, e.g. the developmental series headed by Duneland D1 is largely western and northern and that headed by D2 is eastern (see Figure 3 and the maps accompanying the type descriptions). This western and northern as opposed to eastern trend is similar to that which produced the first division in the site classification (see Section 8.3.1). It is presumably based on the contrast between calcium carbonate-rich soils allied with oceanic climate in the west and north as opposed to acid, siliceous soils and a dryer, more continental climate in the east. Other factors, particularly those of land-use, e.g. cultivation and grazing, and its effect on site boundaries, e.g. truncation, tend to obscure the site classification because they are also correlated with the pedological and climatic trend from west to east. However, the fact that vegetation types follow a similar trend to the site types and are, to some extent, easier to understand in ecological terms suggests that soils and climate are the more fundamental factors whereas land-use and allied factors are secondary.

Ecological relationships and successional trends are discussed in more detail in the context of describing individual vegetation types, starting with the type at the top of Figure 3, Bare ground B.

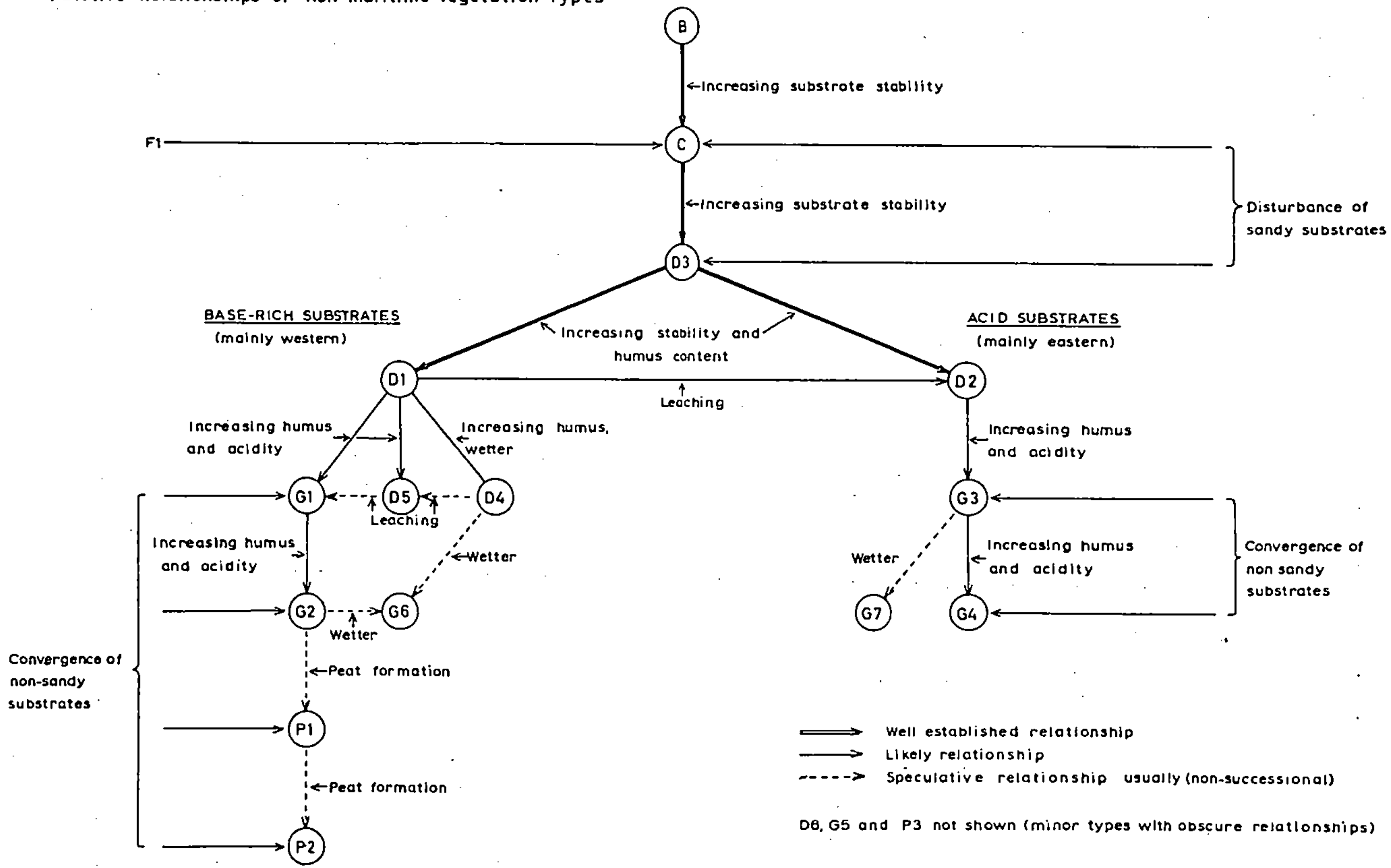
For the sake of clarity, the description of each vegetation type begins at the top of a new righthand page with its map of geographical distribution and related table opposite. Each map shows the location of the 94 sites that were surveyed. Superimposed on this are numerical symbols representing the proportion of a given vegetation type that occurs in a site (weighted frequency). The quantitative definition of these symbols is as follows:

* - none present (site location only)
1 - ,5%
2 - 5-10%
3 - 10-20%
4 - 20-40%
5 - 40-60%
6 - 60-80%
7 - 80-100%

The accompanying table lists the site that contain that vegetation type. The column labelled "QDS." gives the absolute number of quadrats in the site that contained the vegetation type and that labelled "FREQ.%" gives the weighted frequency. It should be noted that in large site recorded in 1975, using a stratified random system of sampling, it is possible for the weighted frequency to be less than 0.5% and this has been rounded off to 0 (zero) in the table.

Figure 3

Putative Relationships of Non-maritime Vegetation Types



B - Bare ground

B - Bare ground

(no vascular plants)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 58)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	1	1	2 Macrihanish Dunes	5	2
3 Laggan Bay	1	2	5 Saligo Bay	2	7
9 Kiloran Bay	1	3	10 Calgary Dunes	2	8
11 Sanna	2	7	12 West Tiree	3	3
14 Hynish Bay	1	3	15 Crossapol and Gunna	5	5
16 Totamore Dunes	1	3	17 Gallanach	1	2
18 Vatersay	2	7	19 West Barra	4	11
22 Orniclate	2	4	26 Borve	2	7
29 Kirkibost	1	4	32 Hosta	1	3
35 Balranald	1	0	39 Northton	6	16
40 Luskintyre	1	3	41 Uig	2	7
42 Valtos	1	4	43 Barvas	1	3
44 Europie	2	7	45 Tolsta	2	7
46 Tong	3	10	50 Redpoint	3	2
52 Achnahaird	1	4	53 Oldshore More	2	1
54 Sheigra	3	4	56 Faraid Head	4	0
57 Bettyhill	1	3	58 Farr Bay	4	2
59 Strathy	1	3	60 Melvich	2	4
61 Reay	2	4	62 Dunnet	5	0
64 Sandwood	11	12	65 Sinclairs Bay	4	4
66 Ferry Links	2	1	70 Morrich More	5	3
71 Whiteness	4	10	72 Culbin Bar	6	12
74 Findhorn	3	1	75 Lossiemouth	11	9
76 Spey Bay (West)	9	8	77 Spey Bay (Central)	4	9
79 Fraserburgh	1	3	80 Strathbeg	1	2
81 St. Fergus	3	7	82 Cruden Bay	11	37
83 Forvie	1	1	84 Don to Ythan	1	2
89 Barry Links	1	1	92 Aberlady	1	3
93 Gullane	2	1	95 Tyninghame	1	1

7.4.1 B - Bare ground

These are the quadrats that contained no vascular plants in the 25 sq m quadrat. A proportion of quadrats have acquired plants by the time the 200 sq m size has been reached and these records are included in the species lists given at the end of the Site Dossiers. A few Bare ground quadrats do support some plant growth; 1.2% bryophytes and 2.4% lichens were recorded.

No attempt has been made to subdivide the Bare ground type, which comprises 166 quadrats (4.3%), according to substrate types, although this would have been possible. The most important substrate types are bare sand with a frequency of 76.5% and mean cover of 71.9%, gravel (31.9% and 5.9%) and cobbles (43.4% and 14.5%). Lesser amounts of boulders, with a frequency of 9.0% and cover of 2.3%, and solid rock (4.8% and 2.3%) are also present. In terms of actual quadrats, rather than means, about 70% are pure bare sand with 100% cover of that substrate whilst others are mixed deposits (mostly beaches), varying from nearly pure cobbles through sand, gravel and cobble mixtures to boulders. It is the first of these types, pure sand or with sand as the majority constituent, that is referred to in Figure 3. Some of the sandy quadrats are upper beaches and others are blow-outs or freshly deposited blown sand. Their coastal nature is indicated by their proximity to HWMST - 42% are within 10m of the sea and a further 45% occur within the 10-50m zone. The mean distance to the sea is 39m. However, at the other extreme, there are a few quadrats as far inland as the 800-1000m zone (blow-outs). The coastal nature of the type is further exemplified by the presence of seaweed debris in 82% of quadrats, along with a wide range of other tidal litter, e.g. wood, metal and plastic. As might be expected, elevation is minimal, 98% of quadrats being below the 50ft contour.

In terms of soil types, Bare ground B is strongly associated with largely unaltered Beach Deposits BD1 and BD2 (together 19.3%), immature (no humus), Sandy Cobble Soil CS2 (4.8%), immature, Deep Sandy Soils DS2 and DS3 (together 30.2%) and Thin Soils TS1 and TS10 (together 8.4%). The above types account for 62.7% out of the 96.4% of quadrats for which there are soil data. A further 18.7% occur on the semi-mature, Deep Sandy Soil type DS6 but this is such a common type (1,109 quadrats in the survey) that this proportion represents a negative association, i.e. there are fewer occurrences than would be expected by chance. There are examples of several other soil types but none exceed 5%. Types DS5 and CS6 do occur but these are also negative associations. This result is more or less what might be expected for the Bare ground type B, the soils being mostly mineral substrates with little or no profile development. Most of the exceptions are influenced by saltwater, either in the form of periodic inundation or scouring, or both.

There is a distinct tendency for aspect, both on a local basis (as measured on the ground with a compass) and on a more general topographical basis (as interpreted from contours on the OS map), for B to be north facing, i.e. in the sector 315 to 45 degrees. These two measures are referred to hereafter as "local aspect" and "general aspect", respectively. For Bare ground B, 41.6% of quadrats have north as the local aspect and 40.4% as the general aspect. The configuration of the ground surface is mostly plane (48.2%) or undulating simple (44.6%) (see definitions in Handbook of Field Methods) but a few quadrats are quite steeply sloping, i.e. 23.5% have slopes greater than 5 degrees. In terms of elevation, the type is low lying, 97.6%

being less than 50ft OD.

For obvious reasons, there are comparatively few signs of grazing animals in type B. Rabbits are most common, being recorded in 7.8% of quadrats, and sheep and cattle each in 4.8%. There are no notable human disturbance features except for the fact that 4.8% of quadrats had vehicle tracks in them and 1.2% had been in some way affected by fire. Rubbish was recorded in 4.2% of quadrats, an unusually low figure compared with nearly all other vegetation types. The absence of ground cover, which tends to produce poor retention of litter, may be the key factor here. There are some aquatic habitats present in the type but, apart from rock pool (4.8%), these only attain very low frequencies.

The geographical distribution of B is very widespread. It occurs all round the Scottish coast but by no means in all sites. The type is least common on South and North Uist in the Outer Hebrides and is most common immediately to the north on Harris and Lewis. Another concentration of the type occurs on the east coast, from the southern shore of the Moray Firth and south towards Aberdeen. The quantity of B within a site can be taken as a rough measure of stability. In this context, Cruden Bay on the Aberdeenshire coast, with 37% of B, could be interpreted as a most unstable site. However, it is known that this site has been severely cut back by coastal erosion since the edition of the OS that was used for survey was produced and it is suspected that the rules for dealing with this type of situation were not correctly observed in this particular case, i.e. some quadrats were erroneously located below HWMST. This may have introduced a bias into the results for this site. It is, nevertheless, an extremely truncated site, being reduced to a fairly narrow coastal strip.

7.4.2 Colonist Family (C)

This is the second type shown in Figure 3 and, in the normal dune sequence, it develops directly from Bare ground B when this takes the form of newly deposited or exposed sandy surfaces. Other forms of surface disturbance, e.g. cultivation, rabbits and fire, also tend to result in a regression of the vegetation type to a condition that resembles C (or D3 or even, possibly, M1). There is just one type in the Colonist family although, with the benefit of hindsight, it might have been more satisfactory to divide it into two types (see discusion of different forms of C below).

C - Colonizing communities

C - Colonizing communities

(dominated by Ammophila arenaria, Agropyron Junceiforme and Festuca rubra)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 60)

NO./NAME	QDS.	FREQ.X	NO./NAME	QDS.	FREQ.X
1 Torrs Warren	13	13	2 Macrihanish Dunes	3	3
3 Laggan Bay	4	10	6 Gruinart	8	12
7 Oronsay	1	2	8 Garvard	1	3
9 Kiloran Bay	6	18	11 Sanna	5	17
12 West Tiree	1	1	15 Crossapol and Gunna	1	1
18 Vatersay	1	3	19 West Barra	1	3
20 North Barra	4	9	21 Daliburgh	3	6
27 Stilligarry (South)	1	1	28 Baleshare	1	2
31 Paible	1	6	33 Vallay	2	6
34 Leathann	2	6	35 Balranald	1	0
37 Berneray	5	8	38 Pabbay	1	2
39 Northton	2	5	40 Luskintyre	2	6
43 Barvas	1	3	44 Europie	2	7
45 Tolsta	1	3	48 Scousburgh	1	3
50 Redpoint	4	6	51 Holland	1	3
52 Achnahaird	2	7	53 Oldshore More	2	2
56 Faraid Head	2	3	57 Bettyhill	7	21
58 Farr Bay	2	2	60 Melvich	2	4
61 Reay	6	8	62 Dunnet	2	1
64 Sandwood	7	16	65 Sinclairs Bay	7	19
66 Ferry Links	2	1	67 Coul Links	3	7
68 Dornoch	2	7	69 Clashmore	1	3
72 Culbin Bar	2	5	74 Findhorn	2	5
75 Lossiemouth	3	9	79 Fraserburgh	4	11
80 Strathbeg	14	22	81 St. Fergus	10	23
82 Cruden Bay	3	10	83 Forvie	13	15
84 Don to Ythan	18	32	89 Barry Links	4	4
90 Tentsmuir	3	4	91 Dumbarnie	2	7
92 Aberlady	2	6	93 Gullane	5	9
94 Yellowcraig	1	6	95 Tyninghame	4	13

C - Colonizing communities on blown sand or disturbed substrate (re-colonization), dominated by Ammophila arenaria, (Agropyron junceiforme and Festuca rubra)

In the case of this vegetation type, Agropyron junceiforme and Festuca rubra have been bracketed because, although technically they are the second and third most common dominants in C (see below), their overall frequency in the type is less than 50%. This means that these two species are more likely to be absent than present in a given quadrat of the type and it is not, therefore, really a very good descriptive feature. It will be recalled (see Section 7.2) that this rule has been observed throughout in the naming of the vegetation types.

There are 217 quadrats (5.6%) allocated to this vegetation type which has six outlets in the key. Step 75 (-ve) isolates the most typical form of C (153 quadrats), which is basically the pioneer stage of dune succession, occurring in the dunes immediately adjacent to the sea or in other places where, for one reason or another, there is mobile sand. This is the form that is generally referred to in the ensuing description of the type. However, it is useful to deal first with the other outlets, giving a brief account of how they differ from the basic form.

The group of four quadrats isolated by step 15 (-ve) is perhaps the most aberrant form. A wide range of species is involved in the type and this does not include the species most typical of C, namely Ammophila arenaria. The common factor in this type appears to be disturbance; two of the four quadrats had been recently ploughed, one was on an artificial embankment and the fourth was situated in a narrow gully part way down a cliff. All four quadrats occur in sites in the south-west of Scotland. The pair of quadrats isolated by step 71 (+ve) are also rather peculiar, being very species-rich. Again disturbance seems to be the factor involved and the most likely explanation is that they are disturbed examples of Duneland D2 (see later). Step 74 (-ve) isolates just five quadrats which are not too dissimilar from the typical form. All these quadrats contain Ammophila arenaria, although the cover of this species seems to be somewhat variable, from 5-100%. The slightly anomalous nature of this form is revealed in step 57 of the key where it is evident that this fraction contains more than the usual complement of species, including some that require more stable conditions. However, once a few Marshland M1 and M2 quadrats have been pared off (steps 66 and 74), the form emerges as a reasonably coherent group. Again, disturbance, in the form of erosion (slumping and marine erosion) and fire, seems to be involved. The above variants of C, three forms with a total of eleven quadrats, are relatively unimportant numerically but the two remaining atypical forms are much more important (a total of 53 quadrats).

Step 76 (-ve) isolates eleven quadrats. In terms of species complement these are rather a heterogeneous collection, except that all contain Ammophila arenaria. What separates this form from the more conventional coast dune type is the presence of some additional species indicative of more stable conditions. In this case, the additional species can be characterized as being acidophilous and they include Calluna vulgaris, Erica cinerea and Empetrum nigrum. Rather than being an example of within-quadrat heterogeneity, i.e. the quadrat straddles a sharp change in species composition, it appears that this type results from invasion of Ammophila by these other acidophilous species. It seems to occur only on rather acid substrate and, hence, has a rather characteristic geographical distribution, occurring in the extreme south-west and on the east coast. Step 68 (-ve) isolates a similar, but less acid type, comprising no less than 42 quadrats. The crucial step in the key that divides this form off from the mainstream of C is step 50 (see Figure 6B), where a number of more acid indicating species such as Agrostis tenuis and Festuca ovina are positive indicators. As with the form resulting from step 76 (-ve), this form has a very characteristic geographical distribution occurring in the south-west and on the east coast (with the exception of 2 quadrats at Bettyhill and 1 at Reay on the north coast).

In summary, it would appear that the original name given to the type of "Coast dune" was not entirely unreasonable although the one later adopted, that of Colonist, is obviously more correct. It should, however, be emphasized that not all colonization is primary and that re-colonization applies to an appreciable proportion of the type.

The most obvious question that arises from the above discussion is, is there more than one type of coast dune vegetation type related to different substrate types, i.e. base-rich, shell sands as compared with silica sands? The evidence is not conclusive but, at the level of classification with which we are dealing here, there does appear to be just one genuine coast dune vegetation that occurs all round the Scottish coast on sandy substrates, regardless of chemical composition. If this is the case, then it means that at this stage in the succession stability dominates all other environmental factors. What at first might appear to be acidic coast dune types, isolated by steps 65 (-ve) and 76 (-ve), are seen, on closer examination, to be rather more stable than the typical coast dune form and are therefore somewhat more advanced in terms of successional development. This higher successional status is evidenced by the presence of species which cannot tolerate more than minor sand movements. The forms of C isolated by steps 65 (-ve) and 76 (-ve) have been placed in the Colonist type for two reasons, firstly, because they still contain Ammophila and, secondly, because they are relatively species-poor (as a direct result of the acidic substrate, perhaps). The combination of these features is highly characteristic of Colonist type C and not of any other vegetation type. A decline in Ammophila and invasion by additional acidophilous species may result in the acid form of C developing, more or less directly, into a Grassland type (G3 is the most likely candidate) rather than into a Duneland type, as suggested in Figure 3, but this would only occur on very acid substrates.

The ensuing description refers to the composite of all six forms of Colonist type C and is, therefore, very heavily weighted towards the typical form isolated by step 75 (-ve).

The most common species in colonizing communities C is Ammophila arenaria with a frequency of 96.3%, i.e. there are only 8 quadrats of the type that do not contain this species. Ammophila is also the species that has the greatest cover with a mean of 19.2%. There is a big drop to the next most common species, Agropyron junceiforme, with a frequency of 32.7%, followed by Festuca rubra (25.3%) and Senecio jacobaea (24.4%). Eight other species have a frequency of 10-20% - Carex arenaria, Cerastium atrovirens, Cirsium arvense, Galium verum, Lotus corniculatus, Cirsium vulgare, Taraxacum spp. and Thymus drucei. After Ammophila there is also a very big drop in cover to Festuca rubra with 2.5%, Calluna vulgaris (2.4%, but with a frequency of only 6.9%, this being the direct result of high cover in the minority acid forms of C referred to above), Agropyron junceiforme (1.4%) and Carex arenaria (1.0%). As might be expected from the above figures, the number of species occurring in the type is quite low; there are only 12 species with a frequency of over 10%. The mean number of species per quadrat is 6.1 and mean cover of vascular plants is 35.5%.

Bryophytes occur in 32.3% of quadrats with a mean cover of 4.3% and the equivalent figures for lichens are 17.5% and 1.4%. The unaccounted for cover is made up largely of bare sand with a frequency of 94.9% and a mean cover of 60.2%. Only one other cover type accounts for more than 1% cover - cobbles with a frequency of 10.1% and mean cover of 1.3%.

In terms of soil types, Colonist type C is highly associated with immature (no humus), Deep Sandy Soils DS1 (7.8%), DS2 (25.8%), DS3 (8.3%) and DS4 (4.1%) and also with immature, Thin Soil TS6 (1.4%). Together these soil types account for 47.4% of quadrats. The residue of quadrats occur mainly on semi-mature, Deep Sandy Soils DS5 and DS6, although the number of quadrats in DS5 (15.7%) represents a negative association. These two types account for a further 44.7% of quadrats, giving a total of 92.1% (out of 99.5% of quadrats for which there are soil data). Examined on a separate basis, only 12% of the soils have any visual evidence of humus in the top 10cm of the profile (these are mainly the disturbance forms).

With the increase in vegetation cover, grazing becomes a factor in C although, probably as a result of the type of plants that dominate this type, i.e. they are largely inedible, the intensity is usually low with 42.4% of quadrats were recorded as none and 45.2% as light (total of 87.6%). The most common grazing animal is the rabbit (65.0%), followed by sheep (18.0%) and cattle (14.7%). Human disturbance was recorded in this type, with fences in 2.8% of quadrats, unsurfaced paths (7.4%), spent cartridges (2.3%) and fire (1.8%) - none of these figures exceptional. However, it is interesting to note that planted marram (a stabilization measure) was recorded in 0.9% of quadrats. Rubbish was recorded from 30.0% of quadrats.

As might be expected in what is essentially a dry vegetation type, there is little evidence of aquatic habitats in Colonist C. Ditch 0.5% and stream 1.4% are the only records.

There is no obvious preference in terms of local aspect but for general aspect there is a slight tendency (36.4%) for Colonist type C to be east facing (probably a direct reflection of its geographical distribution - see below). Only 14.3% of quadrats have a surface type that could be categorized as plane, 44.7% are undulating simple, 26.7% undulating complex and 14.3% broken. Slopes are quite steep, with 59.9% over 5 degrees. In terms of elevation, 87.1% are under the 50ft contour but there are quadrats as high as the 150-200ft zone - presumably these are blow-outs or disturbance types. In contrast to Bare ground B, Colonist C frequently occurs quite well inland, only 38.2% are within 50m of HWMST (compared with 86.2% for B), and the mean distance from the sea is 183m (cf. 39m for B).

Colonizing communities C has quite an interesting geographical distribution. It is least common in the Outer Hebrides and most common on the north and east coasts. The type reaches its peak on the east facing coast of Aberdeenshire where three sites, Strathbeg, St Fergus and Don to Ythan, each contains over 20% of the type (as also does Bettyhill on the north coast).

7.4.3 Duneland Family (D1-D6)

There are six vegetation types in this family and, for convenience, they will be dealt with in order of their successional status (not in numerical order) as shown in Figure 3 (with the exception of D6 which does not appear because there are too few examples to determine its relationship to the other types). This family contains the real "core" of sand dune vegetation types, most of which do not extend on to non-sandy substrates. Numerically, Duneland is the most important family in the survey, with a total of 1,993 quadrats (51.8%) allocated to it (D1=1,099, D2=225, D3=444, D4=159, D5=59 and D6=7). In general, there are strong successional relationships between the types within the family, the main underlying environmental factors being an increase in surface stability and the development of a soil profile in what is initially undifferentiated, mineral sand. Pedogenesis leads to an increase in organic matter in the profile and also to greater availability of most nutrients (particularly nitrogen). Conversely, free calcium carbonate, usually in the form of comminuted shell, tends to become progressively depleted by leaching, and acidification of the soil profile may ensue. The most extreme expression of this process is the formation of peat on the sand surface. This requires an acid substrate, high water table and/or low evapotranspiration. Some western sites apparently provide such conditions over limited areas.

Within the family, there is a marked dichotomy into western and northern as opposed to eastern types (see Figure 3) and this split is also carried over into the Grassland family. Details of developmental trends and geographical distribution are discussed with each type.

D3 - Semi-stable dune grassland

D3 - Semi-stable dune grassland

(dominated by Ammophila arenaria, Festuca rubra and Poa pratensis)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 85)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	6	6	2 Macrihanish Dunes	6	16
3 Laggan Bay	1	2	4 Kilchoman Dunes	3	10
5 Saligo Bay	3	10	6 Gruinart	7	10
7 Oronsay	4	9	8 Garvard	3	10
9 Kiloran Bay	2	6	10 Calgary Dunes	1	4
11 Sanna	1	3	12 West Tiree	3	3
13 Ballevullin	3	8	14 Hynish Bay	1	3
15 Crossapol and Gunna	4	4	16 Totamore Dunes	4	11
17 Gallanach	1	2	18 Vatersay	6	20
19 West Barra	4	11	20 North Barra	1	2
22 Ormiclate	1	2	23 Howbeg	1	5
25 Loch Bee	4	5	27 Stilligarry (South)	1	1
28 Baleshare	2	4	29 Kirkibost	2	7
31 Paible	3	19	32 Hosta	2	7
33 Vallay	1	3	34 Leathann	2	6
35 Balranald	1	2	36 Robach	1	3
37 Berneray	8	13	38 Pabbay	1	2
40 Luskintyre	4	13	41 Uig	2	7
42 Valtos	2	8	43 Barvas	1	3
44 Europie	1	3	45 Tolsta	1	3
47 Quendale	1	3	49 Breckin	2	7
50 Redpoint	2	2	52 Achnahaird	2	7
53 Oldshore More	1	1	54 Sheigra	4	8
56 Faraid Head	3	7	57 Bettyhill	6	18
58 Farr Bay	7	14	59 Strathy	6	21
60 Melvich	4	15	61 Reay	20	57
62 Dunnet	6	9	63 Freswick	17	37
64 Sandwood	4	15	65 Sinclairs Bay	3	7
66 Ferry Links	5	13	67 Coul Links	6	10
68 Dornoch	8	23	69 Clashmore	5	11
70 Morrich More	2	4	71 Whiteness	6	12
72 Culbin Bar	8	16	73 Overbister	4	13
74 Findhorn	3	6	75 Lossiemouth	2	5
76 Spey Bay (West)	7	18	77 Spey Bay (Central)	27	60
78 Spey Bay (East)	1	4	79 Fraserburgh	18	51
80 Strathbeg	9	14	81 St. Fergus	18	42
82 Cruden Bay	14	47	83 Forvie	5	6
84 Don to Ythan	6	11	86 St. Cyrus and Montrose	8	22
87 Lunan Bay	15	79	88 Arbroath	21	72
89 Barry Links	4	4	90 Tentsmuir	6	8
91 Dumbarnie	7	24	92 Aberlady	3	10
93 Gullane	12	27	94 Yellowcraig	7	39
95 Tyninghame	14	43			

D3 - Semi-stable dune grassland, dominated by <u>Ammophila arenaria</u>, <u>Festuca rubra</u> and <u>Poa pratensis</u>

There are 444 quadrats (11.5%) allocated to this vegetation type for which there are just two outlets in the key. One of these, step 73 (+ve), which isolates some 339 quadrats (76.4% of the type), is the "genuine article" referred to in the name above - semi-stable dune grassland. As might be expected, this form of the type is characterized by the <u>Ammophila arenaria</u> (313 out of 339 quadrats or 92%). By contrast the other outlet in step 69 (-ve), with 105 quadrats (23.6%), contains no <u>Ammophila</u> at all. This is the disturbance linked form of D3 which was referred to earlier in relation to Colonist type C. In fact, a good name for this particular form of D3 would probably be "re-colonist" as many quadrats allocated to the type are just this - re-colonization after disturbance. The disturbance can be due to a wide variety of causes, e.g. cultivation, trampling, vehicle tracks, fire, dumping and, in some cases, the effects of shade cast by trees and shrubs. The common factor here is that sensitive species are eliminated, at least temporarily, whilst some of the more persistant ones - in whatever vegetation type was previously present - remain, usually in reduced quantity. What may be termed the "survivors" are joined by a range of disturbance species, depending on the particular conditions produced and what seed is available. None of the disturbance species are consistent enough to be characteristic of the type which is, in reality, determined by absence of species. This negative property is extremely difficult to appreciate by just looking at species lists. In fact, the route through the key that leads eventually to step 69 (-ve) is the nul pathway, i.e. an indicator score of zero at each step leads to this conclusion, and the type is thus seen to be determined by a consistent lack, or conflict, of information. The other vegetation type which may be compared with the step 69 (-ve) form of D3 are all eight outlets for Marshland M1 (37 quadrats in all). This is a highly fractionated type, in which there is invariably some degree of wetness, but which also has disturbance as the common factor. The difference betweem M1 and the disturbance form of D3 is that the soils of the former are usually much more mature, humic and damp or wet.

The ensuing description refers to the composite of both forms of D3 and, as with Colonist type C, this is heavily weighted in favour of the majority form isolated in step 73 (+ve).

The most common species in semi-stable dune grassland D3 is <u>Festuca rubra</u>, with a frequency of 82.2%. Closely similar in frequency are <u>Poa pratensis</u> (76.8%) and <u>Ammophila arenaria</u> (70.5%). Also present with a frequency of over 50% are <u>Plantago lanceolata</u> (57.9%), <u>Senecio jacobaea</u> (56.3%) and <u>Galium verum</u> (53.4%). The number of species occurring in this type is much increased compared with C; there are 33 species with a frequency of over 10% (cf. 12 species for C) and the total number of species recorded in the type is 327 (cf. 153 for C). In fact, this is the highest number of species recorded for any vegetation type and this feature can probably be attributed largely to the effects of disturbance. A number of the species recorded in D3 occur in no other vegetation types and these include a proportion of weed species, aliens and escapes. The mean number of species per quadrat in D3 is also increased to 15.0 (cf. 6.1 for C).

The floristic differences between Colonist C and semi-stable dune grassland D3 can be usefully summarized in terms of preferential species. The term "preferential species" refers only to the comparison between two specified vegetation types. The rule that has been adopted to define preferential species for the vegetation type descriptions in this report is that a species must occur at least twice as frequently in the vegetation type to which it is preferential, i.e. the ratio of % frequency between the two types must be 2.0 or higher. A minimum frequency of 20% in the vegetation type to which a species is preferential has been used as a cut-off point to exclude low frequency species which are of less interest and for which the calculation of a simple ratio is not a reliable test of difference. The following table refers to the comparison between vegetation types C and D3.

Preferential Species for Type C

Species Names	C %	D3 %
No species preferential to C.		

Preferential Species for Type D3

Species Names	C %	D3 %
Achillea millefolium	5.1	36.5
Arrhenatherum elatius	0.9	21.2
Campanula rotundifolia	8.3	20.9
Cerastium holosteoides	3.7	39.4
Cirsium arvense	15.7	34.0
Dactylis glomerata	0.9	25.5
Festuca rubra	25.3	82.2
Galium verum	15.2	53.4
Heracleum sphondylium	1.8	23.6
Holcus lanatus	7.4	33.3
Lotus corniculatus	12.9	40.1
Plantago lanceolata	5.5	57.9
Poa pratensis	9.2	76.8
Senecio jacobaea	24.4	56.3
Taraxacum spp.	11.5	33.3
Trifolium repens	1.8	38.5

It will be noted that there are no species preferential to Colonist C in the above table. This is because there are no species occurring in C that show a significant decline in D3 (there are only four species in C with a frequency of 20% or over anyway - Ammophila arenaria, Agropyron junceiforme, Festuca rubra and Senecio jacobaea). By contrast, there is a long list of species (16) which are preferential to semi-stable dune grassland D3 and this is interpreted as being a reflection of increased stability of the substrate, enabling a wider range of species to become established but without (yet) the loss of species that were specially adapted to the unstable conditions that they themselves have helped to change.

In terms of vascular plant cover, D3 is dominated by just two species, Ammophila arenaria, with a mean cover of 24.9%, and Festuca rubra with 19.1%. Below this there is a sharp drop to Ulex europaeus with 2.8% (but only occurring in 6.1% of quadrats), Arrhenatherum elatius (2.4%), Poa pratensis (2.4%) and Galium verum (2.0%). Mean cover of vascular plants is increased in D3 (85.1%) as compared with C (35.5%), the difference being largely attributable to bare sand (18.8% cover in D3 and 60.2% in C). Semi-stable dune grassland D3 is remarkable by virtue of the wide range of potential dominants (species that achieve a cover of 10% or more in at least one quadrat) that can occur in it. In 444 quadrats there are no less than 95 dominants (cf. 35 for C) and 60 of these occur in two or more quadrats (cf. 17 for C). This feature of the type is thought to be a reflection of the transitional status of D3, being in an active state of colonization or re-colonization. Basically, the type is initiated under conditions where there is a high proportion of reasonably stable bare ground present and upon which plants may become established without undue competition for space. Which species are most successful at this stage may be to some extent a matter of chance, depending on such factors as seed availability and short term climatic conditions. Initially, there may be rapid colonization by relatively few species, some of which temporarily achieve high cover. As more species arrive on the scene, the quantities of the initial species will be reduced by competition. The culmination of this process is the transition from D3 to some more stable vegetation type such as D1 or D2 (depending on substrate type - see below), in which a still larger number of species per unit area is present in a reasonable state of equilibrium, albeit a dynamic one.

The most curious, and apparently contradictory, feature of the disturbance which is an important factor in certain forms of both C and D3 is that it can both decrease and increase the number of species present. The usual sequence of events is that the initial effect of most kinds of disturbance is to decrease the number of species. However, the open conditions and different habitats thus created soon result in an invasion of new species. At this stage the number of species may exceed that in the original, undisturbed condition. Later still, species that cannot compete in closed communities die out and the vegetation returns to something similar to what it was before the perturbation occurred - that is providing no permanent change to the habitat has taken place, i.e. total removal of humus layers or a large change in soil depth.

Bryophytes are also on the increase in D3 as compared with C, with a frequency of 66.4% and mean cover of 4.7%. Lichens are, however, somewhat reduced with a frequency of 13.1% and cover of 0.2%. Again, bare sand is the most common non-living cover type, with a frequency of 58.1% and mean cover of 18.8%. Gravel (7.2% and 1.4%), cobbles (10.8% and 2.9%) and boulders (4.7% and 0.6%) are also significant. The presence of undecomposed plant remains on the soil surface is also quite a common feature (13.7% and 1.7%).

In terms of soil types, D3 is highly associated with immature and semi-mature, Deep Sandy Soils. Types DS1 (2.7%), DS2 (8.6%), DS4 (3.4%) and DS5 (37.6%), along with similar Sandy Cobble Soils CS1 (0.7%) and CS4 (4.1%), together account for 57.1% of quadrats. Other common soil types are the immature DS3 (3.6%), semi-mature DS6 (20.3%) and mature DS7 (5.9%) Deep Sandy Soils, together accounting for a further 29.8% (total 86.9% out of 98.9%). A number of soil types are present but are negatively associated (they occur less frequently in the type than would be expected by chance). These include DS6 and DS7, mentioned above, and also some peaty types - PS3, PS4, PS5 and TS9. As a more direct measure of maturity, 42.6% of soils have visual evidence of humus incorporated in the top 10cm of the profile (cf. 12.0% for

C).

Compared with type C, grazing is on the increase in D3, with only 19.8% of the quadrats having no grazing recorded in them (cf. 42.4% for C) and 51.6% with light grazing (cf. 45.2% for C). A moderate grazing intensity was recorded in 19.1% and heavy grazing in 9.5%. It seems that the nature of the vegetation still inhibits grazing intensity in this type. The most common grazing animals are rabbit (72.3%), cattle (30.0%), sheep (18.0%) and deer (2.7%). Mole hills have now made an appearance in 4.7% of quadrats (a sign of humus accumulation in the sand). Human disturbance is generally on the increase, with fence (5.4%), unsurfaced path (18.7%), spent cartridge (2.7%), fire (2.5%), planted marram (0.2%) and planted trees (2.3%). A few quadrats exhibit signs of cultivation - 1.4% old and 0.5% recent. Rubbish was recorded from 40.3% of quadrats.

Low frequencies of a range of aquatic habitats were recorded in semi-stable dune grassland D3, e.g. stream (1.4%), river (1.6%), dried-up ditch (1.6%) and dried-up stream (1.1%).

There is no obvious preference of D3 for any particular local aspect but, in terms of general aspect, 64.8% face either north or east (probably a reflection of geographical distribution). Semi-stable dune grassland D3 usually occurs on sloping ground (only 13.7% are on slopes of less than 1 degree) and the surface type is usually undulating simple or complex (together 67.3%). It is essentially a low elevation type, with 90.3% of quadrats occurring below the 50ft contour. There is quite a wide variation in distance from the sea but 32.9% are within 50m, the mean distance being 179m (very similar to that for C - 183m).

The distribution of D3 is very like that for C, only more so. It is a widespread type that is least common in the Outer Hebrides and most common on the north and east coasts of mainland Scotland. Three sites, Spey Bay (Central), Lunan Bay and Arbroath, are composed of over 60% of the type. By contrast, about a quarter of the sites on North and South Uist have none of the type, e.g. Daliburgh, Stilligary (North), Borve and Monach Isles, also Northton on Harris.

D1 - Base-rich dune grassland

D1 - Base-rich dune grassland

(dominated by Festuca rubra, Ammophila arenaria and Plantago lanceolata)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 71)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
2 Macrihanish Dunes	4	12	3 Laggan Bay	6	14
4 Kilchoman Dunes	16	53	5 Saligo Bay	10	33
6 Gruinart	16	24	7 Oronsay	3	7
8 Garvard	6	19	9 Kiloran Bay	6	18
10 Calgary Dunes	9	36	11 Sanna	16	53
12 West Tiree	62	65	13 Ballevullin	30	81
14 Hynish Bay	21	62	15 Crossapol and Gunna	51	52
16 Totamore Dunes	23	64	17 Gallanach	29	63
18 Vatersay	18	60	19 West Barra	23	61
20 North Barra	36	80	21 Daliburgh	36	68
22 Graiclate	29	63	23 Howbeg	10	48
24 Stilligarry (North)	12	41	25 Loch Bee	19	23
26 Borve	22	81	27 Stilligarry (South)	19	60
28 Baleshare	25	45	29 Kirkibost	12	43
30 Monach Isles	34	85	31 Paible	7	44
32 Hosta	19	66	33 Vallay	22	69
34 Leathann	26	74	35 Balranald	16	52
36 Robach	29	74	37 Berneray	20	33
38 Pabbay	15	24	39 Northton	14	37
40 Luskintyre	13	42	41 Uig	16	53
42 Valtos	14	54	43 Barvas	17	57
44 Europie	13	43	45 Tolsta	17	57
47 Quendale	11	31	48 Scousburgh	18	60
49 Breckin	10	37	51 Holland	23	74
52 Achnahaird	4	15	53 Oldshore More	14	46
54 Sheigra	3	8	55 Durness	7	23
56 Faraid Head	15	50	57 Bettyhill	3	9
58 Farr Bay	19	68	59 Strathy	4	14
60 Melvich	7	21	61 Reay	7	21
62 Dunnet	9	32	63 Freswick	10	28
64 Sandwood	6	19	65 Sinclairs Bay	6	19
67 Coul Links	1	3	68 Dornoch	3	9
73 Overbister	23	74	79 Fraserburgh	10	29
80 Strathbeg	9	14	81 St. Fergus	6	14
88 Arbroath	5	17	91 Dumbarnie	3	10
94 Yellowcraig	2	11			

D1 - Base-rich dune grassland, dominated by Festuca rubra, Ammophila arenaria and Plantago lanceolata

There are no less than 1,099 quadrats (28.6%) allocated to this vegetation type which is by far the most common in the survey. It has two outlets in the key; step 70 (-ve), isolating the majority of 938 quadrats (85.4%) of the type, and step 72 (-ve) dealing with the remainder of 161 quadrats (14.6%). There are some differences between the forms isolated by these two key pathways, which diverge at step 55 (see Figure 6B). The indicators defining this step give a clue to the nature of the difference. On the negative (majority) side are six species typical of the drier forms of dune grassland - Ammophila arenaria, Euphrasia officinalis agg., Galium verum, Linum catharticum, Lotus corniculatus and Luzula campestris. These can be contrasted with the positive side for which there are four species, indicating a damp, and possibly slightly disturbed, e.g. trampling by cattle or sheep, influence - Agrostis stolonifera, Potentilla anserina, Ranunculus repens and Rumex crispus. Two further divisions of the positive side separate off a form of damp, base-rich dune grassland D4 and a few quadrats which are allocated to an upper saltmarsh/dune transition S5. These unmistakably damper types tend to confirm the interpretation placed on this branch of the hierarchy. The differences between the two forms of D1 are nothing like as important as those described above for the various forms of C and D3 and can virtually be ignored for normal purposes. It should, however, be noted that the form of D1 isolated by step 72 (-ve) is closely related to what is thought to be one of the possible successional developments of this type, namely D4 (isolated in step 64 +ve). In this context, it is also interesting to note that the main form of D4 is isolated from the main form of D1 in step 70 using a similar set of indicators to step 64, i.e. the same ecological interpretation may be placed on them. On the negative side (D1) are Achillea millefolium and Ammophila arenaria whilst on the positive side (D4) are Agrostis stolonifera, Cardamine pratensis, Carex nigra, Hydrocotyle vulgaris, Pinguicula vulgaris, Plantago maritima, Potentilla anserina and Selaginella selaginoides. This parallel isolation of the different forms of closely related vegetation types is repeated a number of times in the key.

The most common species in base-rich dune grassland D1 are Festuca rubra (96.2%), Trifolium repens (95.5%) and Plantago lanceolata (95.5%). Eleven more species occur in over 50% of quadrats: 80-90% - Poa pratensis, Bellis perennis and Galium verum; 70-80% - Cerastium holosteoides, Lotus corniculatus, Ranunculus acris and Euphrasia officinalis agg.; 60-70% - Senecio jacobaea, Achillea millefolium and Holcus lanatus; 50-60% - Ammophila arenaria. A total of 54 species occur in at least 10% of quadrats and this is reflected in the mean number of species per quadrat (species richness) of 23.8 (cf. D3 with 15.0). A total of 265 species have been recorded from D1.

The status of Ammophila, in just over half of the quadrats, requires some comment. Base-rich dune grassland D1 is a fairly stable type of dune grassland and marram grass is becoming progressively more moribund with time (probably as the result of a lack of new sand deposits). This is clearly evident from the poor vigour of the species in most of the quadrats in which it occurs. There is wide variability in the cover conferred by Ammophila which, despite its moderate frequency, is the second most important cover species in D1, with 9.4% mean cover. It is an actual dominant (10% cover or more) in 30.4% of quadrats but cover in individual quadrats can range from over 50% to just a few scattered shoots with negligible cover. All the evidence is that the amount of Ammophila has little effect on the other species present.

Some of the floristic differences between base-rich dune grassland D1 and semi-stable dune grassland D3, from which it is usually derived (see Figure 3), are revealed in the following table of preferential species for the two types.

Preferential Species for Type D3

Species Names	D3 %	D1 %
Cirsium arvense	34.0	13.3
Dactylis glomerata	25.5	11.2

Preferential Species for Type D1

Species Names	D3 %	D1 %
Agrostis stolonifera	9.9	41.7
Bellis perennis	16.2	87.7
Carex flacca	3.8	20.4
Cerastium holosteoides	39.4	79.4
Cynosurus cristatus	3.2	25.4
Daucus carota	7.0	24.8
Euphrasia officinalis agg.	6.5	74.6
Koeleria cristata	11.9	27.7
Leontodon autumnalis	11.7	35.6
Linum catharticum	7.4	44.9
Lolium perenne agg.	9.5	39.4
Luzula campestris	6.5	43.7
Polygala vulgaris	2.5	20.7
Prunella vulgaris	2.3	48.6
Ranunculus acris	11.5	74.8
Ranunculus bulbosus	6.1	21.3
Rumex acetosa	9.7	22.9
Thymus drucei	8.1	32.8
Trifolium pratense	0.9	40.8
Trifolium repens	38.5	95.5

As with the previous comparison between C and D3, there are few preferential species for the parent type, i.e. the type from which the other is derived (or is supposed to be derived), in this case D3. Even then the two species preferential to D3 are devoid of great ecological significance. Both have only moderate frequency and probably represent the more acid portion of D3 which later differentiates into D2 as opposed to D1 (see Figure 3), according to substrate type. Both Cirsium arvense and Dactylis glomerata are less common in D1 as compared with D2 and, indeed, the former is a preferential species between the two types (see description of D2 below). In the second part of the table, the long list of species preferential to D1 (20 species) can be interpreted as a reflection of increased surface stability and humus content of the soil. A number of species show a quite startling increase in frequency, e.g. Bellis perennis (16.2% to 87.7%), Cerastium holosteoides (39.4% to 79.4%), Euphrasia officinalis agg. (6.5% to 74.6%), Ranunculus acris (11.5% to 74.8%) and Trifolium repens (38.5% to 95.3%).

Festuca rubra is by far the most important species conferring cover in D1, with a mean cover of 27.6% (nearly three times that of Ammophila). Other species with relatively high cover are Trifolium repens (5.8%), Plantago lanceolata (5.6%), Poa pratensis (4.3%), Galium verum (3.6%) and Bellis perennis (3.5%). Total cover of vascular plants is 100.1% (cf. D3 with 85.1%). Like D3, the list of potential dominants (species with 10% or more cover) is a long one, 98 species in all, although 25 of these only achieve dominant status in a single quadrat. The large number of quadrats in the type is probably responsible for the wide range of possible dominants. Bryophytes are of increased importance in D1, with a frequency of 91.9% (cf. 66.4% for D3) and with mean cover of 10.2% (cf. 4.7% for D3). Lichens are also slightly increased, with a frequency of 27.2% and cover of 0.3% (cf. 13.1 and 0.2% for D3). Because of the high cover afforded by all forms of plants, non-vegetative cover is comparatively unimportant in D1. Bare sand is the only significant type, with a frequency of 46.9% and a mean cover of 5.2%

In terms of soil types, base-rich dune grassland D1 is probably the best defined of all the vegetation types, which is useful because it is so common. It is particularly associated with just three soil types, all semi-mature or mature Deep Sandy Soils - DS5 (25.9%), DS6 (48.5%) and DS7 (14.8%). Together these three types account for a total of 89.2% of quadrats (out of 100% for which there are soil data). The residue of quadrats are scattered over a wide range of soil types, some of which represent strong negative associations, e.g. DS3 (1.0%), DS2 (0.5%), CS4 (0.6%), PS2 (1.5%), PS3 (0.3%), PS4 (0.3%) and TS9 (0.2%). As a sign of soil maturity, humus was recorded from the top 10cm in 83.3% of quadrats (cf. 12.0% for C and 42.6% for D3).

Grazing is again on the increase in base-rich dune grassland D1 as compared with the types previously described, with no grazing in only 4.0% of quadrats. Light grazing was recorded in 35.4% of quadrats, moderate grazing in 38.7% and heavy grazing in 21.9%. The most common grazing animal is still the rabbit (76.6%), followed by cattle (63.3%) and sheep (52.4%). Human disturbance is on the increase, e.g. fence (5.0%), tarmac road (1.5%), vehicle track (11.2%), unsurfaced path (10.9%) and spent cartridge (2.5%). One of the more striking features of the type is the level of arable agriculture, with 2.5% having recent cultivation and 10.4% old cultivation. The remains of a standing crop were recorded in 1.2% of quadrats. Rubbish was recorded from 25.2% of quadrats (down compared with C with 30.0% and D3 with 40.3%). This is probably because D1 is predominantly a western type and most of the sites in this region have less rubbish deposited on them than those in the east.

There are occasional occurrences of aquatic habitats in base-rich dune grassland D1, e.g. puddles, ruts and ditches of various sorts, but none exceed 1.0% in frequency.

The topographical characteristics of D1 are not particularly notable. Local aspect is neutral but general aspect shows quite a strong preference for west (45.8%). Again, this is probably a direct reflection of geographical distribution (see below). There are a range of slope categories present but only 25.0% of quadrats are at the steep end of the range (5-15 degrees in 23.6% and over 15 degrees in

1.4%). Surface type shows similar characteristics, with 77.5% either flat or undulating simple. In terms of elevation, 75.4% are under the 50ft contour but the type does extend up to 250-300ft OD in a few cases. Distance from the sea is increased compared with C or D3, with a mean of 285m. Modal distance is 100-400m, with 54.2% of quadrats. The idealized distribution of C, D3 and D1 within a site is for them to occur in zones at increasing distance from the sea, i.e. in the order listed. In most bayhead systems there is a central area of instability and the vegetation types occur in concentric zones around this (like the skins of an onion). This feature can be seen on a number of site maps (see Site Dossiers). A good example is Berneray, where the sequence is C, D3, D1, followed by D4 or G1.

The geographical distribution of base-rich dune grassland D1 is particularly interesting. It is very much a western type, achieving its greatest frequency on the Outer Hebrides (with the exception of Tong, which is virtually all saltmarsh), Coll, Tiree and Mull. Sites such as Ballevulin, North Barra, Borve and Monach Isles are composed of over 80% of this vegetation type. The type is still quite common in the south-west (with the exception of Torrs Warren), on the west coast of mainland Scotland (with the exception of Redpoint) and on the north coast. Of the twenty-eight sites from the Moray Firth to the Firth of Forth on the east coast, twenty have no D1 whatsoever. Only the three sites just south of Kinnairds Head on the Aberdeenshire coast, Fraserburgh, Strathbeg and St Fergus, contain much of the type and the probable explanation for this is discussed in Section 8.

The most important environmental factor underlying the base-rich dune grassland type is thought to be, as the name suggests, the calcium content (almost invariably shell) of the sand that constitutes the soil parent material. However, as most shell-rich sands occur in the west it is difficult to separate this factor from others such as climate and land-use which are confounded with it. The availability of soil analyses (in particular, determinations of free calcium carbonate) could help clarify the relationship, i.e. there would almost certainly be a few low calcium soils in the west and high ones in the east, which would provide some test of the hypothesis. Samples are available but have not been worked on at the present time. In the absence of this information, it is possible to at least infer the relationship from the species that are associated with the type or, perhaps even more clearly, when a comparison is made between D1 and its eastern equivalent, slightly acid dune grassland D2 (see Figure 3). Discussion of this difference and the relationship between D1 and D2 is deferred until after the latter type has been fully described.

D2 - Slightly acid dune grassland

D2 - Slightly acid dune grassland

(dominated by Ammophila arenaria, Festuca rubra and Festuca ovina)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 45)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	12	12	2 Macrihanish Dunes	18	62
3 Laggan Bay	1	2	4 Kilchoman Dunes	1	3
5 Saligo Bay	3	10	6 Gruinart	4	6
7 Oronsay	3	7	8 Garvard	1	3
9 Kiloran Bay	6	18	10 Calgary Dunes	1	4
14 Hynish Bay	1	3	15 Crossapol and Gunna	5	5
28 Baleshare	1	2	47 Quendale	3	9
50 Redpoint	1	4	55 Durness	1	3
57 Bettyhill	2	6	59 Strathy	1	3
62 Dunnet	1	4	64 Sandwood	1	4
65 Sinclairs Bay	1	3	66 Ferry Links	9	24
67 Coul Links	5	15	68 Dornoch	2	6
69 Clashmore	5	6	70 Morrich More	1	2
71 Whiteness	6	10	72 Culbin Bar	7	14
74 Findhorn	3	9	75 Lossiemouth	2	8
78 Spey Bay (East)	1	4	79 Fraserburgh	1	3
80 Strathbeg	8	13	81 St. Fergus	4	9
83 Forvie	4	5	84 Don to Ythan	6	11
86 St. Cyrus and Montrose	3	8	87 Lunan Bay	3	16
89 Barry Links	18	17	90 Tentsmuir	16	21
91 Dumbarnie	9	31	92 Aberlady	9	29
93 Gullane	26	62	94 Yellowcraig	8	44
95 Tyninghame	1	1			

D2 - Slightly acid dune grassland, dominated by Ammophila arenaria, Festuca rubra and Festuca ovina

There are 225 quadrats in this type (5.8%) which is about one fifth as common as D1 (28.6%). D2 has three outlets in the key; step 38 (+ve), which isolates 13 quadrats, step 71 (-ve) with 6 quadrats and step 73 (-ve) with the majority of 206 quadrats. Clearly only the majority outlet is really important in numerical terms. Step 3 is a crucial one for outlet 38 (+ve), where the balance between acidophilous and dune species falls more on the acid side so that, initially, the quadrats that take this pathway in the key are regarded as being more like Grassland or Peatland types (see Figure 6A). The 71 (-ve) outlet becomes detached from the mainstream of D2 at step 55 in the key (see Figure 6B). This fraction of D2 is merely a rather species-poor form of the type. To all intents and purposes the minor forms can be ignored and D2 regarded as a pretty "pure" type.

The most common species in slightly acid dune grassland D2 are Festuca rubra (87.6%), Ammophila arenaria (85.8%), Poa pratensis (85.8%), Carex arenaria (78.7%), Galium verum (77.3%), Lotus corniculatus (74.2%), Senecio jacobaea (70.2%) and Cerastium holosteoides (64.0%). Another five species have frequencies between 50-60%: Luzula campestris, Holcus lanatus, Plantago lanceolata, Thymus drucei and Trifolium repens. This list is not all that dissimilar from that for D1 but the following table of preferential species summarizes the difference in terms of species complement.

Preferential Species for Type D1

Species Names	D1 %	D2 %
Achillea millefolium	66.0	16.9
Agrostis stolonifera	41.7	8.4
Bellis perennis	87.7	29.3
Carex flacca	20.4	7.1
Centaurea nigra	22.5	1.8
Cynosurus cristatus	25.4	5.8
Daucus carota	24.8	2.2
Euphrasia officinalis agg.	74.6	15.6
Heracleum sphondylium	22.5	3.1
Leontodon autumnalis	35.6	9.3
Lolium perenne agg.	39.4	6.2
Polygala vulgaris	20.7	5.8
Prunella vulgaris	48.6	10.2
Ranunculus acris	74.8	4.9
Ranunculus bulbosus	21.3	8.4
Rumex acetosa	22.9	4.4
Thalictrum minus	35.0	2.2
Trifolium pratense	40.8	0.9

Preferential Species for Type D2

Species Names	D1 %	D2 %
Agrostis tenuis	12.1	36.9
Aira praecox	2.9	25.8
Anthoxanthum odoratum	9.3	28.0
Campanula rotundifolia	15.1	32.0
Cirsium arvense	13.3	32.9
Festuca ovina	3.5	39.1
Hieraceum pilosella	11.6	31.6
Hypochoeris radicata	2.1	40.0
Veronica chamaedrys	8.0	45.8
Veronica officinalis	1.2	22.2
Viola riviniana	19.5	42.7

In this table perhaps the most striking differences relate to the species that favour D1 as opposed to D2, e.g. Bellis perennis (87.7% in D1 and 29.3% in D2), Ranunculus acris (74.8% and 4.9%) and Euphrasia officinalis agg. (74.6% and 15.6%). Species that are more common in D2 as opposed to D1 are not so impressive in terms of their high frequency in D2 but, together, they add up to an interpretation of increased acidity and dryness, e.g. Agrostis tenuis (36.9% in D2 and 12.1% in D1), Aira praecox (25.8% and 2.9%), Anthoxanthum odoratum (28.0% and 9.3%), Festuca ovina (39.1% and 3.5%), Hypochoeris radicata (40.0% and 2.1%) and Veronica chamaedrys (45.8% and 8.0%).

Although not a preferential species, Ammophila arenaria is more common in D2 than in D1, 85.8% as compared with 56.3%. The most obvious explanation would seem to be greater surface stability in D1 as compared with D2. However, there is no clear-cut evidence of this diffference from the soil types but an increased proportion of bare sand in D2 compared with D1 is probably significant (see below).

A total of 42 species occur in at least 10% of quadrats and 224 species have been recorded in the type. The species richness, as measured by the mean number of species per quadrat, is slightly less than that for D1, 20.6 as compared with 23.8.

In terms of cover, Ammophila arenaria (22.6%) and Festuca rubra (20.3%) are by far the most important species. The cover of Festuca rubra is very similar to that for D1 (27.6%) but that for Ammophila is very much increased (cf. 9.4% for D1). Other species contributing a significant amount of cover are Festuca ovina (6.6%), Carex arenaria (3.2%), Agrostis tenuis (2.7%), Lotus corniculatus (2.1%), Galium verum (2.1%) and Thymus drucei (2.0%). The list of potential dominants (10% or more cover in a quadrat) is quite long, with 59 species having been recorded in the type, although 23 of these occur in one quadrat only. The most common dominants are Ammophila arenaria, Festuca rubra, Festuca ovina, Carex arenaria and Agrostis tenuis, i.e. the same as the high cover species. Total cover of vascular plants is 86.6%, which is rather less than that for D1 (100.1%). The difference is largely made up by an increase in bryophytes, lichens and bare sand. Bryophytes occur in 96.4% of quadrats with a mean cover of 16.6% (cf. 91.9% and 10.2% for D1). Equivalent figures for lichens are 50.7% and 2.7% (cf. 27.3% and 0.3% for D1). Bare sand occurs in 53.3% of quadrats with a mean cover of 7.4% (cf. 46.9% and 5.2% for D1).

Compared with base-rich dune grassland D1, slightly acid dune grassland D2 shows comparatively poor correlations with the soil types. There is only one highly associated type, semi-mature, Deep Sandy Soil DS5 with 43.1% of quadrats. Other common types are also deep sands, DS6 (semi-mature) and DS7 (mature), which together account for another 34.3% (a total of 77.4% out of 95.1% of quadrats for which the soil profile was recorded). The remainder of quadrats cover a range of the drier soil types. There are no significant negative associations (see Table 6).

Grazing pressure in D2 is similar to that of D1, with roughly the same proportion of quadrats moderately or heavily grazed (58.6% for D2 and 60.6% for D1). There is a tendency towards heavy grazing in D2 (32.4% compared with 21.9% in D1). The incidence of grazing animals in D2 and D1 is, however, quite different, cattle and sheep being about half as frequent in the former - cattle 32.9% in D2 and 63.3% in D1 and sheep 27.6% and 52.4% respectively. Rabbits are somewhat more common in D2 (91.1% in D2 compared with 76.6 in D1). The level of grazing pressure and the relative amounts of grazing animals recorded suggest that the rabbit may be very much more important in D2 than D1. General observations by surveyors support this view.

Human disturbance shows an increase in D2 compared with D1 and, in particular, unsurfaced paths are increased from 10.9% to 22.2%. Various other features that are evidence of disturbance are also increased, e.g. armaments (0% in D1 to 3.6% in D2), fire evidence (0.3% to 5.3%), planted trees (0.1% to 2.7%) and rubbish (25.2% to 43.1%). Conversely, arable cultivation is on the decrease - recent cultivation, down from 2.5% in D1 to 0.4% in D2, and old cultivation, down from 10.2% to 0.4%. This reflects the difference between farming on the east coast, where most arable land is so modified that it is not even included in the sites, and crofting in the west, where shifting cultivation occurs actually within the sites.

There are virtually no aquatic habitats recorded for slightly acid dune grassland D2 and even these are in the dried-up category, i.e. temporary or winter wetness.

with dried-up saltmarsh pan in some part of the 200 sq m quadrat.

Topographically there is little to distinguish D2 from D1. Curiously (in view of its geographical distribution) there is a tendency for D2 to occupy south or west facing general aspects (D1 tends to face west). Slopes are moderate with 16.0% under 1 degree (20.8% for D1), 51.1% from 1-5 degrees (54.2% for D1) and 29.3% from 5-15 degrees (23.6% for D1). Surface types show parallel trends, with simple undulating the most common type (52.4%). In terms of elevation, 85.8% of quadrats in D2 lie under the 50ft contour (75.4% for D1), mean elevation for the type being 33.2ft (43.6ft for D1). Distance from the sea is also similar to that for D1, D2=259m and D1=285m. Modal distance is 200-400m, with 25.3% and 30.4% for D2 and D1 respectively.

Despite the high degree of similarity between slightly acid dune grassland D2 and base-rich dune grassland D1 on a number of features (see above), their geographical distributions are quite distinct. D1 is essentially a western type whereas D2 occurs mainly on the east coast and in the south-west. It also occurs at low frequencies in some sites on the north coast but is virtually absent (only one quadrat in Baleshare) on the Outer Hebrides, where D1 achieves its greatest importance. Peak frequencies of the type occur in sites on the Firth of Forth, Dumbarnie with 31% of quadrats, Aberlady (29%), Gullane (62%) and Yellowcraig (44%). In the south-west, Macrihanish has 62% of the type.

Figure 3 shows the supposed relationship of slightly acid dune grassland D2 with the other types of vegetation. Increasing stability of the surface on sandy substrates leads from Bare ground B to Colonist C and thence to the "parent type" for the Duneland types, semi-stable dune grassland D3. This type has already been described in some detail, including the non-typical, disturbance forms. It is suggested that the successional types up to and including D3 are more or less "universal", i.e. they are essentially the same wherever they occur round the Scottish coast. This implies that there is a critical or limiting environmental factor in operation. The critical factor, which is almost certainly surface stability and, possibly, availability of certain nutrients, e.g. nitrogen, is the same wherever it occurs and tends to override differences in other factors such as climate, chemical composition of the substrate and land-use. After type D3, by which stage a considerable degree of stability has been achieved, other factors tend to take over control of further development. Different factors coming into operation are thought to be the basis of the split of D3 into D1 and D2.

The main cause of the divergence in development between D1 and D2 is thought to be substrate type and, in particular, the content of free calcium carbonate in the soil (normally shell fragments). However, as most calcium-rich sands occur on the west coast of Scotland and, to a lesser extent, in the north, it is difficult to isolate the effects of this factor from confounding factors such as climate and management which also show similar east-west trends. In the absence of chemical determinations for calcium carbonate in the sand, it is difficult to explore this relationship in great detail. However, a whole range of indirect evidence combines to confirm the validity of this conclusion; distribution of soil types, i.e. soils with shell visible in the profile occur mainly in the west, and the interpretation which may be placed on the species that occur in the various types, e.g. the preferential species that distinguish D1 and D2, listed above. In general, the vegetation types which are involved in the two branches of Figure 3 (starting with D1 and D2) show fairly distinctive geographical distributions, the lefthand branch occurring mainly in western and northern Scotland and those on the right occurring mainly in the east. The floristic difference between all these types is largely based on the proportion of basophilous and acidophilous species. The hypothesis that calcium carbonate in the sand is the decisive factor (more important than climate) is supported by the presence of an outlier of D1 in the three sites just south of Fraserburgh on the east coast (Fraserburgh, Strathbeg and St Fergus). This is an area of low rainfall but there is some evidence of the sand in the region having a moderate calcium carbonate content. Three other sites on the southern half of the east coast also contain fair amounts of D1 - Arbroath 17%, Dumbarnie 10% and Yellowcraig 11% - whilst the intervening sites contain none at all. This could again be the result of localized sources of calcium carbonate. Only analysis of the soil samples can confirm or refute this theory (see also discussion in Section 8). In the twelve sites located in the Moray Firth, with its acid, siliceous sands and gravels, there are just four quadrats of D1 (Coul Links 1 and Dornoch 3). Conversely, in the twenty-nine sites in the Outer Hebrides, with its predominantly white shell sands, there is just one quadrat of D2, (Baleshare) as already noted.

It is obvious from the above discussion that D1 and D2 represent parts of a continuous range of variation and, therefore, that there must inevitably be borderline types. The species composition and preferential species show the nature of this trend. If the explanation of how the types are determined, advanced above, is correct then it follows that there must be some soils of intermediate calcium carbonate content which, on leaching, undergo a change in vegetation type from D1 to D2. Hence the single solid line from D1 to D2 on Figure 3. The reverse direction seems unlikely. The co-existence of D1 and D2 on the same site can be explained by leaching and non-uniformity of the substrate (either the original deposit or as a result of secondary wind sorting).

D4 - Damp, base-rich dune grassland

D4 - Damp, base-rich dune grassland

(dominated by Festuca rubra, Carex nigra and Agrostis stolonifera)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 52)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
2 Macrihanish Dunes	3	0	4 Kilchoman Dunes	1	3
6 Gruinart	1	1	10 Calgary Dunes	1	4
11 Sanna	2	7	12 West Tiree	8	8
13 Ballevullin	1	3	14 Hynish Bay	3	9
16 Totamore Dunes	3	8	17 Gallanach	1	2
19 West Barra	1	3	20 North Barra	1	2
22 Oraiclate	2	4	24 Stilligarry (North)	6	21
25 Loch Bee	16	19	26 Borve	1	4
27 Stilligarry (South)	2	8	28 Baleshare	15	27
29 Kirkibost	2	7	30 Monach Isles	1	2
31 Paible	1	6	32 Hosta	2	7
33 Vallay	1	3	34 Leathann	1	3
35 Balranald	1	4	36 Robach	3	8
37 Berneray	16	27	38 Pabbay	4	6
39 Northton	2	5	41 Uig	6	20
42 Valtos	2	8	43 Barvas	2	7
44 Europie	4	13	45 Tolsta	2	7
47 Quendale	1	3	48 Scousburgh	4	13
51 Holland	3	10	53 Oldshore More	3	8
54 Sheigra	3	8	55 Durness	1	3
56 Faraid Head	1	3	58 Farr Bay	1	4
61 Reay	1	1	62 Dunnet	2	4
63 Freswick	4	11	65 Sinclairs Bay	6	19
67 Coul Links	2	3	73 Overbister	4	13
80 Strathbeg	2	3	81 St. Fergus	1	2
91 Dumbarnie	1	3	92 Aberlady	1	3

D4 - Damp, base-rich dune grassland, dominated by Festuca rubra, Carex nigra and Agrostis stolonifera

There are 159 quadrats (4.1%) allocated to this type which is represented in Figure 3 as being a development from base-rich dune grassland D1. The underlying cause of this development is thought to be an increase in humus in the profile and wetter soil conditions. This is partly a successional relationship, in the sense that at a given point on the ground D1 can change to D4 with time, but there is, however, a good deal of evidence that D4 is rather different from D1 in terms of such features as local topography and water relations (depth to water table). To what degree the relationship is regarded as successional depends on whether one considers factors like deflation of the dune surface to be a successional process. In more conventional terms, D4 can be regarded as a dune slack vegetation type, in that it tends to occupy the flatter, low-lying ground between or behind the dunes. The vegetation type seems to be the same regardless of the exact process by which the habitat it occupies was formed.

Damp, base-rich dune grassland D4 has two outlets in the key. The first of these, step 64 (+ve), isolates 42 quadrats and the other step, 70 (+ve), isolates 117 quadrats. These outlets closely parallel the two outlets for D1, from which they directly stem (see Figure 6B). The interpretation of the two forms of D4 is, therefore, similar to that given for D1. The form originating from step 64 (+ve) is somewhat wetter and possibly slightly disturbed compared with the more common form originating from step 70 (+ve).

The most common species in D4 are Festuca rubra (96.2%), Trifolium repens (93.1%), Agrostis stolonifera (89.9%), Plantago lanceolata (87.4%), Poa pratensis (87.4%), Ranunculus acris (84.9%), Holcus lanatus (84.3%) and Lotus corniculatus (82.4%). A further 13 species have frequencies of over 50%: 70-80% - Bellis perennis, Euphrasia officinalis agg., Cerastium holosteoides, Galium verum and Prunella vulgaris; 60-70% - Potentilla anserina and Linum catharticum; and 50-60% - Carex nigra, Senecio jacobaea, Trifolium pratense, Leontodon autumnalis, Plantago maritima and Carex arenaria. There are a total of 63 species having a frequency of over 10%. The total species complement is high, with 233 species having been recorded from the 159 quadrats in the type. As the total number of species increases with number of quadrats, this is probably marginally richer than D1, with 265 species from 1,099 quadrats.

At first sight the species list for D4 appears to be quite similar to that for D1 but the following table summarizes the floristic differences in terms of preferential species.

Preferential Species for Type D1

Species Names	D1 %	D4 %
Ammophila arenaria	56.3	22.6
Cerastium atrovirens	25.0	11.3
Heracleum sphondylium	22.5	7.5
Taraxacum spp.	32.5	15.7

Thalictrum minus	35.0	10.1

Preferential Species for Type D4

Species Names	D1 %	D4 %
Agrostis stolonifera	41.7	89.9
Cardamine pratensis	1.5	25.8
Carex flacca	20.4	45.3
Carex nigra	16.2	57.9
Carex panicea	3.9	20.8
Coeloglossum viride	7.7	22.0
Hydrocotyle vulgaris	0.5	23.3
Dactylorchis spp.	5.7	22.6
Juncus articulatus	1.2	33.3
Ophioglossum vulgatum	1.3	21.4
Plantago coronopus	9.0	20.1
Plantago maritima	9.4	54.1
Potentilla anserina	13.0	64.2
Selaginella selaginoides	1.0	25.8
Vicia cracca	9.4	27.7

The species that are preferential to D1 are generally less informative than those for D4. Preferential to D1, and declining in D4, are such dune species as Ammophila arenaria, down from 56.3% to 22.6% (96.3% in C and 70.5% in D3) and Cerastium atrovirens (25.0% to 11.3%). The increase in wettness in D4 is indicated by a decline in Thalictrum minus, down from 35.0% in D1 to 10.1% in D4. Species that are preferential to D4 are much greater in number and interest. In general, they indicate an increase in humus and wetter conditions in the soil, e.g. the three species of Carex. The most characteristic species preferential to D4 are Agrostis stolonifera (up from 41.7% in D1 to 89.9% in D4), Carex nigra (16.2% to 57.9%), Plantago maritima (9.4% to 54.1%) and Potentilla anserina (13.0% to 64.2%).

Damp base-rich, dune grassland D4 is species-rich, with a mean of 28.9 species per 25 sq m quadrat (so is D5 with 28.5) and is only exceeded in this feature by acid, damp grassland G2 with 31.0 species per quadrat. As well as being species-rich, D4 also provides the habitat for quite a large number of less common species or local species (the type of species that are summarized in Section 5.1.4 of the Site Dossiers) such as Primula scotica on the north coast. Other species quite commonly occurring in D4 are Coeloglossum viride (22.0%), Dactylorchis spp. (22.6%), Gentianella armarella (11.9%), Gentianella campestris (7.5%) (plus 1.3% of Gentianella identified to generic level only), Listera ovata (4.4%), Ophioglossum vulgatum (21.4%), Parnassia palustris (8.8%) and Triglochin palustris (6.3%).

In terms of cover, D4 is dominated by Festuca rubra with 21.9% cover (cf. D1 with 27.6%), followed by Carex nigra 7.2% (less than 0.5% in D1) and Agrostis stolonifera 6.6% (2.6% in D1). Other species contributing over 3% cover are Trifolium repens, Potentilla anserina, Bellis perennis, Holcus lanatus, Plantago lanceolata, Poa pratensis and Carex flacca. The list of potential dominants (cover of 10% or over in a quadrat) is long with a total of 58 species (20 in one quadrat only). As might be expected, the same top cover species are also the common dominants and Festuca rubra has 10% or more cover in 74.2% of quadrats.

Mean cover of vascular plants at 99.1% is very similar to that for D1 (100.1%). Bryophytes occur in 95.6% of quadrats with a mean cover of 9.3%. Similar figures for lichens are 29.6% and 0.2%. Bare sand occurs in 35.8% of quadrats with 2.3% cover. The only other non-vegetative cover type of interest is freshwater, occurring in 7.5% of quadrats with a mean cover of 1.4%.

There are quite high associations between damp, base-rich dune grassland D4 and the soil types. Highly associated with D4 are semi-mature and mature Deep Sandy Soils DS6 and DS7 (together 66.7%), Thin Soils TS1 (with high water table, 3.1%) and wet Peaty Soil PS3 (6.3%). Together these four types account for 76.1% (out of 100%) of quadrats. Semi-mature, Deep Sandy Soil DS5 accounts for a further 9.4% but this is in fact a negative association. In total, peaty soils occur in about 10% of quadrats. The main emphasis is on damp to wet, humus-rich soils, often with a high water table. Many quadrats may be flooded in winter but that is not a feature that can be determined by a one visit survey carried out in summer.

Grazing pressure in D4 is somewhat greater than that on D1 or D2, with 65.4% being moderately or heavily grazed (cf. D1 with 60.6% and D2 with 58.6%). Cattle were recorded in 66.0% of quadrats, sheep in 39.6% and rabbits in 78.6% (figures that are fairly similar to those for D1 with 63.3%, 52.4% and 76.6% respectively)

Human disturbance is at a moderate level, with fences in 8.8% of quadrats, vehicle tracks (13.2%), unsurfaced paths (8.8%), recent cultivation (0.6%) and old cultivation (5.7%). No fire evidence was found in D4. Rubbish was recorded from 24.5% of quadrats, fairly typical of a vegetation type with a predominantly western distribution (see below).

Compared with the Duneland types previously described, damp base-rich dune grassland D4 contains a fair range of aquatic habitats, e.g. rut (2.5%), ditch with standing water (2.5%), loch (1.9%), ditch with flowing water (1.9%), stream (3.1%), dried-up rut (2.5%), dried-up ditch (2.5%) and dried-up stream (1.3%).

Topographically, damp, base-rich dune grassland D4 tends to be fairly flat, 84.9% of quadrats having slopes less than 5 degrees. Similarly, 76.6% of quadrats were recorded as being of a surface type that is either plane or simple undulating. The minority of quadrats with steep slopes or more complex surface types are largely explicable by quadrat position, i.e. those located at the edge of a flat area and including some peripheral sloping ground. There is a tendency for D4 to have an eastern or southern local aspect. General aspect shows that 60.4% of quadrats face west but, in view of the relative flatness of the type, this is probably just a reflection of a slight slope towards the sea that usually forms the western boundary of the site because of the geographical distribution of D4 (see below). When determining the general aspect of a quadrat on the OS map, absence of relevant contour lines was interpreted as being an aspect in the direction of the open sea. The majority of quadrats are low-lying, with 84.9% under the 50ft contour. A minority occur at greater elevation (up to 400-450ft), presumably as the result of localized edaphic conditions. Distance from the sea is rather greater than for D1 or D2 with a mean of 367m (about 100m greater than D1 or D2). This is probably a reflection of the more inland location of deflation surfaces.

In terms of geographical distribution, D4 is a predominantly western type, reaching its peak on the Outer Hebrides where Stilligary (North) (21%), Loch Bee (19%), Baleshare (27%), Berneray (27%), and Uig (20%) are sites with a notable proportion of this vegetation type. It is also quite a common type on the Inner Hebrides (Coll, Tiree and Mull) and on the north coast and Orkney. Only five sites on the east coast contain quadrats of this vegetation type and it is notable that, with one exception, these are the same sites which also contain outliers of D1, discussed earlier. This is taken as further evidence of the presence of isolated patches of calcium carbonate rich sand on the east coast.

In conservation terms, damp base-rich dune grassland D4 may be quite an important type containing, as it does, a wide range of species including some of the rarer or local ones. It is also a vegetation type that is vulnerable to disturbance in the form of drainage or enrichment by fertilizers. There is some evidence that it may be favoured for cultivation (but not as much as D1) but it would probably be necessary to drain as well for lasting results. In this respect it is similar to slightly acid, damp grassland G1 (see description below).

D5 - Wet, slightly acid dune grassland

D5 - Wet, slightly acid dune grassland

(dominated by Holcus lanatus, Festuca rubra and Agrostis tenuis)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 31)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
3 Laggan Bay	1	2	4 Kilchoman Dunes	3	10
5 Saligo Bay	2	7	6 Gruinart	2	3
7 Oronsay	1	2	10 Calgary Dunes	7	28
11 Sanna	1	3	15 Crossapol and Gunna	3	3
24 Stilligarry (North)	1	3	27 Stilligarry (South)	1	1
33 Vallay	1	3	47 Quendale	3	9
48 Scousburgh	1	3	49 Breckin	1	4
50 Redpoint	2	7	53 Oldshore More	1	0
54 Sheigra	2	5	55 Durness	1	3
58 Farr Bay	3	8	59 Strathy	4	14
60 Melvich	3	9	61 Reay	2	4
62 Dunnet	1	0	63 Freswick	4	6
65 Sinclairs Bay	1	3	67 Coul Links	2	0
77 Spey Bay (Central)	1	3	79 Fraserburgh	1	3
88 Arbroath	1	3	89 Barry Links	1	1
91 Dumbarnie	1	3			

D5 - Wet, slightly acid dune grassland, dominated by Holcus lanatus, Festuca rubra and Agrostis tenuis

It is tempting to regard wet, slightly acid grassland D5 as simply a wetter derivative of D4. This may indeed be a possible developmental sequence but the greater acidity that is indicated by some of the species and differences in some of the environmental factors that pertain to the type suggest that, at least in part, D5 can develop without going through the stage of D4. One further piece of evidence is found in the geographical distribution of D5 which is quite markedly different from that of D4 (see below).

Wet, slightly acid dune grassland D5 is not a particularly common type, with only 59 quadrats (1.5%). The type has two outlets in the key; steps 27 (-ve) and 36 (-ve), which isolate 48 and 11 quadrats respectively. There is no reason to suppose that there is any real difference between these two outlets, except that 36 (-ve) may be marginally wetter than 27 (-ve). It is worth noting that D5 (like D6 to be dealt with next) does not follow a similar pathway in the key to the other Duneland types (D1, D2, D3 and D4) described so far; these follow the common steps of 1 (-ve), 2 (-ve), 3 (+ve) and 42 (-ve) (see Figure 6). Types D5 and D6 diverge at step 3 (going negative). The implications of this are clear from the negative indicators which define step 3 - Agrostis tenuis, Anthoxanthum odoratum, Calluna vulgaris, Carex nigra, Festuca ovina, Potentilla erecta and Succisa pratensis - namely some degree of acidity. With the exception of part of D6, they then pass through steps 4 (-ve) (avoiding the extreme acid types) and thence to step 5 (+ve). From this it may be concluded that D5 and D6 represent the more acid part of the range contained in the Duneland family of types.

The most common species in D5 are Holcus lanatus (93.2%), Trifolium repens (89.8%), Festuca rubra (84.7%) and Plantago lanceolata (83.1%). Ten other species have frequencies of over 50% and these include several which indicate mildly acid conditions, e.g. Anthoxanthum odoratum (76.3%), Rumex acetosa (76.3%), Agrostis tenuis (66.1%), Cirsium arvense (52.5%) and Cynosurus cristatus (52.5%). The type contains 72 species with a frequency of 10% or over and a total of 232 species were recorded. This is a large number of species for a vegetation type for which there are only 59 quadrats. D5 is similar in species richness to D4, with a mean number of species per quadrat of 28.5.

The difference in species complement between damp, base-rich dune grassland D4 and wet, slightly acid dune grassland D5 is summarized in the following table of preferential species.

Preferential Species for Type D4

Species Names	D4 %	D5 %
Ammophila arenaria	22.6	0.0
Carex arenaria	50.9	5.1
Carex nigra	57.9	18.6
Carex panicea	20.8	5.1

Coeloglossum viride	22.0	1.7
Dactylorchis spp.	22.6	5.1
Daucus carota	20.1	6.8
Euphrasia officinalis agg.	78.6	13.6
Galium verum	75.5	8.5
Hydrocotyle vulgaris	23.3	1.7
Linum catharticum	61.0	10.2
Lotus corniculatus	82.4	28.8
Ophioglossum vulgatum	21.4	0.0
Plantago coronopus	20.1	1.7
Plantago maritima	54.1	10.2
Polygala vulgaris	26.4	3.4
Selaginella selaginoides	25.8	1.7
Senecio jacobaea	57.2	6.8
Thymus drucei	28.3	8.5
Vicia cracca	27.7	13.6

Preferential Species for Type D5

Species Names	D4 %	D5 %
Agrostis tenuis	7.5	66.1
Angelica sylvestris	4.4	25.4
Anthoxanthum odoratum	11.3	76.3
Arrhenatherum elatius	5.0	25.4
Centaurea nigra	11.3	33.9
Cirsium arvense	11.3	52.5
Dactylis glomerata	6.3	44.1
Filipendula ulmaria	6.9	32.2
Heracleum sphondylium	7.5	27.1
Juncus effusus	1.3	28.8
Rumex acetosa	20.1	76.3
Sagina procumbens	13.2	35.6
Stellaria media	5.7	20.3
Succisa pratensis	7.5	22.0
Urtica dioica	1.9	20.3
Veronica chamaedrys	2.5	20.3

The decline of dune type species is now well advanced in D5, e.g. Ammophila arenaria down from 22.6% to 0.0%, Carex arenaria (50.9% to 5.1%), Galium verum (75.5% to 8.5%), Linum catharticum (61.0% to 10.2%), Lotus corniculatus (82.4% to 28.8%), Senecio jacobaea (57.2% to 6.8%) and Euphrasia officinalis agg. (78.6% to 13.6%). Conversely, the species that show increased frequency in D5 as compared with D4 indicate more acid conditions, e.g. Agrostis tenuis (7.5% to 66.1%), Anthoxanthum odoratum (11.3% to 76.3%), or wetter conditions, e.g. Angelica sylvestris (4.4% to 25.4%), Filipendula ulmaria (6.9% to 32.2%), Juncus effusus (1.3% to 28.8%) and Succisa pratensis (7.5% to 22.0%). There are, however, minor contradictions in the species changes. In particular, Heracleum sphondylium is increased from 7.5% to 27.5%, yet the change from D1 to D4 was characterized by a decrease in this species from 22.1% to 7.5%! Heracleum is rather sensitive to grazing, so perhaps the relaxation of this pressure in D5 (see below) has something to do with determining the type. All this suggests is that at least some quadrats of D5 do not develop from D4 (or that the development is highly selective).

An alternative relationship for D5 is as a direct development from D1, and the following table summarizes the difference in terms of preferential species if this is the case.

Preferential Species for Type D1

Species Names	D1 %	D5 %
Ammophila arenaria	56.3	0.0
Carex arenaria	39.9	5.1
Cerastium atrovirens	25.0	0.0
Daucus carota	24.8	6.8
Galium verum	82.3	8.5
Koeleria cristata	27.7	6.8
Linum catharticum	44.9	10.2
Lotus corniculatus	76.2	28.8
Polygala vulgaris	20.7	3.4
Ranunculus bulbosus	21.3	3.4
Senecio jacobaea	66.8	6.8
Thalictrum minus	35.0	1.7
Thymus drucei	32.8	8.5
Euphrasia officinalis agg.	74.6	13.6

Preferential Species for Type D5

Species Names	D1 %	D5 %
Agrostis tenuis	12.1	66.1
Angelica sylvestris	1.1	25.4
Anthoxanthum odoratum	9.3	76.3
Arrhenatherum elatius	12.6	25.4
Cardamine pratensis	1.5	30.5
Cirsium arvense	13.3	52.5
Cynosurus cristatus	25.4	52.5
Dactylis glomerata	11.2	44.1
Equisetum arvense	6.7	23.7
Filipendula ulmaria	0.7	32.2
Juncus articulatus	1.2	32.2
Juncus effusus	0.1	28.8
Potentilla anserina	13.0	33.9
Ranunculus repens	19.5	52.5
Rumex acetosa	22.9	76.3
Sagina procumbens	5.0	35.6
Stellaria media	9.0	20.3
Succisa pratensis	4.7	22.0
Urtica dioica	1.9	20.3
Veronica chamaedrys	8.0	20.3

Again, there is a sharp decline in dune type species and an increase in acid- and wet-loving species and, indeed, many of the species are the same as for the change from D4 to D5. Three species that unexpectedly appear as preferential to D5 in both tables are Sagina procumbens (35.6%), Stellaria media (20.3%) and Urtica dioica (20.3%). The presence of these species may be interpreted as a sign of local disturbance and/or enrichment and is probably the result of grazing animals, i.e. sheep and cattle, trampling the rather wet surface and depositing dung. Against this explanation is the observation that grazing pressure and animal records for D5 (see below) are very similar to those for D1 and D4 but there may be an internal division of the type into more and less intensive grazing, with the disturbance species in the more heavily grazed examples. There is evidence that D5 is more intensively managed than D1 and D4, i.e. frequency of fences, tracks and paths (see below).

In terms of cover, D5 is the first of the Duneland family not to be dominated by Ammophila arenaria or Festuca rubra. Holcus lanatus (10.9%) is the species with the highest cover, displacing Festuca rubra (10.1%) into second place. Of the eight most important cover species, only Trifolium repens (5.9%) is not a grass. In addition to Holcus and Festuca, other grasses with high cover are Agrostis tenuis (7.3%), Agrostis stolonifera (6.6%), Poa pratensis (6.4%), Anthoxanthum odoratum (4.6%) and Lolium perenne (3.8%). Together these seven grasses contribute just short of 50% of the cover. Other grasses with appreciable cover include Cynosurus cristatus (2.2%), Dactylis glomerata (2.2%), Phragmites communis (2.0%) and Arrhenatherum elatius (1.8%). This is clearly a very "grassy" vegetation type in which broadleaved species have a comparatively minor role. It is thought that some quadrats of the type may be the result of "gone back" re-seeding.

Total cover of vascular plants is marginally higher than for the previous Duneland types at 104.1%. Bryophytes occur in 93.2% of quadrats but their cover is much reduced compared with D1 (10.2%) to 3.3%. Lichens are also very much reduced in frequency at 8.5% and with negligible cover (less than 0.1%). Most of the non-vegetative cover categories occur with the exception of saltmarsh mud. Only two have really appreciable frequency and cover; bare sand occurs in 20.3% of quadrats with a mean cover of 3.4% and the equivalent figures for boulders are 16.9% and 2.9%. Freshwater occurs in 27.1% of quadrats with a mean cover of 7.7%

The list of potential dominants is closely related to the high cover species. Twenty-four species occur as dominants (10% or more cover) in at least two of the 59 quadrats assigned to the type and a further 27 species occur as a dominant in one quadrat only (total for potential dominants of 51 species). Potential dominants include some shrubs or trees, e.g. Ulex europaeus, Alnus glutinosa, Rosa canina agg. and Salix cinerea agg.

Wet, slightly acid dune grassland D5 is not particularly well-defined in terms of the soil types it occupies. Three soil types are highly associated with D5; damp Peaty Soil PS2 accounts for 15.3% of quadrats, whilst Thin Soils (peaty and wet types) TS5 and TS9 account for 3.4% and 15.3% respectively (a total of 34.0%). Other common soil types are semi-mature and mature Deep Sandy Soils DS5 (15.3%), DS6 (11.9%) and DS7 (13.6%) giving a total of 74.8% of quadrats accounted for. The figure for DS6 represents a negative association. The common factor is that most of the quadrats occur on peaty or wet soil types.

As already noted above, grazing pressure on D5 is very similar to the other Duneland types, e.g. D1 and D4, with grazing absent in 8.5% of quadrats, lightly grazed 30.5%, moderately grazed 44.1%, heavily grazed 16.9%. Cattle and sheep occur with exactly equal frequency at 59.3% but rabbits show a significant decline to 54.2% (cf. over 75% in D1 and D4). The reduction in rabbits may be an effect of greater grazing management or possibly it reflects the greater difficulty in finding rabbit droppings (the usual evidence of rabbits) in the taller grass sward that is typical of D5. In any case, rabbits do not like grazing tall grass so it is really a question of the chicken or the egg. Rabbit burrows and scrapes (recorded separately) are also on the decline but, as D5 is characterized by being wet, i.e. rabbits do not burrow in wet ground, it is again difficult to interpret this statistic sensibly.

In terms of human disturbance of a wide range of types, wet, slightly acid dune grassland D5 is quite severely affected. Artificial embankments were recorded in 3.4% of quadrats, with wall (6.8%), fence (18.6%), tarmac road (3.4%), dirt road (1.7%), vehicle tracks (11.9%), unsurfaced paths (25.4%) and infill (1.7%). There is nothing particularly consistent about these varied effects but it all adds up to a high level of disturbance of one kind or another. Recent cultivation was recorded from 6.8% of quadrats and old cultivation from 1.7%. Standing crops occurred in 3.4% of quadrats and other unspecified agricultural effects were recorded in 6.8%. Curiously, rubbish is not particularly common at 23.7%.

Aquatic habitats in the form of dried-up, standing and flowing water are quite a feature of the type, the most common being stream in 16.9% of quadrats and river (greater than 2m wide) in 8.5%.

In terms of local aspect, there is a tendency for D5 not to face east, whereas the general aspect tends to be west. No explanation is offered for this feature. Slopes are generally moderate, 69.5% of quadrats having a slope between 1-15 degrees (18.6% are flat). The surface type tends to be plane (50.8%) and simple undulating (23.7%) - the combined effect of deflation surfaces and ploughing? Most quadrats of the type are low-lying (76.3% under 50ft contour) with a mean elevation of 4.45 OD. Although there are some quadrats near to the sea (15.3% within 100m of the sea), D5 is generally located well inland with modal distance 400-600m (25.4%) and a mean value of 483m (the most inland of all the Duneland types).

Slightly acid, wet dune grassland D5, has a curious geographical distribution, being located in two distinct areas about as far apart in the survey as it is possible to get. The first of these areas is in the south-west of Scotland, on Islay, Mull and Ardnamurchan (Calgary Dunes contain 28% of the type) and again on the north coast (Strathy has 14% of the type) and Shetland. The distribution of vegetation type D5 is quite similar to that of Site Type 3, North and West Coast truncated, and the linking factor is almost certainly the presence of streams. Apart from the direct evidence of aquatic habitats within the confines of the quadrat, examination of the location of D5 in sites shows that other quadrats are sufficiently near to streams and other water bodies to be within their sphere of influence. Other quadrats have no obvious aquatic influence but are wet nevertheless, the reason being undetermined but probably varied. If one had to typify D4 and D5 one would call D4 a wet slack type of vegetation and D5 a stream side or alluvial flat type. Inevitably this generalization would do injustice to some examples of the type.

D6 - Shrub invaded dune grassland

D6 - Shrub invaded dune grassland

(dominated by Festuca rubra, Ulex europaeus and Pteridium aquilinum)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 5)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	1	1	6 Gruinart	1	1
66 Ferry Links	1	4	77 Spey Bay (Central)	3	8
78 Spey Bay (East)	1	4			

D6 - Shrub invaded dune grassland, dominated by Festuca rubra, Ulex europaeus and Pteridium aquilinum

This type with only seven quadrats (0.2%) can be dealt with summarily. In terms of its frequency, it is unimportant and there is no evidence that it is a "rare" vegetation type dependent on a specialized habitat. The most likely explanation of the type is that it is a transitional stage leading to woodland, but not woodland of any very specific type. This is evidenced by the presence of a number of shrubs, e.g. Ulex europaeus, Rubus fruticosus, Sarothamnus scoparius and Rosa canina, and a number of species commonly found in woodlands, e.g. Pteridium aquilinum, Teucrium scorodonia, Dryopteris dilitata agg., Dryopteris filix-mas agg., Lapsana communis, Oxalis acetosella, Endymion non-scriptus and Lonicera periclymenum.

The most common species in the D6 are Poa pratensis (100%), Agrostis stolonifera (85.7%), Anthoxanthum odoratum (85.7%), Holcus lanatus (85.7%) and Festuca rubra (71.4%). A total of 65 species were recorded from the seven quadrats allocated to the type, and the mean number of species per quadrat is 16.7.

In terms of cover, Festuca rubra tops the list with 22.1% cover but is closely followed by Ulex europaeus with 20.0%. Other species contributing a fair amount of cover are Pteridium aquilinum (9.3%), Rubus fruticosus agg. (8.0%), Holcus lanatus (6.1%) and Agrostis tenuis (3.0%). Total cover of vascular plants is 86.6%.

Bryophytes were recorded from 85.7% of quadrats with an unusually high mean cover of 25.1%. Lichens were recorded from one quadrat (14.3%) with negligible cover. None of the non-living cover categories are very important except that in two quadrats (28.6%) there was a fair amount of undecomposed litter (21.4% cover for the type).

Shrub invaded dune grassland D6 is strongly associated with soils containing cobbles; five out of seven quadrats occur on Sandy Cobble types (CS4, CS5, CS6). Other soils are semi-mature Deep Sand (DS6) and Peaty Soil (PS1), which also tends to be rather sandy.

Grazing pressure in the type is moderate to light, with rabbit being the most common animal recorded (57.1%). Sheep and cattle are uncommon with one quadrat each (14.3%). Unsurfaced paths occur in 42.9% of quadrats and one quadrat had been subjected to sand quarrying. Rubbish was recorded from 57.1% of quadrats.

Topographically, most quadrats have northern aspects (the geographical distribution below explains this), slopes are moderate and surface types either plane or simple undulating. The type is low-lying with only one quadrat higher than the 50ft contour. In terms of distance from the sea, there is no detectable trend but the mean distance is 233m.

Five of the seven quadrats allocated to the type are located in sites on the Moray Firth, three of them in the unique site of Spey Bay (Central) (see Section 8.4.14). The remaining two examples occur in the south-west (Torrs Warren and Gruinart). Little can be concluded about the distribution except that it seems to be related in some way to shingle deposits.

7.4.4 Grassland Family (G1-G7)

There are seven vegetation types in this family, the putative relationships of which are shown in Figure 3 (with the exception of G5 for which there are too few examples to determine its relationships). In the case of the Bare ground B, Colonist C and the Duneland family (D1-D6), it is suggested that the relationship contains a strong successional element. In its strictest interpretation, this means that at a given point on the ground one type can develop into another with the passage of time only. To what extent this occurs in practice is not clear and could only be determined by monitoring particular types over quite a long period. It seems more probable that the observed distribution of vegetation types results from a mixture of successional and catenal trends related mainly to pedogenesis.

An idealized site (in western Scotland) shows a characteristic zonation of types, starting with C (and perhaps B) near to HWMST and changing to D3 a little further inland. This is followed still further inland by a broad zone occupied largely by D1 but possibly mixed with some D4. Behind this zone, usually on rising ground, D1 gives way to Grassland G1 and possibly G2. If there are elevated, rocky areas, there may be local occurrences of the Peatland types P1 and P2. The presence of other types, e.g. Marshland and Saltmarsh, is largely related to the occurrence of the specialized habitats on which they depend for their existence. If successional trends were really active, this zonation would be quickly obliterated or would require a high rate of accretion at the seaward edge to appear to be maintained ("appear" because the positions of types would have changed). Some sites are, indeed accreting, but others are eroding and what appears to be the most common mechanism for the maintenance of a range of vegetation is a sort of dynamic equilibrium. As a general rule, disturbance and instability of the surface are at a maximum near to the sea with a diminishing gradient inland or with increasing elevation. High levels of disturbance, mainly in the form of sand movements (at a given point there may be either a loss or gain), help to maintain the early successional stages near to the sea. Further inland there is less disturbance or the intervals between phases of disturbance may be longer. In the more stable areas, other factors such as grazing may help suspend successional trends, e.g. the development of D1 into G1. Still further inland, where little sand movement occurs, at least at the present time, the vegetation may have been reasonably stable for a prolonged period. Indeed, the inland part of some sites may be so little influenced by blown sand that it cannot be considered as part of the dune system proper.

In the case of the Grassland family of vegetation types, it seems likely that they have an inherent duality of origin. Some examples may represent a fairly extreme end point of the dune succession (woodland would be the true extreme) whilst other examples are of independent origin. From a management point of view, it is important to know what changes are possible and what factors are likely to produce a particular change. In the Duneland family, most changes are probably possible, some more easily than others, but for the Grassland family changes are less likely and more long term. The relationships of the Grassland types shown in Figure 3 are accordingly less successional than for the Duneland types and more related to underlying trends in the environment and, in particular, edaphic factors.

G1 - Slightly acid, damp grassland

G1 - Slightly acid, damp grassland

(dominated by Festuca rubra, Carex nigra and Anthoxanthum odoratum)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 61)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	1	1	3 Lassan Bay	1	2
4 Kilchoman Dunes	6	20	5 Saligo Bay	3	10
6 Gruinart	6	9	7 Oronsay	3	7
8 Garvard	2	6	10 Calgary Dunes	2	8
11 Sanna	2	7	12 West Tiree	3	3
14 Hynish Bay	7	21	15 Crossapol and Gunna	12	12
16 Totamore Dunes	1	3	17 Gallanach	6	13
19 West Barra	1	3	20 North Barra	1	2
21 Daliburgh	4	8	22 Ormiclate	4	9
23 Howbeg	5	24	24 Stilligarry (North)	5	17
25 Loch Bee	23	27	26 Borve	1	4
27 Stilligarry (South)	1	4	28 Baleshare	9	16
29 Kirkibost	2	7	30 Monach Isles	2	5
31 Paible	1	6	32 Hosta	3	10
33 Vallay	2	6	34 Leathann	1	3
35 Balranald	6	16	36 Robach	3	8
37 Berneray	8	13	38 Pabbay	14	23
39 Northton	4	11	42 Valtos	3	12
43 Barvas	4	13	44 Europie	3	10
46 Tong	1	3	47 Quendale	15	43
48 Scousburgh	2	7	49 Breckin	6	22
50 Redpoint	1	0	51 Holland	1	3
52 Achnahaird	6	22	53 Oldshore More	8	14
54 Sheigra	9	19	55 Durness	16	53
56 Faraid Head	3	10	57 Bettyhill	1	3
58 Farr Bay	3	1	59 Strathy	7	24
60 Melvich	7	18	62 Dunnet	8	28
63 Freswick	5	12	65 Sinclairs Bay	5	16
67 Coul Links	1	0	70 Morrich More	5	16
80 Strathbeg	2	3	89 Barry Links	3	3
91 Dumbarnie	2	7			

G1 - Slightly acid, damp grassland, dominated by Festuca rubra, Festuca ovina and Anthoxanthum odoratum

This is a fairly common type with 282 quadrats (7.3%) which has two outlets in the key; step 26 (+ve) with 196 quadrats and step 35 (-ve) with 86 quadrats. These two outlets are closely related in the key (steps 26 and 35 are only concerned with separating G1 from G2) and there is no reason to suppose that there are significant ecological differences between the two forms of G1 (see Figure 6A). The form of G1 isolated by step 26 (+ve) may be slightly wetter than that for step 35 (-ve).

The most common species in G1 are Festuca rubra (92.6%), Trifolium repens (88.7%), Plantago lanceolata (87.9%), Holcus lanatus (86.5%) and Lotus corniculatus (81.6%). Eleven further species have frequencies over 50%: 70-80% - Carex nigra, Ranunculus acris, Poa pratensis and Prunella vulgaris; 60-70% - Cerastium holosteoides, Anthoxanthum odoratum, Euphrasia officinalis agg. and Bellis perennis; and 50-60% - Leontodon autumnalis, Agrostis stolonifera and Trifolium pratense.

This list of common species for slightly acid, damp grassland G1 is superficially similar to that for base-rich dune grassland D1 but the following table of preferential species underlines the differences.

Preferential Species for Type D1

Species Names	D1 %	G1 %
Achillea millefolium	66.0	30.9
Ammophila arenaria	56.3	7.4
Carex arenaria	39.9	17.7
Cerastium atrovirens	25.0	5.7
Daucus carota	24.8	9.2
Galium verum	82.3	29.8
Heracleum sphondylium	22.5	7.1
Ranunculus bulbosus	21.3	8.5
Senecio jacobaea	66.8	19.5
Thalictrum minus	35.0	5.7

Preferential Species for Type G1

Species Names	D1 %	G1 %
Agrostis tenuis	12.1	39.4
Anthoxanthum odoratum	9.3	67.4
Carex nigra	16.2	77.3
Carex panicea	3.9	26.2
Dactylorchis spp.	5.7	22.0
Juncus articulatus	1.2	31.9
Molinia caerulea	0.0	21.3

Plantago maritima	9.4	46.8
Potentilla anserina	13.0	34.8
Potentilla erecta	0.0	24.8
Sagina procumbens	5.0	20.2
Selaginella selaginoides	1.0	21.3
Sieglingia decumbens	1.5	34.0
Succisa pratensis	4.7	42.2
Vicia cracca	9.4	28.7

Species preferential to D1 and declining in G1 are largely those associated with the dune habitat. Those most characteristic of the change are Ammophila arenaria (down from 56.3% in D1 to 7.4% in G1), Galium verum (82.3% to 29.8%) and Senecio jacobaea (66.8% to 19.5%). On the increase in G1, as compared with D1, are a whole series of species which indicate an increase in acidity and moisture content of the soil. The most striking of these are Anthoxanthum odoratum (9.3% to 67.4%), Carex nigra (16.2% to 77.3%), Plantago maritima (9.4% to 46.8%) and Succisa pratensis (4.7% to 42.2%).

Slightly acid, damp grassland G1 is a very species-rich vegetation type, with 70 species occurring in 10% or more of quadrats and a total of 272 species having been recorded for the type. The mean number of species per quadrat is high at 28.6 (similar to D4 and D5 but less than G2 with 31.0).

The species contributing the greatest amount of cover to G1 is Festuca rubra (15.9%). A number of other species have high cover - Carex nigra (6.4%), Holcus lanatus (4.8%), Trifolium repens (4.5%), Agrostis stolonifera (4.1%), Anthoxanthum odoratum (4.0%), Molinia caerulea (3.6%), Plantago lanceolata (3.4%), Agrostis tenuis (3.2%) and Poa pratensis (3.1%). In this list, grasses (for this purpose, including Carex) have a total cover of just over 45% compared with about 8% for broadleaved species. This trend is continued throughout the rest of the species that have a significant cover, so G1 is seen as a fairly grassy type compared with most of the Duneland types which have high cover of broadleaved species. Similar figures for D1, listing species down to 3.0% cover, are grasses 41.3% and broadleaved species 18.5%. In this respect, G1 is more similar to wet, slightly acid dune grassland D5, also a conspicuously grassy type.

In terms of potential dominants (species with 10% or greater cover in quadrat), there is a very long list, with 54 species in more than one quadrat and a further 32 in one quadrat only (a total of 86 species). The number of potential dominants for G1 is only exceeded by that for D3 with a total of 95 species (many of which are the result of disturbance).

Bryophytes are quite an important component of G1, occurring in 98.2% of quadrats and with a mean cover of 8.1%. Lichens are much less important with a frequency of 24.1% and mean cover of 0.2%. Bare sand occurs in 20.6% of quadrats (cf. D1 with 46.9%) and a mean cover of 1.2% (cf. D1 with 5.2%). Other substrate types were also recorded in moderate amounts, e.g. gravel with a frequency of 2.8% and cover of 0.1%, cobbles (6.4% and 0.5%), boulders (8.2% and 0.5%) and solid rock (8.5% and 1.7%). Freshwater occurs in 10.3% of quadrats with a mean cover of 1.8% (cf. D1 with 0.4% and 0.1% cover respectively). Mean cover of vascular plants is very similar to D1 (100.1%) at 102.1%.

Slightly acid, damp grassland G1 is associated with a number of soil types, most of them with a high organic content or some peat formation. It is highly associated with mature, Deep Sandy Soil DS7 (16.7%), four of the Thin Soil types, TS1, TS2, TS7 and TS9, totalling 15.3% (all of them with peaty influences), and with Peaty Soils PS2 (7.4%), PS3 (6.7%) and PS4 (4.6%). Peaty types (including PS1) total 18.7%. Together these soil types account for 50.7% of the quadrats allocated to G1. Other common soil types are semi-mature, Deep Sands DS5 (6.7%) and DS6 (28 4%), the former representing a negative association. These types increase the proportion of quadrats accounted for to 85.7% (out of 97.5% for which there are soil data). This situation is in contrast to D1 which is associated with three soil types only - DS5, DS6 and DS7 (totalling 89.2% of quadrats) with few peaty influences. There is, however, no pedological barrier to D1 developing into G1, but the converse is not necessarily so and some soils recorded in G1 could never have supported D1.

In terms of grazing pressure, slightly acid, damp grassland G1 is remarkably similar to base-rich dune grassland D1, with no grazing in 4.3% (4.0% for D1), light grazing in 37.9% (35.4% for D1), moderate grazing in 37.2% (38.7% for D1) and heavy grazing in 20.6% (21.9% for D1). The animals responsible for this grazing are also very similar, with cattle in 59.9% (63.3% for D1) and sheep in 61.0% (52.4% for D1). Only the rabbit is somewhat less common in G1, with 55.7% as opposed to 60.6% in D1 (scrapes and burrows show a similar decline). The frequency with which various disturbance effects were recorded in G1 was also very similar to those for D1, with wall in 2.1% (0.7% for D1), fence in 3.9% (5.0% for D1), tarmac road in 1.1% (1.5% for D1), vehicle tracks in 8.5% (11.2% for D1) and unsurfaced path in 10.6% (10.9% for D1). Only cultivation is rather different, with recent 1.1% (2.5% for D1) and old 4.6% (10.4% for D1). Rubbish was recorded in 20.2% of quadrats (cf. 25.2% for D1).

There is also an increase in aquatic habitats for G1 as compared with D1, in which there are virtually none. Quite a wide range of types were recorded but most common are puddle (3.5%), stream (6.4%), dried-up rut (2.5%) and dried-up ditch (3.5%). Although this is not a spectacular proportion of quadrats with aquatic habitats actually within their confines, it is good indication that these habitats do occur quite frequently in areas where G1 exists.

The topography of G1 is quite interesting, particularly as compared and contrasted with D1. Local aspect shows no obvious trend but general aspect shows a strong bias towards west, with 50.0% of quadrats (cf. D1 with 45.8% west). D1 is quite flat but G1 is even flatter. In terms of slope, 81.5% of quadrats in G1 have slopes less than 5 degrees (75.0% for D1) and 90.8% have surface types that are either plane or simple undulating (77.5% for D1). There is quite a wide range of elevation for G1 but 63.1% of quadrats are under the 50ft contour (75.4% for D1). As suggested above in the discussion of the typical zonation of D1 and G1 on a site, the latter tends to be further from the sea, i.e. nearly twice as far on average, with a mean of 535m for G1 as compared with 285m for D1.

Although only about a quarter as common as D1, slightly acid, damp grassland G1 shows a closely similar geographical distribution. Of the 71 sites containing D1, 56 also contain G1 and, conversely, only 5 sites have G1 but no D1 (usually just one quadrat each). Slightly acid, damp grassland G1 is predominantly a western and northern type. Relatively speaking, it is more common on the north coast than D1. Durness on the north coast, with 53% of quadrats allocated to G1, has the highest frequency of the type.

G2 - Acid, damp grassland

G2 - Acid, damp grassland

(dominated by Festuca rubra, Festuca ovina and Anthoxanthum odoratum)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 37)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
3 Laggan Bay	1	2	5 Saligo Bay	1	3
6 Gruinart	2	3	7 Oronsay	3	7
8 Garvard	2	6	9 Kiloran Bay	3	9
12 West Tiree	5	5	15 Crossapol and Gunna	2	2
17 Gallanach	3	7	20 North Barra	1	2
25 Loch Bee	1	1	27 Stilligarry (South)	1	4
30 Monach Isles	1	2	38 Pabbay	8	13
39 Northton	3	8	40 Luskintyre	1	3
41 Uig	1	3	42 Valtos	1	4
44 Europie	1	3	45 Tolsta	1	3
49 Breckin	5	19	50 Redpoint	4	5
52 Achnahaird	1	4	53 Oldshore More	3	11
54 Sheigra	9	28	55 Durness	3	10
56 Faraid Head	4	13	57 Bettyhill	7	21
59 Strathy	2	7	60 Melvich	5	14
62 Dunnet	3	8	64 Sandwood	3	8
65 Sinclairs Bay	1	3	67 Coul Links	3	10
69 Clashmore	1	3	70 Morrich More	2	6
76 Spey Bay (West)	1	4			

G2 - Acid, damp grassland, dominated by Festuca rubra, (Festuca ovina) and Anthoxanthum odoratum

It will be noted from the list of dominants in the type name that the only difference from G1 is that Carex nigra is replaced by Festuca ovina. This suggests that the difference between the types is minimal and, also, that it is closely related to these two species. In fact, the difference between the types is quite clear-cut but, unfortunately, it is not well exemplified by Carex nigra. By contrast, Festuca ovina gives a good impression of the difference between the two vegetation types - as good as can be expected from a single species. Carex nigra is not even a preferential species for G1 as compared with G2, its frequency in G1 being 77.3% and in G2 50.5%. In terms of cover, Carex nigra contributes 6.4% to G1 and 3.3% to G2. It is a dominant in 29.8% of quadrats in G1 and 13.1% in G2. Similar figures for Festuca ovina are frequency 15.2% and 49.5%, mean cover 1.3% and 8.4%, and dominance in 4.6% and 23.2% of quadrats. This underlines the danger of drawing superficial conclusions from single dominants. The prime example of this is Festuca rubra which is the top dominant, i.e. it occurs with 10% or more cover in most quadrats, in D1 (81.4%), D4 (74.2%), D6 (57.1%), G1 (57.8%), G2 (53.5%), S4 (75.3%) and S5 (86.7%). Together these types comprise about 46% of the quadrats in the survey. In addition, several other vegetation types have Festuca rubra as an important dominant. To classify vegetation types simply on the basis that Festuca rubra is the dominant species is thus seen to be facile or, worse still, downright misleading.

Acid, damp grassland G2 is not a particularly common vegetation type with 99 quadrats (2.6%). There are two outlets for this type in the key; step 30 (+ve) isolates 33 quadrats and step 35 (+ve) isolates 66 quadrats. There is no reason to suppose that there are significant ecological differences between these two forms of G2. Step 35 (+ve) is a straightforward separation of G2 from G1, based on the proportion of acid species present. Step 30 is in a totally different part of the key, but one which is also concerned with acid vegetation types. Here, the separation is between G2 and a mixture of D2 and G3 (dry, semi-acid or acid types) using species which indicate damper conditions, e.g. Euphrasia officinalis agg., Plantago maritima and Succisa pratensis, to isolate the former (see Figure 6A).

The most common species in acid, damp grassland G2 is Lotus corniculatus (94.9%), followed by Plantago lanceolata (89.9%) and Thymus drucei (84.8%). Twenty other species have frequencies of 50% or over: 70-80% - Plantago maritima, Potentilla erecta, Trifolium repens, Anthoxanthum odoratum, Festuca rubra, Prunella vulgaris, Euphrasia officinalis agg. and Sieglingia decumbens; 60-70% - Holcus lanatus, Viola riviniana, Agrostis tenuis, Calluna vulgaris and Succisa pratensis; and 50-60% - Bellis perennis, Cerastium holosteoides, Koeleria cristata, Linum catharticum, Ranunculus acris, Galium verum and Carex nigra.

Many of the above common species occur in both G1 and G2 and the following list of preferential species indicates the floristic difference between the two types.

Preferential Species for Type G1

Species Names	G1 %	G2 %
Agrostis stolonifera	57.1	28.3
Juncus articulatus	31.9	15.2
Potentilla anserina	34.8	7.1
Ranunculus repens	26.6	4.0
Rhinanthus minor agg.	27.3	11.1
Sagina procumbens	20.2	9.1
Vicia cracca	28.7	2.0

Preferential Species for Type G2

Species Names	G1 %	G2 %
Calluna vulgaris	12.1	64.6
Campanula rotundifolia	10.3	22.2
Carex pulicaris	15.2	45.5
Erica tetralix	4.6	22.2
Festuca ovina	15.2	49.5
Festuca vivipara	5.3	23.2
Hieraceum pilosella	9.6	31.3
Hypochoeris radicata	10.6	36.4
Koeleria cristata	19.9	57.6
Nardus stricta	10.6	24.2
Polygala vulgaris	14.5	37.4
Potentilla erecta	24.8	78.8
Salix repens	7.4	21.2
Sieglingia decumbens	34.0	70.7
Thymus drucei	27.7	84.8
Viola riviniana	28.4	68.7

The species preferential to G1 and declining in G2 are interpreted as being indicative of damp, slightly acid conditions, e.g. Agrostis stolonifera (57.1% in G1 to 28.3% in G2), Juncus articulatus (31.9% to 15.2%), and Vicia cracca (28.7% to 2.0%). Conversely, species on the increase in G2 are mostly a reflection of more acid wet conditions, e.g. Carex pulicaris (15.2% in G1 to 45.5% in G2), Erica tetralix (4.6% to 22.2%), Nardus stricta (10.6% to 24.2%) and Potentilla erecta (24.8% to 78.8%). Other species preferential to G2 are straightforward acid species, not dependent on wetter conditions, e.g. Calluna vulgaris (12.1% to 64.6%), Festuca ovina (15.2% to 49.5%), Festuca vivipara (5.3% to 23.2%) and Thymus drucei (27.7% to 84.8%). In fact, this combination of wet and dry acid species in G2 suggests a complex of environmental conditions consisting of drier, raised ground (hummocks) interspersed with damp to wet, lower ground (hollows). This interpretation is confirmed by the topographical data (see below) and by an examination of the sketch map and section diagrams recorded for quadrats in the field (see Handbook of Field Methods).

As measured by the mean number of species per quadrats, G2 is the most species-rich vegetation type in the survey with a mean of 31.0 species per quadrat. However, the total number of species recorded in the type at 178 is not exceptional, even allowing for the relatively small number of samples (cf. D4 and D5 with 233 and 232 species respectively). This discrepancy can be explained by the complex habitat characteristic of the type, hummocks and hollows with species from both situations being present in virtually all quadrats.

Species contributing most to the vascular plant cover are Festuca rubra (14.9%) and Festuca ovina (8.4%). Nine other species have mean cover of 3% or more - Calluna vulgaris (6.2%), Anthoxanthum odoratum (4.8%), Holcus lanatus (4.1%), Sieglingia decumbens (4.0%), Agrostis tenuis (3.9%), Plantago lanceolata (3.5%), Plantago maritima (3.5%), Carex panicea (3.3%) and Carex nigra (3.3%). Twenty-two other species have mean cover of 0.5% or more.

In terms of potential dominants, the same species top the list as for cover. Forty-nine species have cover of 10% or more in the 99 quadrats that compose the type but 17 of these occur in one quadrat only.

Total cover of vascular plants is very similar (a complete cover) to D1 or G1, at 102.1%. Bryophytes are as frequent in G2 (100%) as in G1 (98.2%) but mean cover is nearly halved from 8.1% in G1 to 4.4% in G2. Conversely, lichens are almost twice as frequent (24.1% in G1 and 52.5% in G2) and cover is also increased (0.2% to 0.4%). Bare sand is slightly reduced in frequency (20.6% to 15.2%) but increased in cover (1.2% to 3.9%) in G2 as compared to G1. Other hard substrates are increased in G2 as compared to G1, e.g. gravel and cobbles but, in particular, boulders have a frequency of 15.2% (cover 0.7%) and solid rock 22.2% (cover 3.6%). Like G1, there is a small amount of freshwater present in the type (8.1% frequency and 1.2% cover).

In terms of soil types, as defined in this survey, G1 and G2 are very similar. Acid, damp grassland G2 is highly associated with mature, Deep Sandy Soil DS7 (21.2%), Thin Soil (peaty) TS7 (8.1%), Sandy Cobble Soil (highly organic) CS7 (2.0%) and Peaty Soils PS1 (3.0%), PS2 (23.2) and PS4 (5.1%). Together these six soil types account for 62.6% of the type. Other common soils are semi-mature Deep Sands DS5 (10.1%) and DS6 (5.1%) and Thin Soil (high water table) TS9 (5.1%). Together these account for a further 20.3%, bringing the proportion of quadrats accounted for to 82.9% (out of 98.0% of quadrats with soil data). However, despite being common, DS5 and DS6 represent negative associations, i.e. they occur less commonly than would be expected by chance.

Grazing pressure in G2 seems to be marginally heavier than for G1, with no grazing in 1.0% for G2 (cf. 4.3% in G1), light grazing in 27.3% (cf. 37.9% in G1) moderate grazing in 45.5% (cf. 37.2% in G1) and heavy grazing in 26.3% (cf. 20.6% in G1). Cattle are slightly reduced in importance in G2 as compared with G1 (to 50.5% from 59.9%), but sheep are increased (82.8% from 61.0%) and so are rabbits (67.7% from 55.7%). Most disturbance factors are reduced in G2 as compared with G1. The only significant ones are fence (5.1%), vehicle track (6.1%) and unsurfaced path (7.1%). Cultivation is reduced to none of recent origin and 2.0% old (cf. recent 1.1% and old 4.6% for G1) and rubbish is almost halved to 12.1% (20.2% for G1). Evidence of fire as a factor in G2 is minimal, with only 1.0% of quadrats showing any signs of burning at the time of survey (none in G1).

Acid, damp grassland G2 shows no preference for any particular aspect either local or general. Slopes are steeper than for G1, with 57.6% over 5 degrees (cf. 18.5% for G1). Surface type parallels this trend with only 36.4% being recorded as plane (cf. 50.4% for G1). G2 also tends to occur at greater elevation than G1 and only 38.4% are under the 50ft contour (cf. 63.1% for G1), the mean height OD being 95.7ft (cf. 57.8ft for G1). Apparently running slightly counter to this is the statistic that G2 is nearer the sea than G1, with a mean distance of 319m compared with 535m for the latter. The explanation for this is that G2 tends to occupy rocky outcrops wherever they occur (particularly on the sides of bayhead systems), and some are quite near the sea, whereas G1 occurs mainly on less rocky ground as it rises away from the coastline.

The geographical distribution of G2 is superficially similar to that for G1, i.e. western and northern. However, a more detailed examination shows that it is absent from most sites in the southern half of the Outer Hebrides (Barra, North and South Uist), where it occurs in only four out of twenty sites (one quadrat each). In the northern half of the Outer Hebrides (Harris and Lewis), it occurs in most sites but, apart from Pabbay (13% of quadrats), it is not particularly common. The type reaches its peak importance on the north coast, e.g. Sheigra (28%), Durness (10%), Faraid Head (13%), Bettyhill (21%) and Melvich (14%), and also on Shetland where Brechin has 19%. G2 is also quite common in sites in the south-west and, in particular, on Colonsay. On the east coast it occurs sporadically as far south as the Moray Firth but is only common in Coul Links (10%). It does not occur further south on the east coast. From this it can be concluded that, although G2 is a western type, related to high rainfall and humidity, it also requires the presence of rock outcrops and boulders to produce the type of hummock and hollow topography on which it usually occurs.

Slightly acid, damp grassland G1 and acid, damp grassland G2 are a good example of the two vegetation types which are obviously linked along an ecological gradient but which, in most cases, does not constitute a successional relationship. For a number of quadrats of G2, the habitat is so specialized that it is doubtful if it could ever have been occupied by G1. It is also unlikely that the habitat itself could have undergone some sort of developmental process leading from one vegetation type to the other. On the other hand, some examples of G2 on sandy soils may have developed directly from G1 as indicated in Figure 3. Closer examination of individual quadrats would be required to investigate the process; the sandy quadrats of G2 should show continuous variation with similar quadrats of G1, whereas rocky quadrats should be discontinuous.

G3 - Acid, dry grassland

G3 - Acid, dry grassland

(dominated by Calluna vulgaris, Festuca ovina and Agrostis tenuis)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 32)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	54	52	3 Lassan Bay	5	12
5 Saligo Bay	4	13	6 Gruinart	2	3
7 Oronsay	8	19	8 Garvard	1	3
9 Kiloran Bay	1	3	10 Calgary Dunes	1	4
15 Crossapol and Gunna	1	1	31 Paible	1	6
47 Quendale	1	3	50 Redpoint	6	16
57 Bettyhill	3	9	60 Melvich	4	8
66 Ferry Links	16	57	67 Coul Links	13	43
69 Clashmore	24	77	70 Morrich More	9	28
71 Whiteness	13	21	72 Culbin Bar	7	14
74 Findhorn	22	76	75 Lossiemouth	17	62
76 Spey Bay (West)	5	18	77 Spey Bay (Central)	1	3
78 Spey Bay (East)	20	83	80 Strathbeg	3	5
83 Forvie	56	64	84 Don to Ythan	23	40
86 St. Cyrus and Montrose	23	62	89 Barry Links	61	56
90 Tentsmuir	31	40	91 Dumbarnie	1	3

G3 - Acid, dry grassland, dominated by Calluna vulgaris, Festuca ovina and Agrostis tenuis

Attention has now moved to the righthand side of Figure 3 where G3 is shown as a development of D2 giving rise, in succession, to G4.

Acid, dry grassland G3 is the second most common vegetation type recorded in the survey with 437 quadrats (11.4%). The type has two outlets in the key; step 38 (-ve) isolates 35 quadrats and step 39 (-ve) isolates the majority form, with 402 quadrats. These divisions are entirely in accord with the putative relationships shown in Figure 3, with step 38 separating G3 and D2 and step 39 separating G3 and G4. These two parts of the hierarchy have their origin in step 22, where the negative side (leading to step 38) is defined by a series of base-rich to slightly acid species, e.g. Bellis perennis, Galium verum, Lotus corniculatus and Trifolium repens, and the positive side, leading to step 39, is defined by just one species, Galium saxatile (see Figure 6A). The implication of this is that step 38 (-ve) isolates the least acid fraction of G3, most similar to D2. It is unlikely, however, that the two forms of G3 have significant ecological differences at the level of resolution at which the vegetation classification attempts to define types.

The most common species in acid, dry grassland G3 is Agrostis tenuis (83.5%), followed by Festuca ovina (70.3%), Carex arenaria (69.6%) and Calluna vulgaris (61.3%). Only three more species have frequencies over 50% - Poa pratensis (57.4%), Anthoxanthum odoratum (57.0%) and Galium saxatile (53.1%). This is a comparatively low number of "constant" species (those with frequency of 50% or more) and a check against D2 shows a marked fall in this feature from 13 to 7 species. Species richness, as expressed by the mean number of species per quadrat, is similarly affected, showing a drop from 20.6 in D2 to 14.8 in G3.

The difference in species composition between D2 and G3 is clearly defined in the following table of preferential species.

Preferential Species for Type D2

Species Names	D2 %	G3 %
Ammophila arenaria	85.8	31.6
Bellis perennis	29.3	4.3
Cerastium atrovirens	27.6	5.7
Cerastium holosteoides	64.0	29.1
Cirsium arvense	32.9	4.3
Cirsium vulgare	22.2	5.5
Galium verum	77.3	14.9
Hieraceum pilosella	31.6	14.4
Hypochoeris radicata	40.0	19.5
Koeleria cristata	33.3	15.1
Linum catharticum	24.9	3.0
Lotus corniculatus	74.2	35.9
Plantago lanceolata	56.4	14.6
Senecio jacobaea	70.2	17.2

Taraxacum spp.	45.8	5.3
Thymus drucei	56.4	11.2
Trifolium repens	52.9	22.4
Veronica chamaedrys	45.8	12.6

Preferential Species for Type G3

Species Names	D2 %	G3 %
Agrostis tenuis	36.9	83.5
Anthoxanthum odoratum	28.0	57.0
Calluna vulgaris	4.9	61.3
Erica cinerea	3.1	36.4
Galium saxatile	15.6	53.1
Potentilla erecta	3.1	31.8

As might be expected, the list of preferentials for D2 is much longer than that for G3. Species common in D2 but declining in G3 are all very similar, being characteristic of slightly acid, dune vegetation. Most notable species in this respect are Ammophila arenaria (down from 85.8% in D2 to 31.6% in G3), Galium verum (77.3% to 14.9%), Lotus corniculatus (74.2% to 35.9%) and Senecio jacobaea (70.2% to 17.2%). In the lower part of the table, species preferential to G3 can all be interpreted as being indicative of dry, acid habitats. There is a marked increase in the two grasses, Agrostis tenuis (36.9% in D1 to 83.5% in G3) and Anthoxanthum odoratum (28.0% to 57.0%), and also in dwarf shrubs, Calluna vulgaris (4.9% to 61.3%) and Erica cinerea (3.1% to 36.4%).

As has already been noted, species richness, as measured by the mean number of species per quadrat, is low in G3 at 14.8, and there are only 41 species with a frequency of 10% or more. Despite these statistics, which are low compared with other types, e.g. D2, a large number of species have been recorded in G3, 229 species from 437 quadrats. This total is composed of relatively few species in a high proportion of quadrats and a large number of species which occur in only a few. Many of the low frequency species are genuine occasionals due to disturbance, planting and escapes of various sorts. However, there are in addition a number of rare species that are obviously related to the particular habitat provided by G3, e.g. Arctostaphylos uva-ursi (0.2%), Goodyera repens (1.1%), Listera cordata (1.4%) and Pyrola minor (0.7%).

Despite being present in only 61.3% of quadrats, Calluna vulgaris is the species contributing most cover to G3, with a mean of 16.2%. Ten other species have cover of 3% or more - Festuca ovina (8.8%), Agrostis tenuis (7.0%), Carex arenaria (6.8%), Ulex europaeus (5.8%), Festuca rubra (4.9%), Ammophila arenaria (3.9%), Pinus sylvestris (3.5%), Pteridium aquilinum (3.4%), Empetrum nigrum (3.1%) and Anthoxanthum odoratum (3.1%). It is notable that two species in this list are dwarf shrubs (Calluna and Empetrum), one is a shrub (Ulex) and one a tree (Pinus). An examination of the list of potential dominants (species which achieve a cover of 10% or more in a quadrat) is even more informative. For example, Calluna vulgaris is seen to occur in 61.3% of quadrats, is a dominant in 35.2% and the mean cover in these quadrats is 44.7%. By contrast, other species such as Festuca ovina and Agrostis tenuis are more commonly present (70.3% and 83.5% respectively) but are less common as a dominant (29.1% and 25.6%) and their mean cover as a dominant is lower (27.6% and 22.5%). Apart from Calluna, other dwarf shrubs which achieve the status of a potential dominant in G3 are Erica cinerea, Salix repens, Empetrum nigrum and Erica tetralix. There are also a number of shrubs - Ulex europaeus (present in 19.5%, dominant in 12.8% and with a mean cover as a dominant of 43.4%), Sarothamnus scoparius and Rubus fruticosus. Trees, most of them planted, are also quite important in the type - Pinus sylvestris, Pinus contorta, Betula spp., Pinus nigra, Salix cinerea agg. and Picea abies. The three species of pine tend to dominate whole quadrats when they occur. Another important potential dominant is Pteridium aquilinum which, although it occurs in only 10.3% of quadrats and is dominant in 6.6%, has a mean cover as a dominant of 50.2%. What this wide range of dominants means in practice is that a high proportion of quadrats in the type are dominated by genuine physiognomic dominants which cast a shade. This reduction of light at ground level has the effect of reducing the cover of other species which are actually more constant to G3 or even eliminating light-demanding species altogether, e.g. Calluna vulgaris.

Acid, dry grassland G3 is a perfect example of a vegetation type which is defined by species that are sensitive to the environment but where the species that is dominant, in terms of cover, can be very variable. Several of these dominants are either wide ranging species or are the direct result of human activity. In addition, their status as a dominant may be rather ephemeral. In short, it would be ecologically misleading to classify these quadrats according to their dominant species.

The cover of vascular plants in G3 is somewhat increased compared with that for D2 (up from 86.6% to 94.2%). However, the status of bryophytes (frequency 96.6% and cover 13.1%) and lichens (54.2% and 2.9%) is very similar to D2 (bryophytes 96.4% and 16.6% and lichens 50.7% and 2.7%). In terms of non-living cover categories, bare sand is reduced in frequency from 53.3% in D2 to 37.8% in G3 and cover from 7.4% to 5.9%. Undecomposed organic matter becomes a significant cover category in G3 as a result of such species as Pteridium, Calluna and pines. Undecomposed organic matter was recorded in 28.8% of quadrats with a mean cover of 4.6%, but these figures may be somewhat unreliable due to seasonal effects, i.e. more litter is present (and more obvious) in early summer than the autumn when it may have largely decomposed.

Acid, dry grassland G3 is reasonably well correlated with the soil types. Highly associated with this vegetation type are semi-mature Deep Sandy Soils DS5 (33.0%) (this is a relatively dry soil type) and mature Deep Sandy Soil DS8 (3.2%). Another dry soil, Sandy Cobble Soil CS4 (9.2%), is also highly associated, as is Thin Soil TS3 (1.8%). Together these significantly associated types total 47.2% (out of 91.6% of quadrats for which soil data are available - the two military sites, Morrich More and Barry Links, contained a high proportion of G3, hence the missing data). Other common soil types are semi-mature and mature, Deep Sandy Soils DS6 (19.9%) and DS7 (13.3%), raising the proportion of quadrats accounted for to 80.4%. Peaty soils are limited to less than 2% and, indeed, peaty types PS2 and PS4 are negatively associated. The predominant characteristic of soils supporting vegetation type G3 is dryness. Were soil analyses available, they would almost certainly show minimal calcium carbonate and low pH as factors related to G3.

Grazing pressure is somewhat less in G3 as compared with D2; no grazing in 4.3% of quadrats in G3 (cf. 1.8% in D2), light grazing in 57.7% (cf. 39.6% in D2), moderate grazing in 23.8% (cf. 26.2% in D2) and heavy grazing in 14.2% (cf. 32.4% in D2). Records of grazing animals are similarly reduced, with cattle in 19.5% (32.9% in D2), sheep in 19.9% (27.6% in D2) and rabbit in 89.7% (91.1% in D2). Signs of deer were also recorded from 5.7% of quadrats in G3. Some human disturbance factors are increased and others decreased. Most common are embankment (2.3%), fence (3.4%), dirt road (2.7%), vehicle track (12.1%), unsurfaced path (8.7%), spent cartridge (4.1%), other armament (5.7%), fire evidence (8.9%), planted trees (12.8%), old cultivation (1.4%). Particularly notable are fire and tree planting. Rubbish was recorded from 31.8% of quadrats (cf. D2 with 43.1%).

Acid, dry grassland G3 is neutral as far as local aspect is concerned but shows a marked tendency towards a general aspect of south (40.5%) and away from west (7.8%). This is probably a direct result of the geographical distribution of the type (see below). The next vegetation type to be described, G4, is similar (see below) but both are rather different from D2, which favours both south (30.2%) and west (30.7%) aspects. G3 tends to occupy fairly flat ground, 84.9% of quadrats having a slope of less than 5 degrees. Surface type is similar with 83.9% either plane or simple undulating. Like D2, vegetation type G3 is low lying with 81.7% of quadrats under the 50ft contour and with a mean elevation of 40.8ft OD (cf. 85.8% and 33.2ft for D2). As might be expected from an examination of the distribution of vegetation types within sites, G3 occurs a good deal further from the sea than D2; 591m compared with 259m. In this respect, D2 and G3 are very similar to their western and northern equivalents (on base-rich substrates) D1 and G2.

The geographical distribution of acid, dry grassland G3 is very similar to that for slightly acid dune grassland D2, the main concentration of the type occurring in sites on the east coast from the Moray Firth south. The type is particularly common on Ferry Links (57%), Coul Links (43%), Clashmore (77%), Findhorn (76%), Lossiemouth (62%), Spey Bay (East) (83%), Forvie (64%), Don to Ythan (40%), St Cyrus and Montrose (62%), Barry Links (56%) and Tentsmuir (40%). There is an outlier of the type in the south-west mainly on Colonsay and Islay but Torrs Warren in Galloway has 52% of the type. In the Outer Hebrides only one site, Paible, contains one quadrat allocated to G3. On the north coast and on Orkney and Shetland, G3 is rather less common than D2, whereas, on a proportional basis, it might be expected to be about twice as frequent. The exact reason is not known but is probably connected with topography.

G4 - Very acid, damp grassland

G4 - Very acid, damp grassland

(dominated by Nardus stricta, Festuca ovina and Agrostis tenuis)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 6)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	1	1	67 Coul Links	1	3
83 Forvie	6	7	86 St. Cyrus and Montrose	1	3
89 Barry Links	10	9	90 Tentsmuir	10	13

G4 - Very acid, damp grassland, dominated by Nardus stricta, Festuca ovina and Agrostis tenuis

This is not a common vegetation type with only 29 quadrats (0.8%) allocated to it. The type has just one outlet in the key, step 39 (+ve) where it is separated from the majority of the previous type, G3 (see Figure 6A). The indicators which define this division are very illuminating; the one negative indicator (for G3) is Erica cinerea and the five positive indicators (for G4) are Agrostis canina, Carex nigra, Juncus effusus, Nardus stricta and Potentilla erecta. However, it should be noted that a score of 4 or more is required for a quadrat to be allocated to G4, i.e. only one negative indicator and five positive or no negative and four positive indicators can produce this score. This is quite a tight definition for G4 within what is likely to be continuous variation.

The most common species in very acid, damp grassland G4 are Nardus stricta (96.6%) and Potentilla erecta (96.6%). These are followed in the frequency range 80-90% by - Agrostis canina, Festuca ovina, Galium saxatile, Agrostis tenuis, Carex nigra and Poa pratensis; 70-80% - Anthoxanthum odoratum and Juncus effusus; 60-70% - Carex arenaria and Holcus lanatus; and 50-60% - Rumex acetosa, Festuca rubra and Luzula multiflora, i.e. total of 15 species with a frequency of 50% or more.

The difference in species composition between very acid, damp grassland G4 and the type to which it is closely related, but from which it is unlikely to be derived, acid, dry grassland G3 is summarized in the following table of preferential species.

Preferential Species for Type G3

Species Names	G3 %	G4 %
Ammophila arenaria	31.6	3.4
Campanula rotundifolia	25.4	0.0
Erica cinerea	36.4	0.0
Lotus corniculatus	35.9	17.2
Rumex acetosella	22.2	10.3
Veronica officinalis	25.4	10.3
Viola riviniana	28.1	3.4

Preferential Species for Type G4

Species Names	G3 %	G4 %
Achillea ptarmica	1.8	24.1
Agrostis canina	9.8	89.7
Agrostis stolonifera	8.7	34.5
Carex nigra	8.5	86.2
Cirsium palustre	1.6	20.7
Erica tetralix	10.3	41.4
Holcus mollis	5.0	34.5

Juncus acutiflorus	1.4	27.6
Juncus effusus	5.5	72.4
Juncus squarrosus	10.8	37.9
Luzula multiflora	15.1	51.7
Nardus stricta	15.8	96.6
Potentilla erecta	31.8	96.6
Rumex acetosa	12.8	55.2
Viola palustris	1.1	31.0

Species preferential to G3 and declining in G4 are fewer in number, less striking and more difficult to interpret than those which are increasing in G4. Ammophila arenaria (down from 31.6% in G3 to 3.4% in G4) is just part of the trend of increasing stability, whilst the total loss of Erica cinerea (36.4% to 0%) is obviously connected with moisture relations, i.e. there are no longer dry, acid habitats present. Species preferential to G4 can be interpreted as being indicative of wetter acid conditions, e.g. Agrostis canina (9.8% in G3 to 89.7% in G4), Carex nigra (8.5% to 86.2%), Erica tetralix (10.3% to 41.4%), Juncus effusus (5.5% to 72.4%), Luzula multiflora (15.1% to 51.7%), Nardus stricta (15.8% to 90.6%), Potentilla erecta (31.8% to 96.6%) and Rumex acetosa (12.8% to 55.2%).

In contrast to dry, acid grassland G3, very acid, dry grassland G4 shows an increase in species richness with a mean number of species per quadrat of 21.2. Thus from D2 to G3 species richness declined (20.6 to 14.8 species per quadrat) and is now increasing again. This trend is also reflected by the number of species with a frequency of 50% or more (7 for G3 and 15 for G4). The total number of species recorded in G4 is 101 but it is difficult to assess this figure when it relates to only 29 quadrats (the curve of species recruitment is unlikely to have flattened out at this sample size).

The main cover species in very acid, damp grassland G4 is Nardus stricta with 22.0% cover, and next most important is Festuca ovina with 12.5%. Twelve other species have mean cover of 3% or more - Calluna vulgaris (6.5%), Anthoxanthum odoratum (5.2%), Agrostis tenuis (5.2%), Agrostis canina (5.0%), Juncus effusus (4.8%), Carex nigra (4.7%), Potentilla erecta (4.3%), Festuca rubra (4.1%), Holcus lanatus (3.9%), Salix repens (3.4%), Carex arenaria (3.2%) and Galium saxatile (3.0%). There are 29 potential dominants recorded for this type, 19 of them in more than one quadrat. Unlike G3, most potential dominants in G4 have high frequencies and are more or less synonymous with the main cover species, i.e. there are few species that occur in just a few quadrats but in large amounts.

Total cover of vascular plants in G4 is very high at 112.7%, indicating the regular occurrence of multi-layered vegetation. Bryophytes were recorded from 100% of quadrats in G4. This is similar to G3 but the cover is less than half (6.4% in G4 compared with 13.1% in G3). Lichens are depleted both in frequency and in cover (frequency 31.0% in G4 and 54.2% in G3, cover 0.4% and 2.9% respectively). There are very few records for the non-living cover categories, except for undecomposed organic matter in 31.0% of quadrats (cover 2.3%) and bare sand 20.7% (0.6% cover).

Very acid, damp grassland G4 is only associated with one soil type, i.e. it occurs more frequently than would be expected by chance, Deep Sandy (mature) Soil DS7 (27.6%). Other common types are semi-mature Deep Sands DS5 (20.7%) and DS6 (34.5%). These three types together account for 82.8% of the type (out of 93.1%). Another 10.2% occur on

Peaty Soils PS2, PS3 and PS5.

Grazing pressure in G4 is very similar to that for G3, with 3.4% with no recorded grazing, 55.2% light grazing, 37.9% moderate grazing and 3.4% heavy grazing (c.f. 4.3%, 57.7%, 23.8% and 14.2% for G3). There is a slight increase in the incidence of cattle in G4 as compared with G3 (34.5% from 19.5%), sheep are down (10.3% from 19.9%) and rabbit marginally increased (93.1% from 89.7%). Human disturbance factors worthy of note are embankment (13.8%), vehicle tracks (10.3%), unsurfaced path (13.8%), spent cartridge (6.9%), fire evidence (3.4%), planted trees (6.9%) and old cultivation (3.4%). Rubbish was recorded from 20.7% of quadrats (cf. 31.8% for G3).

Very acid, damp grassland G4 contains some aquatic habitats, e.g. pond (3.4%), dried-up puddle (3.4%) and dried-up ditch (10.3%). These habitats are probably indicative of a fair degree of seasonal wetness.

Although local aspect is more or less neutral, general aspect for G4 exhibits a strong tendency to being either east (41.4%) or south (37.9%) (together 79.3%) and not west or north (together 20.6%). The type occupies fairly flat ground, no quadrats having slopes of over 5 degrees. Surface types are similar, with 72.4% plane and 13.8% simple undulating. The type is low-lying with 82.8% of quadrats under the 50ft contour. Perhaps the most notable topographic feature of G4 is its distance from the sea with a mean distance of 1,191m (cf. D2 with 259m and G3 with 591m). Only one quadrat occurs in the 100-200m zone, the nearest the type gets to the sea. This is confirmed by the zonation of D2, G3 and G4 within individual sites, this being the normal order of occurrence proceeding in an inland direction.

Whether very acid, damp grassland G4 develops from acid, dry grassland G3 with the passage of time as the only factor is open to question. It is possible that the build-up of organic matter in an already damp soil could tip the balance between the two types, but it seems more likely that G4 is the direct result of rather different hydrological conditions from G3, perhaps related to flushing at the landward edge of the sand deposit, but there is no direct evidence of this in the data collected.

An examination of the geographical distribution of G4 shows that it only occurs in six sites; five sites on the east coast and one in the south-west, Torrs Warren. Another feature that is immediately obvious is that, with the exception of Coul Links (167ha), all the sites are very large - Torrs Warren (881ha), Forvie (720ha), St Cyrus and Montrose (448ha), Barry Links (993ha) and Tentsmuir (704ha). In fact, Forvie, Barry Links and Tentsmuir contain 26 out of the 29 quadrats allocated to the type (the others contain just one quadrat). This is now seen, in effect, as a very restricted distribution, the presence of G4 apparently being determined by the particular conditions on a few large sites. A closer examination shows that all six sites belong to Site Type 9 - East Coast, Main Type. These mainly east coast sites are characterized by their completeness, i.e. their lack of truncation on the inland side. On these sites, G4 occurs mostly near the landward boundary, usually in close proximity to G3.

G5 - Sea spray community

G5 - Sea spray community

(too few quadrats to determine dominance)

LIST OF SITES WITH RECORDS:-

QUADRAT.SURVEY (NO. OF RECORDS = 2)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
7 Oronsay	1	2	71 Whiteness	1	2

G5 - Sea spray community

With only two quadrats in the survey, it is doubtful if G5 can really be accorded the status of a vegetation type. However, the two quadrats concerned are so different from anything else that it is simply not possible to merge them with some other type. The only alternatives are, therefore, to regard them either as unclassifiable or give them the status of a "minor" type. The latter solution was adopted.

The type has one outlet in the key in step 82 (-ve). Interestingly, this step is buried in the largely saltmarsh part of the key (the salt influence?), where G5 is separated out from S4 or S5 by the presence of the non-maritime species Festuca ovina or Thymus drucei (see Figure 6C).

Three species, Armeria maritima, Festuca ovina and Thymus drucei, occur in both quadrats of G5. All other species, of which there are 23, occur in one quadrat only. These include such widely dissimilar species as Ammophila arenaria and Cerastium glomeratum but also present are species fairly typical of the spray zone habitat, e.g. Plantago coronopus, Sagina procumbens and Sedum anglicum. Cover of vascular plants is low at 18.4%, the rest being made up by gravel 10%, cobbles 33% and solid rock 45%. Bryophytes are present in both quadrats (cover 0.6%) and lichens in one with negligible cover. No vascular plant achieves cover of 10% or over so there cannot be said to be any dominants in the type.

In terms of soil types, one quadrat occurs on a Beach Deposit BD2 (cobbles and rock) and the other on Thin Soil TS10 (solid rock). Both quadrats are under the 50ft contour and are in 10-50m zone from the sea (mean distance 15m). One quadrat occurs at Oronsay, on Colonsay, and the other at Whiteness on the Moray Firth.

Sea spray community G5 can probably be best thought of as a type which occupies a very specialized habitat, i.e. well drained soils close to the shore where they can receive spray, which is extremely rare in the context of the present survey but may be much more common in a different population, e.g. hard coast. No obvious relationship can be seen with other vegetation types in the survey. In terms of species composition, it is most similar to the upper saltmarsh types S4 and S5, which also contain a mixture of maritime and non-maritime species.

G6 - Slightly acid, wet grassland

G6 - Slightly acid, wet grassland

(dominated by Carex nigra, Agrostis stolonifera and Carex panicea)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 33)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
3 Lagan Bay	1	2	5 Saligo Bay	2	7
6 Gruinart	7	10	8 Garvard	1	3
12 West Tiree	6	6	13 Ballevullin	1	3
15 Crossapol and Gunna	1	1	16 Totamore Dunes	3	8
17 Gallanach	1	2	21 Daliburgh	7	13
22 Orgiclate	3	7	23 Howbeg	3	14
24 Stilligarry (North)	5	17	25 Loch Bee	11	13
27 Stilligarry (South)	2	4	29 Kirkibost	3	11
30 Monach Isles	2	5	34 Leathann	2	6
35 Balranald	6	11	36 Robach	1	3
37 Berneray	2	3	38 Pabbay	3	5
42 Valtos	1	4	48 Scousburgh	1	3
52 Achnahaird	2	7	54 Sheigra	1	4
59 Strathy	1	3	62 Dunnet	1	4
63 Freswick	1	3	65 Sinclairs Bay	1	3
67 Coul Links	1	3	70 Morrich More	5	9
81 St. Fergus	1	2			

G6 - Slightly acid, wet grassland, dominated by Carex nigra, Agrostis stolonifera and Carex panicea

This vegetation type, with 89 quadrats (2.3%), at first sight appears to be badly fractionated in the key with no less than six outlets. However, four of these outlets are in the same part the key and together they isolate 80 quadrats (90%) of the type (see Figure 6A). Steps 21 (+ve) with 5 quadrats, 29 (-ve) with 43 quadrats, 36 (+ve) with 16 quadrats and 37 (-ve) with 16 quadrats are concerned with separating out the various parts of G6 and also isolating a small part of Peatland type P1. It is clear from an examination of this section of the key that, although it is a reasonably homogeneous type, G6 does contain some rather different forms of the basic type. This is almost certainly the result of the presence of minor habitats complexed with the main wet habitat that G6 occupies. Step 18 (+ve) isolates a slightly drier form of G6 (again, the separation is from P1) and step 83 (-ve) deals with 7 quadrats which are influenced by saline as well as fresh water and, therefore, contain some saltmarsh species, e.g. Glaux maritima and Triglochin maritima. In fact, it is the presence of Glaux maritima (and the absence of Plantago lanceolata or Poa pratensis) in all 7 quadrats that causes them to go positive at step 2 in the key and join the maritime types in step 77. From this point on the non-maritime species prevail, first of all in isolating this form of G6 with the upper saltmarsh and then separating it from this in step 83. Ignoring minor differences between the various outlets for G6, the following description refers to the composite of all six forms.

The most common species in slightly acid, wet grassland G6 is Carex nigra (92.1%), followed by Hydrocotyle vulgaris (82.0%), Trifolium repens (82.0%) and Ranunculus flammula (80.9%). Fifteen other species occur in 50% or more quadrats: 70-80% - Agrostis stolonifera, Festuca rubra, Holcus lanatus, Caltha palustris and Ranunculus acris; 60-70% - Cardamine pratensis, Prunella vulgaris, Juncus articulatus and Succisa pratensis; and 50-60% - Leontodon autumnalis, Carex panicea, Anthoxanthum odoratum, Bellis perennis, Ranunculus repens and Dactylorchis spp.

It is difficult to say for certain what vegetation type G6 is developed from, if any. Figure 3 shows a tentative relationships with D4 and G2 but whether this is, in fact, a successional relationship is open to doubt. The following table shows the difference between D4 and G6 in terms of preferential species.

Preferential Species for Type D4

Species Names	D4 %	G6 %
Achillea millefolium	33.3	2.2
Ammophila arenaria	22.6	0.0
Carex arenaria	50.9	3.4
Coeloglossum viride	22.0	1.1
Daucus carota	20.1	0.0
Euphrasia officinalis agg.	78.6	38.2
Galium verum	75.5	1.1
Linum catharticum	61.0	3.4

Lolium perenne agg.	23.3	10.1
Lotus corniculatus	82.4	30.3
Ophioglossum vulgatum	21.4	3.4
Plantago coronopus	20.1	1.1
Plantago lanceolata	87.4	42.7
Plantago maritima	54.1	23.6
Polygala vulgaris	26.4	1.1
Selaginella selaginoides	25.8	9.0
Senecio jacobaea	57.2	11.2
Thymus drucei	28.3	0.0
Viola riviniana	24.5	1.1

Preferential Species for Type G6

Species Names	D4 %	G6 %
Anagallis tenella	8.8	43.8
Anthoxanthum odoratum	11.3	56.2
Caltha palustris	8.2	76.4
Cardamine pratensis	25.8	69.7
Carex echinata	0.0	27.0
Carex flava agg.	0.6	25.8
Carex panicea	20.8	57.3
Carex pulicaris	10.7	27.0
Dactylorchis spp.	22.6	51.7
Eleocharis palustris	5.7	25.8
Epilobium palustre	4.4	32.6
Eriophorum angustifolium	1.3	46.1
Galium palustre	6.3	46.1
Hydrocotyle vulgaris	23.3	82.0
Juncus bulbosus/kochii	0.6	20.2
Juncus effusus	1.3	21.3
Luzula multiflora	6.3	20.2
Lychnis flos-cuculi	13.8	43.8
Mentha aquatica	4.4	27.0
Molinia caerulea	5.0	42.7
Myosotis caespitosa	5.7	21.3
Oenanthe lachenalii	1.3	21.3
Pedicularis palustris	2.5	30.3
Pinguicula vulgaris	10.7	24.7
Potentilla erecta	1.9	23.6
Potentilla palustris	0.6	29.2
Ranunculus flammula	3.8	80.9
Sagina procumbens	13.2	38.2
Senecio aquaticus	4.4	33.7
Succisa pratensis	7.5	61.8
Triglochin maritima	2.5	32.6

Preferential to D4 and declining in G6 are a whole series of damp, base-rich dune species, whilst those preferential to G6 are mostly species favouring wet, flushed habitats but covering a wide range of micro-habitats, i.e. degrees of wetness, base-richness and aeration of the soil, which are capable of being extremely localized within a quadrat as large as 25 sq m.

The list of preferentials for the equivalent change from G2 to G6 is as follows.

Preferential Species for Type G2

Species Names	G2 %	G6 %
Achillea millefolium	44.4	2.2
Agrostis tenuis	67.7	9.0
Calluna vulgaris	64.6	9.0
Campanula rotundifolia	22.2	0.0
Centaurea nigra	20.2	3.4
Festuca ovina	49.5	7.9
Festuca vivipara	23.2	2.2
Galium verum	54.5	1.1
Hieraceum pilosella	31.3	0.0
Hypochoeris radicata	36.4	3.4
Koeleria cristata	57.6	0.0
Linum catharticum	55.6	3.4
Lotus corniculatus	94.9	30.3
Plantago lanceolata	89.9	42.7
Plantago maritima	78.8	23.6
Polygala vulgaris	37.4	1.1
Potentilla erecta	78.8	23.6
Rumex acetosa	28.3	12.4
Salix repens	21.2	9.0
Selaginella selaginoides	29.3	9.0
Seiglingia decumbens	70.7	18.0
Thymus drucei	84.8	0.0
Viola riviniana	68.7	1.1

Preferential Species for Type G6

Species Names	G2 %	G6 %
Agrostis stolonifera	28.3	79.8
Anagallis tenella	13.1	43.8
Caltha palustris	3.0	76.4
Cardamine pratensis	4.0	69.7
Carex echinata	9.1	27.0
Dactylorchis spp.	17.2	51.7
Eleocharis palustris	0.0	25.8
Epilobium palustre	0.0	32.6
Equisetum arvense	5.1	24.7
Eriophorum angustifolium	7.1	46.1
Galium palustre	1.0	46.1
Hydrocotyle vulgaris	7.1	82.0
Juncus articulatus	15.2	61.8
Juncus bulbosus/kochii	3.0	20.2
Juncus effusus	6.1	21.3
Lychnis flos-cuculi	2.0	43.8
Mentha aquatica	0.0	27.0
Myosotis caespitosa	0.0	21.3
Oenanthe lachenalii	0.0	21.3

Pedicularis palustris	2.0	30.3
Pinguicula vulgaris	9.1	24.7
Potentilla anserina	7.1	48.3
Potentilla palustris	0.0	29.2
Ranunculus flammula	8.1	80.9
Ranunculus repens	4.0	51.7
Rhinanthus minor agg.	11.1	27.0
Sagina procumbens	9.1	38.2
Senecio aquaticus	0.0	33.7
Triglochin maritima	0.0	32.6
Vicia cracca	2.0	32.6

Again, the species declining in G6 as compared with G2, and vice versa can be interpreted in a similar manner to those for the D4/G6 comparison. For both sets of comparisons, the list of preferentials for both halves of the table is long, longer than for most other comparisons encountered so far. This suggests that G6 is substantially different from its two putative relations.

Examination of the distribution of slightly acid, wet grassland G6 on the sites on which it occurs reveals that it is usually associated with the low ground surrounding lochs (without actually extending into them), ponds, slow streams and old drainage channels which may have filled in. There is no evidence that G6 occurs in close proximity to either D4 or G2 more than would be expected by chance so it must be assumed that the successional relationship is either of rare occurrence or non-existent. On the other hand, G6 does occur in close proximity to some of the Marshland types (M1-M4) and this relationship will be examined in more detail in the context of this more specialized family.

Slightly acid, wet grassland is an extremely species-rich type, with a mean of 31.5 species per quadrat - the highest of all types. This may be compared with D4 with 28.9 and G2 with 31.0 species per quadrat. However, the total number of species recorded is by no means so extreme at 186. What this means in practice is that there is quite a wide range of species present and a high proportion of them have intermediate frequencies, i.e. there are not so many species with one or two occurrences, as in some other types. The statistic that there are 79 species with a frequency of 10% or more emphasizes this feature (cf. D4 with 63 and G2 with 70).

The species which contributes most cover to slightly acid, wet grassland G6 is Carex nigra (15.1%) and there are five other species with cover of 3% or more - Agrostis stolonifera (6.8%), Carex panicea (5.8%), Festuca rubra (5.8%), Molinia caerulea (5.4%) and Holcus lanatus (3.2%). As might be expected from the previous discussion of the range of specialized habitats that exist in the type, there is a long list of potential dominants, some of which have quite low frequencies, e.g. Molinia caerulea, with a frequency of 42.7%, is a dominant in 16.9% of quadrats with a mean cover as a dominant of 28.3%. Another notable species of this type is Iris pseudacorus with figures of 13.5%, 5.6% and 18.0% respectively. A total of 52 potential dominants were recorded from 89 quadrats of the type but 18 of these occur in one quadrat only. The majority of these species are indicative of wet conditions.

Despite the species richness of this type, there is not a complete cover of vascular plants; mean cover of vascular plants is 92.1% (cf. D4 with 99.1% and G2 with 102.2%). However, bryophytes, with a frequency of 98.9% and a mean cover of 14.7%, more or less make up the discrepancy in living cover (cf. D4 with 9.3% and G2 with 4.4%). By contrast, lichens are insignificant, with a frequency of 6.7% (cf. D4 with 29.6% and G2 with 52.5%) and negligible cover (0.1%). A wide range of substrates have been recorded from the type but those yielding significant cover are decomposed organic matter, with a frequency of 32.6% and cover of 2.5%, bare sand 18.0% and 3.8% and freshwater 27.0% and 5.3%. In relation to the discussion about the form of G6 isolated by step 82 (-ve), saltmarsh mud was recorded from 3.4% of quadrats (mean cover 0.3%) and saline water also in 3.4% (mean cover 0.2%).

In terms of soil types, G6 is quite well defined, being highly associated with two wet Peaty Soils, PS3 (20.2%) and PS5 (6.7%), and two Thin Soils, TS8 (4.5%) and TS9 (27.0%). Both Thin Soils tend to be peaty with a high water table. Together, these four types account for 58.4% (out of 94.4%) of the quadrats allocated to G6. Other common soil types are semi-mature Deep Sand DS6 (6.7%), mature Deep Sand DS7 (14.6%) and damp Peaty Soil PS4 (4.5%). Together these account for a further 25.8%, bringing the total to 84.2%. However, it should be noted that the proportion in DS6 represents a negative association.

Grazing pressure is not particularly high in G6, with 7.9% of quadrats having no grazing, 57.3% with light grazing, 30.3% with moderate grazing and 4.5% with heavy grazing. Grazing animals show a strong bias towards use by cattle which were recorded in 77.5% of quadrats. Sheep in 39.3% of quadrats and rabbit in 25.8% are much less important. As might be expected under such wet soil conditions, no rabbit burrows or scrapes were recorded. Also, because of the wet conditions presumably, other human disturbance is somewhat reduced compared with most other vegetation types. Walls and fences were recorded in 3.4% of quadrats, vehicle tracks (6.7%), unsurfaced path (3.4%), armaments (2.2%) and old cultivation (4.5%). Rubbish was recorded from 27.0% of quadrats.

A wide range of aquatic habitats were recorded in the type, mostly standing water, i.e. puddle (11.2%), ditch (6.7%), pond (6.7%), loch (5.6%) and saltmarsh pan (1.1%). Flowing water is rather less common, with stream (2.2%), river (1.1%) and saltmarsh creek (1.1%). Dried-up water is also present, with puddle (2.2%), rut (1.1%), ditch (5.6%), stream (1.1%), pond (2.2%), loch (2.2%). Together these records add up to a strong association with a high water table in various forms.

Slightly acid, wet grassland G6 has a slight tendency to face either east (29.2%) or south (30.3%) in terms of local aspect but general aspect shows the type to be strongly linked with western aspects (56.2%). No explanation can be offered for this feature, except that the general aspect is obviously related to the geographical distribution of the type (mainly western - see below). Because slopes are minimal, 61.8% under one degree and 37.1 under 5 degrees (total 98.9% under 5 degrees), local aspect is clearly not a strong feature of the type. In fact, G6 probably occupies the flattest habitat of all types except for some members of the Saltmarsh family. Surface type is either plane (76.4%) or simple undulating (21.3%). Most quadrats are low-lying, with 86.5% under the 50ft contour. Apart from the minority of quadrats that are affected by saline water (6.7% within 100m of the sea), G6 is very much an inland type with a mean distance from the sea of 706m.

The geographical distribution of G6 is very interesting. It achieves its peak frequency in sites on South and North Uist in the Outer Hebrides. Sites in this region are all low-lying, contain, or are backed on the inland side by lochs and lochans of various sizes. These water bodies are usually surrounded by peatlands which are often called the "blackland". Sites with 10% or more of this vegetation type are Daliburgh (13%), Stilligary (North) (17%), Loch Bee (13%), Kirkibost (11%) and Balranald (11%). The type is also quite common in sites on Coll, Tiree and Islay (Gruinart has 10%) but is sparse elsewhere. There is one occurrence on Harris, one on Shetland, a few on the west and north coasts of mainland Scotland (Achnahaird has 7%) and on the north side of the Moray Firth (Morrich More has 9%). There is only one occurrence south of this on the east coast, at St Fergus. As noted above, the occurrence of G6 within a site is almost inevitably associated with some feature that can actually be seen on the site map such as a loch, marsh, stream or drainage channel.

G7 - Acid, wet grassland

G7 - Acid, wet grassland

(dominated by Juncus effusus, Agrostis stolonifera and Holcus lanatus)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 11)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	5	5	7 Oronsay	1	2
50 Redpoint	1	4	58 Farr Bay	1	0
60 Melvich	1	5	75 Lossiemouth	1	4
76 Spey Bay (West)	5	18	80 Strathbeg	2	3
84 Don to Ythan	1	2	89 Barry Links	1	1
90 Tentsmuir	4	5			

G7 - Acid, wet grassland, dominated by Juncus effusus, Agrostis stolonifera and Holcus lanatus

This is not a common vegetation type with only 23 quadrats (0.6%) allocated to it. The type has three outlets in the key; step 8 (+ve) isolates 17 quadrats (the majority) of the type, step 28 (+ve) isolates 2 quadrats and step 40 (-ve) 4 quadrats. There is no evidence to show that these outlets are very different, although the form of G7 isolated by step 40 (-ve) may be slightly more acid than the other two forms.

The most frequent species in G7 is Holcus lanatus (87.0%), followed closely by Juncus effusus (82.6%). Nine other species have frequencies of 50% or more: 70-80% - Carex nigra, 60-70% - Potentilla erecta, Agrostis stolonifera, Cirsium palustre, Galium palustre, Hydrocotyle vulgaris and Viola palustre; and 50-60% - Epilobium palustre and Anthoxanthum odoratum. There are 11 species with a frequency of 50% or more in G7, a total of 126 species have been recorded from the 23 quadrats of the type and the mean number of species per quadrat is 20.1. This may be compared with the equivalent figures for G6, its western equivalent, of 19, 186 (from 89 quadrats) and 31.5. It is clear from this that, in all aspects, G7 is nowhere near as species-rich as G6.

Figure 3 shows a tentative relationship (dotted line) between acid, dry grassland G3 and acid wet grassland G7. It is tempting to also relate the type with very acid, damp grassland G4, on the basis of increasing wetness, but the number of extreme acid species in this type and absent from G7, more or less precludes the idea. If valid, this relationship would necessitate a rapid increase in acid species from G3 to G4 and then a sharp decline again in G7 which is unlikely to be a common developmental sequence. Examination of the distribution of vegetation types within sites shows that G7 usually occurs in close proximity to G3 which is taken as strong evidence to support a relationship of some sort, although it is not necessarily a successional one. The following table lists the preferential species for G3 as compared with G7.

Preferential Species for Type G3

Species Names	G3 %	G7 %
Achillea millefolium	20.6	4.3
Agrostis tenuis	83.5	34.8
Ammophila arenaria	31.6	0.0
Calluna vulgaris	61.3	17.4
Campanula rotundifolia	25.4	4.3
Carex arenaria	69.6	4.3
Cerastium holosteoides	29.1	4.3
Erica cinerea	36.4	8.7
Festuca ovina	70.3	0.0
Lotus corniculatus	35.9	4.3
Rumex acetosella	22.2	4.3
Veronica officinalis	25.4	0.0
Viola riviniana	28.1	13.0

Preferential Species for Type G7

Species Names	G3 %	G7 %
Achillea ptarmica	1.8	30.4
Agrostis canina	9.8	21.7
Agrostis stolonifera	8.7	60.9
Angelica sylvestris	0.9	26.1
Carex echinata	0.2	21.7
Carex nigra	8.5	73.9
Cirsium palustre	1.6	60.9
Deschampsia cespitosa	0.9	21.7
Epilobium palustre	0.2	56.5
Equisetum fluviatile	0.0	21.7
Galium palustre	0.7	60.9
Hydrocotyle vulgaris	0.9	60.9
Juncus articulatus	1.4	21.7
Juncus effusus	5.5	82.6
Potentilla erecta	31.8	65.2
Potentilla palustris	0.2	34.8
Ranunculus flammula	0.5	21.7
Ranunculus repens	5.0	26.1
Sagina procumbens	3.4	21.7
Viola palustris	1.1	60.9

Species which are preferential to G3 and declining in G7 are mostly the remnants of dune species (left over from D2) such as Ammophila arenaria (31.6% in G3 down to 0.0% in G7) or Carex arenaria (69.6% to 4.3%), or dry acid species such as Calluna vulgaris (61.3% to 17.4%), Erica cinerea (36.4% to 8.7%) and Festuca ovina (70.3% to 0.0%). Species preferential to G7 are mostly acid, wet species such as Carex nigra (8.5% in G3 to 73.9% in G7), Galium palustre (0.7% to 60.9%), Hydrocotyle vulgaris (0.9% to 60.9%) and Juncus effusus (5.5% to 82.6%). So many species are involved in both directions, and their relative frequencies are so sharply different, that the change from G3 to G7 must be regarded as something approaching a discontinuity. Detailed analysis of the two types using existing data could reveal to what extent this is so or whether there is sufficient within-class variation to bridge the difference between the two vegetation types. In the other direction, that of increasing wetness, it is possible to compare G7 with one of the Marshland types, namely wet marsh M2. This comparison will be deferred until the section on the Marshland family but both slightly acid, wet grassland G6 and acid, wet grassland type G7 can be regarded as being possible transitions to the Marshland types. The nature of the transition is unexpectedly complex and will be discussed in the context of the comparisons mentioned above.

It is also possible to compare slightly acid, wet grassland, G6 (western), directly with its eastern equivalent, acid, wet grassland G7, not because one can develop into the other but just to illustrate the difference between the types in floristic terms (in the same way that it was done for D1 and D2 above). The list of preferentials for this comparison is given in the following table.

Preferential Species for Type G6

Species Names	G6 %	G7 %
Anagallis tenella	43.8	4.3
Bellis perennis	56.2	0.0
Caltha palustris	76.4	4.3
Cardamine pratensis	69.7	17.4
Carex flacca	28.1	4.3
Carex flava agg.	25.8	4.3
Carex panicea	57.3	8.7
Carex pulicaris	27.0	0.0
Cerastium holosteoides	47.2	4.3
Cynosurus cristatus	43.8	0.0
Dactylorchis spp.	51.7	0.0
Eleocharis palustris	25.8	0.0
Equisetum arvense	24.7	4.3
Eriophorum angustifolium	46.1	8.7
Euphrasia officinalis agg.	38.2	0.0
Juncus articulatus	61.8	21.7
Juncus bulbosus/kochii	20.2	0.0
Leontodon autumnalis	59.6	17.4
Lotus corniculatus	30.3	4.3
Lychnis flos-cuculi	43.8	13.0
Mentha aquatica	27.0	0.0
Molinia caerulea	42.7	13.0
Myosotis caespitosa	21.3	4.3
Oenanthe lachenalii	21.3	0.0
Pedicularis palustris	30.3	0.0
Pinguicula vulgaris	24.7	0.0
Plantago lanceolata	42.7	4.3
Plantago maritima	23.6	0.0
Potentilla anserina	48.3	8.7
Prunella vulgaris	62.9	17.4
Ranunculus acris	70.8	17.4
Ranunculus flammula	80.9	21.7
Senecio aquaticus	33.7	4.3
Succisa pratensis	61.8	17.4
Trifolium pratense	32.6	0.0
Trifolium repens	82.0	30.4
Triglochin maritima	32.6	0.0
Vicia cracca	32.6	4.3

Preferential Species for Type G7

Species Names	G6 %	G7 %
Achillea ptarmica	5.6	30.4
Agrostis canina	9.0	21.7
Agrostis tenuis	9.0	34.8
Cirsium palustre	1.1	60.9
Deschampsia cespitosa	1.1	21.7
Galium saxatile	1.1	34.8
Juncus effusus	21.3	82.6
Potentilla erecta	23.6	65.2
Ulex europaeus	2.2	26.1
Viola palustris	3.4	60.9

The extreme species richness of G6 as compared with G7 is emphasized by the long list of species (38 in all) preferential to G6. Most of the species preferential to G6 can be interpreted as being indicative of wet, slightly acid, fairly nutrient-rich conditions. As already discussed, there is probably a strong element of flushed soils in the type. By contrast, the species preferential to G7 are more acid and less nutrient demanding.

The most important cover species in G7 is Juncus effusus (16.0%), followed closely by Agrostis stolonifera (13.3%), Pteridium aquilinum (9.1%) and Ulex europaeus (8.3%). Seven other species have mean cover of 3% or more - Holcus lanatus (4.1%), Carex nigra (4.0%), Agrostis tenuis (3.8%), Agrostis canina (3.5%), Festuca rubra (3.5%), Molinia caerulea (3.5%) and Calluna vulgaris (3.1%). However, a closer examination of the main cover species reveals a curious situation. The species tend to be polarized between those that are quite frequent with moderate cover, e.g. Juncus effusus (82.6% and 16.0%), Agrostis stolonifera (60.9% and 13.3%), Holcus lanatus (87.0% and 4.1%) and Carex nigra (73.9% and 4.0%), or those restricted to relatively few quadrats with high cover, e.g. Pteridium aquilinum (13.0% and 9.1%), Ulex europaeus (26.1% and 8.3%), Agrostis tenuis (34.8% and 3.8%), Agrostis canina (21.7% and 3.5%), Molinia caerulea (13.0% and 3.5%) and Calluna vulgaris (17.4% and 3.1%). The prime example of a low frequency, high cover species is Pteridium aquilinum which is a dominant in all 13.0% of the quadrats in which it occurs with a mean cover of 70.0%. Ulex europaeus is similar, being present in 26.1% of quadrats and is is dominant in 21.7% with a mean cover of 38.0%. In fact, this is a general feature of acid, wet grassland G7, that it can exhibit a wide range of dominant species whilst still retaining the basic species complement which causes it to be considered as a type. A more detailed study of G7 would be required to establish the underlying causes or dynamics of this situation. One relevant factor is almost certainly habitat complexity, there being raised, better drained areas within the generally wet habitat. This is inferred from the presence of such species as Pteridium, Ulex and Calluna. In this type of situation, dominance of a particular species may be determined by the relative amounts of various habitats within the confines of the quadrat.

The total cover of vascular plants in G7 is high at 106.1%, suggesting some degree of multi-layering in the cover. In addition to this, bryophytes occur in 95.7% of quadrats with a mean cover of 7.9%. Lichens are much less common, with a frequency of 13.0% and mean cover of 0.1%. A wide range of other cover types occur in G7 with low frequency and cover. The only one worth detailing is freshwater, recorded in 26.1% of quadrats with a mean cover of 3.5%.

Acid, wet grassland G7 is not strongly associated with any soil type. Thin Soils TS1 (8.7%) and TS8 (8.7%) are significantly associated but only account for 17.4% (out of 95.7%). Both of these types are characterized by high water table. Other common soil types are semi-mature, Deep Sandy Soil DS6 (17.4%) and mature Deep Sandy Soil DS7 (13%). Peaty Soils (PS1-PS5) account for 25.9% of quadrats.

Grazing pressure in G7 is even lower than in G6, where this feature was noted. No grazing was recorded in 17.4% of quadrats, light grazing in 60.9%, moderate grazing in 13.0% and heavy grazing in 8.7%. The most common grazing animal is the rabbit with 43.5%, followed by cattle (34.8%) and sheep (21.7%). Signs of deer were recorded in 13.0% of quadrats. Human disturbance is not an important feature of G7 and no particular pattern can be detected with so few examples of the type. Some quadrats contain aquatic habitats - puddle (13.0%), pond (8.7%), river (4.3%) and dried-up puddle (4.3%).

In terms of local aspect, G7 shows no marked trend but in general aspect there is a marked preference for north and east (together 73.9%) as opposed to west (4.3%). Slopes are generally shallow, with 91.3% under 5 degrees. Surface type is similar, with 73.9% plane and 17.4% undulating simple (total of 91.3%). G7 is a low-lying type with 95.7% of quadrats below the 50ft contour. Its position in relation to the sea is very similar to that of G6, exhibiting a wide range of distance from HWMST and a mean of 681m.

The geographical distribution of acid, wet grassland G7 is very interesting as superficially, at least, it seems to be the eastern equivalent of the predominantly western G6. This is taken as fairly good evidence that G6 and G7 are not developmentally related. In the west, G7 is totally absent from the Outer Hebrides but there are single examples on Oronsay and at Redpoint. There are also two quadrats of the type at Torrs Warren in the extreme south-west but, as this site is included in the East Coast, Main Type (Site Type 9), this is not unexpected. The rest of the quadrats allocated to G7 occur in sites on the east or north coasts, with a peak at Spey Bay (West) where 18% of the type is present.

7.4.5 Peatland Family (P1-P3)

There are three vegetation types in this family. Two of these, P1 and P2, are shown in Figure 3 as either successional developments of acid, damp grassland G2 or as being of independent development. This situation is interpreted as being an example of convergence, i.e. that different origins can lead to the same end point. The third type, P3, is not shown. It is not a common type (only 8 quadrats) and its relationship with the other vegetation types, if any, is not immediately obvious. The comparative rarity of P3 and its lack of affinity with other vegetation types is probably because it depends on a rather specialized edaphic habitat. The drainge conditions that give rise to flushing of the soil profile, i.e. receiving sites, are relatively uncommon and localized in the population under consideration.

The common factor in the Peatland family is, as the name suggests, the peaty nature of the soil. This soil type has the possibility of two distinct origins. Firstly, as a successional development, where peat formation takes place on what was originally a sandy substrate. For example, a number of soil profiles recorded in the survey contained peat overlying what appeared to be blown sand. However, other conditions, such as high water table and a fairly siliceous type of sand, are prerequisites of this developmental sequence. Other profiles consist of peat overlying water laid deposits of sand or sand, gravel and cobble mixtures. The second mode of origin of a peaty soil is quite different. Examples of this type include peat overlying rocks or boulders or other compacted substrates, i.e. blanket peat, and deep peat in which the underlying material is unknown, i.e. basin peat or estuarine peat. The presence within a site of this type of peat is dependent on the position of the site boundary and its geographical distribution, i.e. where on the Scottish coast it occurs. With respect to site boundary, some sites follow or are within the confines of blown sand, or other soft deposits, whilst others extend beyond these limits. The most common source of peaty soils is raised rocky areas within the site, e.g. rocky headlands at the side of bays or more elevated land at the inland boundary of the site. As far as geographical distribution is concerned, there are more peaty soils in the west and north where high rainfall and humidity favour this development. As a result, P1 is a predominantly western and northern type and P2 has an exclusively western distribution (there are too few examples of P3 to comment). The few eastern examples of the Peatland family, e.g. 9% of P1 at Morrich More, seen to be associated with high water table around small lochs or other water bodies where, for one reason or another, sufficiently acid conditions have pertained. More commonly, such situations are occupied by one of the Marshland types (M1 or M2), wet, slightly acid dune grassland D5 or one of the wetter Grassland types such as G6 or G7. Details of distribution for the Peatland family are discussed in the context of the individual type descriptions below.

Finally, it should be noted that peat and peat bogs are very much a marginal habitat as far as the Coastal Survey is concerned. Firstly, there are not many quadrats (155 or 4.0%) in the whole family and, secondly, this is inevitably a somewhat biased sample of the vegetation that grows in peaty habitats, being restricted to those types which occur at relatively low elevation in coastal situations. The key cannot, therefore, be expected to identify vegetation from any peaty habitat, but only those that occur bordering on sandy, coastal deposits. Even within this narrow context, the three types of peaty vegetation identified are fairly broad as compared with, say, the Duneland or Grassland family and within-type variation is almost certainly higher.

P1 - Transitional peat bog

P1 - Transitional peat bog

(dnainated by Molinia caerulea, alluna vulgaris and Festuca ovina)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 29)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
3 Laggan Bay	3	7	6 Gruinart	3	4
7 Oronsay	11	26	8 Garvard	5	16
9 Kiloran Bay	7	21	15 Crossapol and Gunna	11	11
17 Gallanach	3	7	20 North Barra	1	2
25 Loch Bee	1	1	27 Stilligarry (South)	1	4
32 Hosta	1	3	33 Vallay	1	3
38 Pabbay	14	23	39 Northton	2	5
41 Uig	1	3	42 Valtos	1	4
43 Barvas	3	10	45 Tolsta	1	3
50 Redpoint	9	27	52 Achnahaird	3	11
53 Oldshore More	6	16	54 Sheigra	1	4
55 Durness	1	3	56 Faraid Head	2	7
57 Bettyhill	2	6	59 Strathy	3	10
64 Sandwood	7	20	70 Morrich More	3	9
90 Tentsmuir	1	1			

P1 - Transitional peat bog, dominated by Molinia caerulea, Calluna vulgaris and (Festuca ovina)

This is by far the most common Peatland type with 108 quadrats (2.8%) for which there are five outlets in the key (see Figure 6A). However, two of these outlets, steps 10 (-ve) and 18 (-ve), account for 87 of the 108 quadrats (80.6% of the type). The three other outlets, 19 (+ve) with 4 quadrats, 33 (+ve) with 14 quadrats and 37 (+ve) with 3 quadrats, isolate the remainder of the type. The difference between the five forms of P1 is probably not very significant ecologically. The crucial division is step 4 in the key, where the six negative indicators - Agrostis stolonifera, Carex nigra, Leontodon autumnalis, Prunella vulgaris, Ranunculus acris and Trifolium repens - can be interpreted as wet and mildly acid, whilst the four positive indicators - Agrostis tenuis, Calluna vulgaris, Carex arenaria and Festuca ovina - suggest rather drier and more acid conditions. Outlets 18 (-ve), 19 (+ve) and 37 (+ve), with a total of quadrats, stem from the negative side of step 4 and outlets 10 (-ve) and 33 (+ve), with 60 quadrats, from the positive side and may thus be interpreted in relation to these indicators. Peatland P1 has been given the name "transitional" because quadrats allocated to this type usually contain some species that are a more nomally associated with the Grassland (or even Duneland) types along with the more acidophilous and peaty species. Step 10 of the key, which divides the most common form of P1 from P2 and P3 (plus another more extreme form of P1), serves to illustrate this point, with such species as Euphrasia officinalis agg., Lotus corniculatus, Plantago lanceolata, Thymus drucei, Trifolium repens and Viola riviniana as indicators for P1. Step 11 assists in the interpretation of the second most common form (18 (-ve)), with positive indicators such as Carex echinata, Erica tetralix, Eriophorum angustifolium, Molinia caerulea and Nardus stricta, being interpreted as acid, wet conditions.

The following description of P1 is based on the composite of all five forms of the type and is thus biased towards the two most common forms, outlets 10 (-ve) and 18 (-ve).

The two most common species in transitional peat bog P1 are Potentilla erecta (97.2%) and Calluna vulgaris (91.7%). Twelve other species have frequencies of 50% or more: 80-90% - Anthoxanthum odoratum, Molinia caerulea, Succisa pratensis, and Erica tetralix; 70-80% - Sieglingia decumbens; 60-70% - Carex panicea, Nardus stricta and Holcus lanatus; and 50-60% - Carex nigra, Carex echinata, Trifolium repens and Lotus corniculatus. All but the last two of these species can be interpreted as indicating acid or wet conditions, or both. The type contains 69 species with a frequency of 10% or more. A number of these, with intermediate frequencies, are more typical of drier, less acid conditions, e.g. Festuca rubra (46.3%), Euphrasia officinalis agg. (38.9%), Plantago lanceolata (36.1%), Viola riviniana (28.7%) and Thymus drucei (25.0%). Hence the use of the word "transitional" in the type name. Typical quadrats include both peat or peat bog and drier more raised habitats within the same 25 sq m quadrat.

As already suggested above (see also Figure 3), the most likely developmental relationship of transitional peat bog P1 is with acid, damp grassland G2. The preferential species for the comparison between these two types are given in the following table.

Preferential Species for Type G2:-

Species Names	G2 %	P1 %
Achillea millefolium	44.4	7.4
Bellis perennis	59.6	6.5
Campanula rotundifolia	22.2	1.9
Centaurea nigra	20.2	3.7
Cerastium holosteoides	57.6	14.8
Cynosurus cristatus	41.4	17.6
Galium verum	54.5	6.5
Hieraceum pilosella	31.3	6.5
Koeleria cristata	57.6	14.8
Leontodon autumnalis	39.4	18.5
Linum catharticum	55.6	8.3
Plantago lanceolata	89.9	36.1
Poa pratensis	43.4	14.8
Prunella vulgaris	74.7	35.2
Ranunculus acris	55.6	21.3
Rumex acetosa	28.3	8.3
Thymus drucei	84.8	25.0
Trifolium pratense	40.4	16.7
Viola riviniana	68.7	28.7

Preferential Species for Type P1:-

Species Names	G2 %	P1 %
Agrostis canina	11.1	42.6
Anagallis tenella	13.1	26.9
Carex echinata	9.1	55.6
Drosera rotundifolia	0.0	21.3
Erica cinerea	10.1	33.3
Erica tetralix	22.2	82.4
Eriophorum angustifolium	7.1	44.4
Hydrocotyle vulgaris	7.1	21.3
Juncus effusus	6.1	23.1
Juncus squarrosus	6.1	23.1
Molinia caerulea	27.3	87.0
Nardus stricta	24.2	68.5
Narthecium ossifragum	3.0	40.7
Pedicularis sylvatica	8.1	28.7
Ranunculus flammula	8.1	27.8
Trichophorum cespitosum	1.0	22.2

Common in G2 but declining in P1 are a number of mainly acidophilous, dry or damp species such as Bellis perennis, down from 59.6% in G2 to 6.5% in P1, Plantago lanceolata (89.9% to 36.1%), Prunella vulgaris (74.7% to 35.2%), Thymus drucei (84.8% to 25.0%) and Viola riviniana (68.7% to 28.7%). Species increasing in P1 as compared with G2 are mostly indicative of more acid or wet conditions, e.g. Carex echinata, up from 9.1% in G2 to 55.6% in P1, Erica tetralix (22.2% to 82.4%), Molinia caerulea (27.3% to 87.0%) and Nardus stricta (24.2% to 68.5%). Other obligate peat bog species such as Drosera rotundifolia, Narthecium ossifragum and Trichophorum cespitosum are (virtually) absent from G2 but have put in an appearance in P1. These same species will go on to be even more common in P2, to be described next.

In terms of cover, transitional peat bog P1 is dominated by Molinia caerulea (23.0%) and Calluna vulgaris (16.2%). There is then a big drop to the next most important cover species, Festuca ovina and Nardus stricta each with 4.2% cover. Three other species have mean cover of 3% or more - Erica tetralix (3.5%), Anthoxanthum odoratum (3.5%) and Carex panicea (3.4%). Total cover of vascular plants is quite high at 101.0% and vegetation cover is significantly added to by bryophytes which occur in 97.2% of quadrats with a mean cover of 9.9% (cf. 100.0% and 4.4% for G2). Lichens are somewhat less important in P1, being present in 50.9% of quadrats with cover of only 0.4% (cf. G2 with 52.5% and 0.4%). As might be expected, there is very little bare sand in P1, it being present in only 4.6% of quadrats with 0.5% cover (cf. 15.2% and 3.9% in G2). The only important non-vegetative cover categories are boulders, recorded in 15.7% of quadrats with 1.1% cover, and solid rock (28.7% and 4.8%). Decomposed organic matter, i.e. bare peat surface, occurs in 14.8% of quadrats with a cover of 0.6%. Freshwater is present in small quantities, 14.8% of quadrats with a cover of 1.5%.

Acid, damp grassland G2 is the most species-rich vegetation type in the survey (mean of 31.0 species per quadrat) and transitional peat bog P1 is still quite rich with 26.5 species per quadrat. The total number of species recorded in the type is also quite high at 171 (cf. 178 for G2).

A total of 46 potential dominants (species with 10% or more cover in a quadrat) were recorded for P1, 30 in more than one quadrat. In general, these dominants conform closely with the top cover species (see above). One of the more interesting species is Myrica gale which, although it only occurs in 16.7% of quadrats, is a dominant in 7.4% with a mean cover in these quadrats of 23.8% (this becomes a really important dominant in P2). Salix repens can also be a local dominant in the type (4.6% of quadrats).

There are strong correlations between P1 and the soil types. Highly associated are the two (peaty) Thin Soil types TS5 (2.8%) and TS7 (13.0%) and all five of the Peaty Soil types - PS1 (4.6%), PS2 (13.0%), PS3 (6.5%), PS4 (18.5%) and PS5 (13.0%). Together these seven soil types account for 71.4% (out of 97.2%) of the quadrats. Other relatively common soil types are semi-mature, Deep Sandy Soils DS5 (3.7%) and DS6 (4.6%) (both of these negative associations), mature, Deep Sandy Soil DS7 (6.5%) and Thin Soil TS9 (5.6%). The dominant feature here is the peaty nature of the soil. The presence of some non-peaty soils is only to be expected in a transitional type, depending on the exact position of the quadrat centre. There is even a small minority of non-peaty soils in P2 (see below).

Grazing pressure is reduced in P1 compared with G2, with no grazing in 3.7% of quadrats (1.0% in G2), light grazing in 42.6% (27.3% in G2), moderate grazing in 49.1% (45.5% in G2) and heavy in 4.6% (26.3% in G2). This is probably, at least in part, a reflection of the difference in dominant species in the two types; Festuca rubra, Festuca ovina and a wide range of other grass species dominate G2 and Molinia caerulea and Calluna vulgaris in P1, the latter species being less palatable. Records of grazing animals bear out the difference to some extent, with cattle in 47.2% of quadrats (50.5% for G2), sheep in 76.9% (82.8% for G2) and rabbit in 54.6% (67.7% for G2).

Human disturbance is also less in P1 as compared with G2, with wall (3.7%), fence (3.7%), vehicle track (3.7%), paths unsurfaced (3.7%), old cultivation (1.9%). The most interesting feature is that fire evidence was recorded in 6.5% of quadrats (cf. 1.0% for G2 and 7.7% for P2). The possible interpretation of fire evidence is dicussed in more detail later, in the type description for P2. Rubbish was recorded in 15.7% of quadrats (cf. 12.1% for G2).

Aquatic habitats are much more important in P1 than in G2. For the standing water habitats, puddles occurred in 5.6% of quadrats, rut in 2.8%, ditch in 6.5%, pond in 2.8% and loch in 1.9%. Similarly, with flowing water, stream (6.5%) and spring/flush (4.6%). Dried-up water habitats are also present, with puddle (2.8%), rut (3.7%), ditch (0.9%) and stream (2.8%).

As far as local aspect is concerned, transitional peat bog P1 is more or less neutral but general aspect shows a slight preference for south or west (together 62.1%). Slope is very variable, with 51.9% in the 1-5 degree category, 24.1% in the 5-15 degree and 5.6% over 15 degrees. Surface type is similarly variable with 31.5% plane, 48.1% undulating simple, 14.8% undulating complex and 5.6% broken. If, as suggested, P1 is mostly blanket bog, or the fringe of basin bog, this is what might be expected. Elevation is an important feature of P1 and only 38.0% of quadrats are under the 50ft contour. The type extends as high as the 300-350ft zone and mean elevation is 93.5ft (cf. G2 with 95.7ft). There is also a wide range in distance from the the sea for P1, from 10-50m zone up to the 1500m+. Mean distance is 437m (cf. 319m for G2). As already noted, some examples of the type occur on rocky headlands set into or at the sides of the main sandy areas. This type of location produces examples of P1 that are nearer to the sea.

Transitional peat bog P1 has an interesting geographical distribution. It is essentially a western type, only occurring in two sites east of Strathy on the north coast - Morrich More with 3 quadrats and Tentsmuir with 1. The type is particularly common on Colonsay, where Oronsay has 26%, Garvard (16%) and Kiloran Bay (21%). It is absent from Tiree but two of the three sites on Coll contain several quadrats of the type - Crossapol and Gunna (11%) and Gallanach (7%). P1 is very uncommon in the low-lying sites on South and North Uist but reappears on Harris and Lewis. Another area of concentration for the type is in the mainland sites from Redpoint on the west coast to Strathy in the middle of the north coast.

P2 - Wet peat bog

P2 - Wet peat bog

(dominated by Molinia caerulea, Calluna vulgaris and Myrica gale)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 8)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	2	2	3 Laggan Bay	17	40
7 Oronsay	2	5	8 Garvard	9	29
38 Pabbay	1	2	41 Uig	1	3
50 Redpoint	6	22	64 Sandwood	1	4

P2 - Wet peat bog, dominated by Molinia caerulea, Calluna vulgaris and Myrica gale

It will be noted that the first two species in the above name are the same, and in the same order, as for P1. Only Myrica gale is different replacing Festuca ovina. Despite this apparent similarity, the two types are fairly distinct.

Wet peat bog P2 is not a particularly common type, with only 39 quadrats (1.0%). The type has four outlets in the key; step 25 (-ve) with 5 quadrats, 33 (-ve) with 23 quadrats, 34 (+ve) with 5 quadrats and 41 (-ve) with 6 quadrats. Numerically, step 33 (-ve) is the most important, isolating over half of the type, but, because all four outlets are in the same branch of the key, originating at step 6 (-ve) (see Figure 6A), there are unlikely to be serious differences between the forms. This branch of the key is entirely devoted to sorting out the three Peatland types.

The most common species in P2 are Potentilla erecta (100.0%), Calluna vulgaris (94.9%) and Molinia caerulea (94.9%). Only four other species (7 in all) have a frequency of 50% or more - Erica tetralix (89.7%), Eriophorum angustifolium (69.2%), Myrica gale (53.8%) and Trichophorum cespitosum (51.3%).

The difference between transitional peat bog P1 and wet peat bog P2 is summarized by the following table of species preferential to the two types.

Preferential Species for Type P1:-

Species Names	P1 %	P2 %
Agrostis stolonifera	25.0	2.6
Agrostis tenuis	34.3	0.0
Anagallis tenella	26.9	0.0
Carex echinata	55.6	20.5
Carex flacca	20.4	0.0
Carex flava agg.	25.9	2.6
Carex nigra	58.3	25.6
Carex pulicaris	41.7	0.0
Euphrasia officinalis agg.	38.9	0.0
Festuca ovina	47.2	12.8
Festuca rubra	46.3	10.3
Festuca vivipara	27.8	7.7
Holcus lanatus	63.0	5.1
Hydrocotyle vulgaris	21.3	2.6
Hypochoeris radicata	21.3	0.0
Lotus corniculatus	50.0	0.0
Luzula campestris	24.1	10.3
Luzula multiflora	35.2	12.8
Nardus stricta	68.5	12.8
Pedicularis sylvatica	28.7	10.3
Plantago lanceolata	36.1	0.0
Plantago maritima	43.5	0.0
Prunella vulgaris	35.2	0.0

Ranunculus acris	21.3	0.0
Ranunculus flammula	27.8	2.6
Salix repens	32.4	15.4
Selaginella selaginoides	22.2	0.0
Sieglingia decumbens	76.9	0.0
Succisa pratensis	85.2	33.3
Thymus drucei	25.0	0.0
Trifolium repens	50.9	0.0
Viola riviniana	28.7	0.0

Preferential Species for Type P2:-

Species Names	P1 %	P2 %
Myrica gale	16.7	53.8
Trichophorum cespitosum	22.2	51.3
Eriophorum vaginatum	2.8	33.3

The first feature to be noted about this table is the large number of species (32) which are preferential to P1 and declining in P2, whereas there are only three species preferential to P2. It should also be noted, that half of the species preferential to P1 are totally absent in P2, i.e. percentage frequency is 0.0 in the latter type. Virtually all the species that are preferential to P1 are absent or much reduced in P2, e.g. Holcus lanatus, down from 63.0% in P1 to 5.1% in P2, Lotus corniculatus (50.0% to 0.0%), Sieglingia decumbens (76.9% to 0.0%) and Trifolium repens (50.9% to 0.0%). Even such species as Nardus stricta are much reduced (68.5% down to 12.8%). The three species preferential to wet peat bog P2 are all extreme wet, acidophilous species - Myrica gale (16.7% to 53.8%), Trichophorum cespitosum (22.2% to 51.3%) and Eriophorum vaginatum (2.8% to 33.3%).

As might be expected from the above tables, the species richness of P2 is much reduced compared with P1. The mean number of species per quadrat is reduced from 26.5 in P1 to 12.8 in P2 and the total number of species recorded in the type is reduced from 171 from 108 quadrats in P1 to 68 from 39 quadrats in P2. As already noted, the number of species with a frequency of 10% or more is 69 in P1 but this is reduced to 31 in P2.

The two main species contributing vegetative cover in P2 are the same as for P1 - Calluna vulgaris (30.4%) (cf. 16.2% in P1) and Molinia caerulea (27.7%) (cf. 23.0% in P1). Molinia is seen to be virtually unchanged but the cover of Calluna in P2 is nearly double that in P1. Other important cover species in P2 are Myrica gale (7.5%), Eriophorum angustifolium (5.3%), Erica tetralix (4.1%) and Trichophorum cespitosum (3.9%). Pteridium aquilinum also acheives some cover, with a mean of 3.2% but from only 7.7% of the quadrats (this means that it has a mean cover of about 40% in just 3 out of 39 quadrats allocated to P2). Total cover of vascular plants is 101.5% (cf. 101.0% for P1), or more or less complete cover of vascular plants. However, bryophytes must be considered as an addition to this and, with a frequency of 100.0% and mean cover of 20.3%, they are seen as an important element of this vegetation type (cf. 97.2% and 9.9% for P1). Various Sphagnum species make up a high proportion of the cover in this type (for details see Appendix 6 - Bryophytes in the Scottish Coastal Survey).

Lichens are less important, occurring in 38.5% of quadrats with a mean cover of 1.1%. Non-vegetative cover is relatively unimportant, with no bare sand at all recorded. Undecomposed organic matter occurs in 28.2% of quadrats with a mean cover of 3.3% and the equivalent figures for decomposed organic matter are 12.8% and 0.8%. Solid rock occurs in 23.1% of quadrats with a mean cover of 5.3%, i.e. about 20% cover in the quadrats in which it is present. Freshwater was recorded in 10.3% of quadrats with a mean cover of 0.4%.

Wet peat bog P2 is quite well characterized in terms of soil types. It is highly associated with two of the more extreme wet, Peaty Soils, PS4 (35.9%) and PS5 (23.1%). One of the Thin Soils, TS7 with (10.3%), is also significantly associated. Together these account for 69.3% of quadrats in the type. Other common soil types are Peaty Soils PS2 (7.7%) and Thin Soil TS9 (5.6%). This raises the proportion accounted for to 82.6%. The remaining soils recorded for P2 are types which are at least rich in organic matter.

The trend of decreasing grazing pressure from G2 to P1 is continued in P2. No grazing was recorded in 7.7% of quadrats, light grazing in 74.4%, moderate grazing in 17.9% and heavy grazing did not occur at all. Records of herbivores show a similar decline, with cattle in 28.2% (47.2% in P1), sheep in 56.4% (76.9% in P1) and rabbit in 48.7% (54.6% in P1).

There is not much evidence of human disturbance in wet peat bog P2, except that 10.3% of quadrats had embankments in them (spoil from drainage ditches?) and 15.4% had unsurfaced paths. Rubbish was recorded in 7.7% of quadrats (cf. 15.7% in P1). The only other disturbance feature of interest is fire evidence, which was recorded from 7.7% of quadrats in P2. From G2 to P2 (see Figure 3) there is increasing evidence of fire as an influencing factor (1.0% in G2, 6.5% in P1 to 7.7% in P2). This is a similar trend to that noted for the eastern series D2, G3 and G4. The trend would seem to be an almost direct reflection of the degree of flammability of the vegetation. In this case, the most readily burnt species are _Calluna vulgaris_ (6.2% cover in G2, 16.2% in P1 and 30.4% in P2) and _Molinia caerulea_ (2.8% in G2, 23.0% in P1 and 27.7% in P2). Some other species, such as _Myrica gale_, _Eriophorum angustifolium_ and _Trichophorum cespitosum_ may also play a part.

Despite the relatively low figures for fire evidence (never greater than 10%), there is little doubt that fire can be an important factor in certain coastal vegetation types, e.g. G3, (in the east), P1 and P2 (in the west). As noted above, flammability seems to be the common factor and this is largely influenced by the cover of _Calluna_, _Molinia_ and _Ulex_. The problem now arises as to what frequency of burning does a single observation proportion of, say, 5% of quadrats showing fire evidence, indicate? The answer to this question depends entirely on how long clear evidence of burning remains on the ground and, unfortunately, this tends to be longest with woody species like _Calluna_ and _Ulex_ and least where grasses such as _Ammophila_ and _Molinia_ are concerned. It is, therefore, possible that the increased frequency of burning in heather dominated types may be an observational artefact, caused by the relative persistence of evidence. A light spring fire in _Ammophila_ or _Molinia_ may be undetectable after a matter of a few weeks, whereas, in tall heather or gorse the evidence may persist for several years. In shorter (more regularly burnt) heather, fire evidence may persist for as little as a year, depending on the intensity of the burn.

In summary, neither question - whether fire evidence is biased toward woody vegetation types (?) or, with what frequency do fires occur (?) - is really answerable on the basis of a single visit survey. A frequency of fire evidence of 5% and a persistence of one year would predict that the probability of fire in a given year was 1 in 20 whereas a persistence of three years would reduce this to 1 in 60. Direct evidence drawn from the size (age) of Calluna and Ulex suggests that, in most sites, fire is quite common. Only in Torrs Warren were there really extensive areas of tall, old Calluna and this site is known to have remained unburnt since about 1936 (an extensive fire has since occurred at this site).

Like transitional peat bog P1, wet peat bog P2 is characterized by the presence of a range of aquatic habitats. For the standing water type, puddles occurred in 10.3% of quadrats, ditch (2.6%) and loch (2.6%). No flowing water was recorded but dried-up water, in the form of puddle (5.1%), ditch (10.3%), stream (2.6%) and loch (2.6%), was recorded in the type. These levels of aquatic habitats are very similar to P1 (see above).

Wet peat bog P2 shows a strong preference for west in both local aspect (53.8%) and general aspect (59.0%). Slopes are slightly more gentle than for P1, with less than 1 degree 25.6% (18.5% for P1), 1-5 degrees 48.7% (51.9% for P1), 5-15 degrees 20.5% (24.1% for P1) and over 15 degrees 5.1% (5.6% for P1). The proportion of steeper slopes in the type is a little unexpected until a closer examination of individual quadrats is undertaken. This shows that a number of the quadrats allocated to the type occur on quite localized peaty areas, e.g. hollows in raised rocky localities. This means that most steep slopes are probably an edge effect. Also, it should be noted that slopes were recorded for the full 200 sq m quadrat and were not limited to the central 25 sq m, on which the vegetation classification is based. Surface types show similar trends, with 79.5% of quadrats either plane or simple undulating. P2 is a more low-lying type than P1, with 59.0% of quadrats under the 50ft contour (cf. 38.0% for P1) and with a mean elevation of 50.6ft (93.9ft for P1). Like P1, P2 occurs at widely different distances from the sea (10-50m zone up to 1500m+) with a mean of 504m (cf. 437m for P1).

The geographical distribution of wet peat bog P2 is very characteristic, occurring in only eight sites. All of these sites are in the west of Scotland and mostly on the inner Hebrides (Colonsay and Islay) or on the mainland. There are only two quadrats of the type in the Outer Hebrides (Pabbay and Uig). The greatest frequency of the type is at Laggan Bay on Islay, where no less than 40% of that site is occupied by P2 (17 out of 39 examples of the type). Garvard, on Colonsay, is composed of 29% of P2 and Redpoint on the mainland 22%. The remaining five sites have no more than two quadrats each. From Sandwood on the north-western tip of Scotland along the north coast and right down the east coast there are no examples of wet peat bog P2 in any site.

P3 - Flushed peat bog

P3 - Flushed peat bog

(dominated by Molinia caerulea, Calluna vulgaris and Myrica gale)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 5)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	3	3	27 Stilligarry (South)	1	4
50 Redpoint	1	4	83 Forvie	2	2
84 Don to Ythan	1	2			

P3 - Flushed peat bog, dominated by Molinia caerulea, Calluna vulgaris and (Myrica gale)

It will be immediately noted that the three most common dominants in P3 are exactly the same and in the same order as for wet peat bog P2. Again, this shows how dominants can be misleading for, in fact, the two types are quite different in a large number of other respects.

Flushed peat bog P3 is a very uncommon type with only 8 quadrats (0.2%) in the survey. This is considered to be too few quadrats to draw firm conclusions and the following is a rather brief description of the type, which is all that is possible in the circumstances. The type has three outlets in the key; step 17 (+ve) with 2 quadrats, step 25 (+ve) with 3 quadrats and step 41 (+ve) also with 3 quadrats. There is no reason to suppose there are ecologically significant differences between these three forms. Steps 25 and 41 are both in the part of the key that is entirely devoted to Peatland types (see Figure 6A) and step 17 (+ve) is an isolate from quadrats that otherwise proceed to G1 or G2.

The most common species in P3 is Potentilla erecta (87.5%). Below this there is a big drop to seven species with a frequency of 62.5%, i.e. 5 out of the 8 quadrats - Carex nigra, Erica tetralix, Holcus lanatus, Juncus effusus, Nardus stricta, Rumex acetosa and Viola palustris. A further six species occur in 50% of quadrats - Agrostis canina, Anthoxanthum odoratum, Calluna vulgaris, Carex echinata, Molinia caerulea and Potentilla palustris. This means that there are 14 species with a frequency of 50% or more and 58 with 10% or more (which is also the total complement of species for the type).

It is difficult to decide from what flushed peat bog P3 has developed or to what other type it is most closely related. It is similar to P1 and P2 by being peaty but is less acid and, probably, more mineral rich (hence the use of the term "flushed" in the type name). In terms of mineral richness, it is more like acid, wet grassland G7, which type also has a rather similar geographical distribution. Finally, it can also be regarded as being similar to very acid, damp grassland G4 and, in fact, purely in terms of species change as measured by the preferential species for the two types, this relationship involves the minimum change in composition. The return to partly mineral soils in P3 also makes it similar to G4 (and G7) but, against this, is the geographical distribution of G4, which is exclusively eastern. P3 is also rather a hummocky type with wet hollows and drier raised areas, often in the form of closely packed tussocks. In this respect it resembles G7.

Because P3 is not a common type it would be superfluous to explore the above relationships in further detail. However, just to illustrate one of these possible relationships, and it is not seriously suggested it is a successional one, the following table of preferential species makes the comparison between very acid, damp grassland G4 and flushed peat bog P3.

Preferential Species for Type G4:-

Species Names	G4 %	P3 %
Agrostis tenuis	86.2	12.5
Carex arenaria	69.0	0.0
Cerastium holosteoides	24.1	0.0
Festuca ovina	89.7	25.0
Galium saxatile	89.7	25.0
Juncus squarrosus	37.9	12.5
Luzula campestris	44.8	12.5
Luzula multiflora	51.7	25.0
Poa pratensis	86.2	0.0
Salix repens	31.0	12.5
Senecio jacobaea	27.6	0.0
Sieglingia decumbens	20.7	0.0
Trifolium repens	27.6	0.0

Preferential Species for Type P3:-

Species Names	G4 %	P3 %
Angelica sylvestris	0.0	25.0
Carex echinata	3.4	50.0
Dryopteris dilatata agg.	6.9	25.0
Empetrum nigrum	6.9	25.0
Equisetum palustre	10.3	25.0
Eriophorum angustifolium	0.0	37.5
Molinia caerulea	6.9	50.0
Myrica gale	0.0	25.0
Potentilla palustris	3.4	50.0
Viola palustris	31.0	62.5

In this table, a series of species favouring damp, acid soils, (with free drainage) in G4, e.g. Agrostis tenuis, Festuca ovina, Galium saxatile and Poa pratensis, give way to species that require wetter conditions (with high water table) in P3, e.g. Carex echinata, Molinia caerulea, Potentilla palustris and Viola palustris. One feature that is not apparent from the above comparisons between types is the behaviour of certain species which range over all the types under consideration. The most striking of these is Potentilla erecta, with 96.6% in G4, 65.2% in G7, 97.2% in P1, 100.0% in P2 and 87.5% in P3.

In terms of cover species, flushed peat bog P3 is remarkably similar to the two other Peatland types P1 and P2. The most important species is Molinia caerulea with 27.5% cover (cf. P1 with 23.0% and P2 with 27.7%) and Calluna vulgaris 23.1% (cf. P1 with 16.2% and P2 with 30.4%). Even the third most important species Eriophorum angustifolium (4.5%) occurs in the other two types (P1 with 1.3% and P2 with 5.3%). Again, this is a warning against jumping to hasty conclusions about the ecological relationships of vegetation types based purely on dominants. Several further species have mean cover of 3% or more - Juncus effusus (3.3%), Nardus stricta (3.3%), Potentilla palustris (3.3%), Festuca rubra (3.2%) and Juncus acutiflorus (3.2%). Mean cover of vascular plants is 97.6% and this is supplemented by that for bryophytes, which occur in 100.0% of quadrats with a mean cover of 13.4% (cf. 9.9% in P1 and 20.3% in P2). Lichens are totally absent from P3. There is a very restricted range of non-vegetative cover types in P3 but undecomposed organic matter occurs in 37.5% of quadrats with a mean cover of 10.1%, decomposed organic matter 12.5% with negligible cover and freshwater in 37.5% and 1.4%.

As might be expected with such an uncommon type, the range of potential dominants (15 species) is limited to those species that make a major contribution to the overall cover within the type. Peatland P3 is moderately species-rich, with a mean of 16.3 species per quadrat (cf. 26.5 for P1 and 12.8 for P2).

The only significant association between flushed peat bog and the soil types involves Thin Soil TS8 (a peaty type) with 37.5% of quadrats. Other types which occur are Deep Sandy Soils DS6 (2 quadrats) and DS7 (1 quadrat), Peaty Soil PS3 (1 quadrat) and Thin Soil TS9 (1 quadrat). The main emphasis is thus seen to be is on peaty soils with a high water table or overlying rock.

Grazing pressure is much reduced in P3, with 25% of quadrats ungrazed and 75% lightly grazed. Cattle were recorded in 12.5% of quadrats, sheep in 25.0% and rabbit in 25.0%. There are few records of human disturbance of any type but fire evidence was recorded in one quadrat (12.5%) and rubbish from 37.5%.

No sensible conclusions can be drawn about aspect. Slopes are fairly gentle, with 87.5% under 5 degrees, and the surface type is similar with 87.5% either plane or simple undulating. Most quadrats (62.5%) are located under the 50ft contour with a mean height of 56.3ft. Mean distance from the sea of 964m is higher than for any other Peatland type (cf. P1 with 437m and P2 with 504m).

No real conclusions can be drawn about the geographical distribution of flushed peat bog P3, which occurs in only five sites. There are three quadrats of the type at Torrs Warren in the south-west of Scotland and two at Forvie in the east. Looking at the distribution of P3 within sites does little to resolve the relationships of the type. Generally it occurs in close proximity to G3, G4, P1 or P2.

7.5 Vegetation Types Influenced by Freshwater

There is just one family, Marshland, in this section of the vegetation classification. The family itself comprises four types (two of them very minor) in which the common factor is, as the family name suggests, the water relations of the soil. As might be expected, there is no discontinuity between the Marshland types and some vegetation types in other families which are influenced by water, but to a lesser degree. Other families with which the Marshland types have some affinities include Duneland (wet, slightly acid dune grassland D5), Grassland (slightly acid, wet grassland G6 and acid, wet grassland G7), Peatland (flushed peat bog P3) and Saltmarsh (upper saltmarsh S4). In the case of S4, the wet influence is largely in terms of brackish water but the borderline between fresh and saltwater marsh is inevitably somewhat blurred. The distinction between the Marshland family and these types is largely arbitrary. In floristic terms, it depends on the balance between genuine marsh species, i.e. those that do not grow anywhere else, and those species requiring a different type of habitat. In environmental terms, the marshland habitat is characterized by high water table and largely anaerobic soil conditions throughout most of the year. It is the continuity of these factors that may be the important feature. Other habitats, e.g. some low dune slacks, may have a temporarily high water table - usually in the winter - but this is lowered throughout most of the growing season. Many sand dune areas have quite wide fluctuations in the level of their water table. In general, the Marshland types escape this fluctuation in water level by having some special relationship with the drainage pattern of the site. Usually they are in close proximity to some permanent water body or some major (artificial or natural) drainage channel. Other examples of the type are found in water receiving situations, i.e. flushed areas.

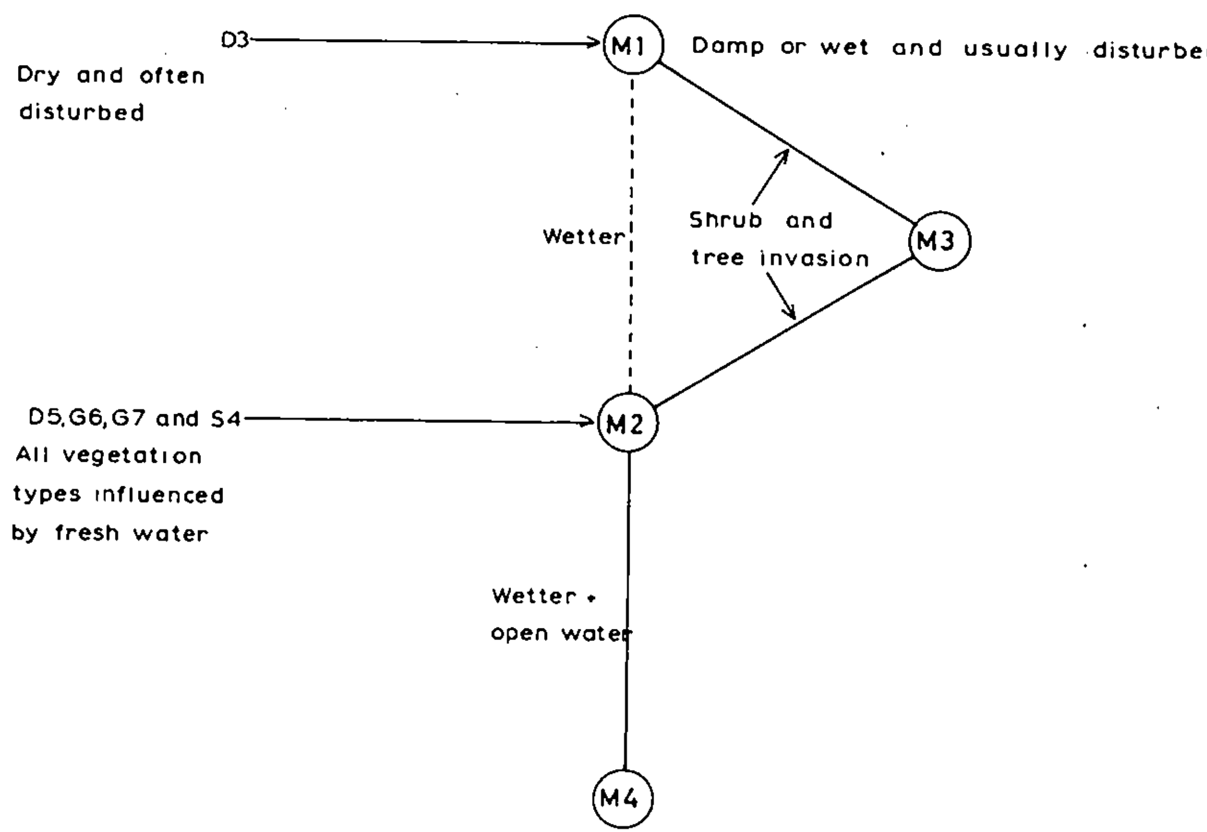
Because the Marshland types are fairly uncommon in the coastal habitat as compared with other families, e.g. Duneland and Grassland families, this presents certain analytical problems. These are problems that have been solved (see Section 6.3) but only at the expense of increased complication of the key that can be used to derive these vegetaation types. Marshland type M1 has 8 outlets in the key, M2 has 9 and M3 and M4 2 each. The same situation arises in the maritime part of the population, the Saltmarsh and Foredune families, where upper saltmarsh S4 has no less than 13 outlets in the key for 81 quadrats. This does not imply that the key is any less accurate for such types than it is for a type with only one or two outlets, but that most of the quadrats in minority types contain conflicting evidence as to their affinities. This is because, as well as the specialized species which only they support, they also contain an assortment of species that are typical of the more common vegetation types. This type of complexity is not always easy to resolve.

Initially, the sorting process of the key tends to be based on the common species found in the common vegetation types. Only later does it take much account of the rarer species found in the rarer vegetation types. This is what causes the fractionation of the rarer vegetation types, a condition which has to be rectified by the re-allocation procedure. The apparently curious mixture of species often found in the rarer vegetation types is usually the result of transitions with, or occlusions of, other types. Rare types tend to have a large edge effect, i.e. a sample is likely to fall on an edge, partly because they occupy a small total area - otherwise they would not be rare - and also because they tend to be broken up into a number of smaller, discontinuous patches. In either case, the length of edge is high in proportion to the area. The most extreme example of this effect is found where there are linear habitats, such as a stream or loch edge, and this is exactly where most of the Marshland types of quadrats occur. In the first year of the survey (1975), water edge (loch or stream) was sampled as a separate stratum (see Section 4.2). Because of the low area sampled, allied to a fixed number of samples, the sampling intensity in this type was higher in 1975 than in subsequent years (when sampling was proportionate to area). Hence a disproportionate number of Marshland type quadrats emanate from that year (N.B. this is corrected for by calculating weighted frequencies in all maps or tables showing proportions of vegetation types in sites). To be surveyed properly, such linear vegetation types really require a smaller sized, or even linear, quadrat as the basis of sampling. This fact was realized in advance of the survey but it was considered that the detailed study of specialized habitats was not really a legitimate pursuit in a large scale, general survey.

As with the Peatland family above, no claim is made that the classification of marshy or boggy types is satisfactory in a wider context. The reasons for this limitation are the same as for the Peatland family, i.e. the sample on which the types are based is small and almost certainly represents a biased view of the total population which can occur in this type of habitat.

Figure 4

Putative Relationships of Vegetation Types Influenced by Fresh Water



7.5.1 Marshland Family (M1-M4)

This family, with 134 (3.5%) quadrats allocated to it, does not represent a particularly important part of coastal vegetation. With the exception of M2, the family is not a very satisfactory one. However, in partial mitigation, M2 does comprise 87 out of 134 quadrats (64.9%) of the family.

Figure 4 shows the putative relationship between the types. The absence of arrows, except for two cases (M1 and M2 to M3), is meant to indicate that development of one type from another is not considered to be a likely or normal event. The possible relationship with other families is shown on the lefthand side of the diagram.

M1 - Damp, disturbed marsh

M1 - Damp, disturbed marsh

(dominated by Agrostis stolonifera, Holcus lanatus and Arrhenatherum elatius)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 21)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
2 Macrihanish Dunes	2	4	6 Gruinart	2	3
27 Stilligarry (South)	1	0	43 Barvas	1	3
44 Europie	1	3	45 Tolsta	4	13
51 Holland	1	3	61 Reay	3	5
62 Dunnet	1	4	71 Whiteness	1	4
76 Spey Bay (West)	2	4	77 Spey Bay (Central)	2	5
78 Spey Bay (East)	1	4	82 Cruden Bay	1	3
84 Don to Ythan	1	2	87 Lunan Bay	1	5
88 Arbroath	2	7	89 Barry Links	2	2
91 Dumbarnie	3	10	92 Aberlady	3	10
95 Tyninghame	2	10			

M1 - Damp, disturbed marsh, dominated by (Agrostis stolonifera), Holcus lanatus and (Arrhenatherum elatius)

There are 37 quadrats of this type (1.0%) for which there are 8 outlets in the key; step 23 (+ve) isolates 4 quadrats, step 54 (-ve) with 8, step 56 (+ve) with 11, step 61 (+ve) with 3, step 65 (+ve) with 2, step 66 (+ve) with 2, step 68 (+ve) with 5 and step 76 (+ve) with 2. First of all, it should be noted that just two outlets, step 54 (-ve) and 56 (+ve), determine over 50% of the type (19 out of 37 quadrats) and, secondly, that all but one of the outlets occur in the same part of the classification (see Figure 6B). This part of the hierarchy, determined by step 1 (-ve), step 2 (-ve) and step 3 (+ve), is largely concerned with sorting out the base-rich members of the Duneland family (types D1, D2, D3 and D4) and Colonist type C. The section of key stemming from the next step (42 (+ve)) is entirely concerned with Marshland types (M1, M2 and M4) and Foredune types (F1 and F2). This is taken as evidence that damp, disturbed community M1 is a reasonably valid type in which the common factors are some degree of base-richness and wetness, i.e. there are few acid elements present because these are represented by the Grassland (part) and Peatland families.

The first notable feature of M1 is that it has no really "constant" species, i.e. no species has a high frequency in the type. There is no species with a frequency of over 60% and only four in the 50%-60% range - Cirsium arvense (56.8%), Ranunculus repens (56.8%), Holcus lanatus (54.1%) and Festuca rubra (51.4%). This feature is also found to a lesser extent in wet marsh M2 (to be dealt with next), which has only Agrostis stolonifera (86.2%) with a frequency of over 60%. The reason for the lack of constant species in what are moderately species-rich types (18.2 and 17.2 species per quadrat for M1 and M2 respectively) is not really understood at the present time. The most obvious explanation is that they are not very homogeneous types and this may be true, in the sense that they are not such tightly defined types as are found in the Duneland or Grassland families. Disturbance in M1 and the presence of specialized habitats in M2 may account for some of the effect. There are 51 species in M1 with a frequency of 10% or more.

Figure 4 shows a relationship between damp, disturbed marsh M1 and semi-stable dune grassland D3. It is not seriously suggested that this is a normal successional relationship but it is, at least theoretically, possible for D3 to change into M1 under conditions that lead to an increase in wetness, e.g. raised water table or a blowout or erosion cutting down to produce a new land surface nearer the water table. The following table of preferential species makes the comparison between the two types.

Preferential Species for Type D3:-

Species Names	D3 %	M1 %
Ammophila arenaria	70.5	29.7

Preferential Species for Type M1:-

Species Names	D3 %	M1 %
Agrostis stolonifera	9.9	48.6
Equisetum palustre	0.2	24.3
Filipendula ulmaria	4.7	27.0
Lathyrus pratensis	4.7	32.4
Lolium perenne agg.	9.5	21.6
Ranunculus repens	10.8	56.8
Rumex acetosa	9.7	24.3

The abbreviated nature of this table is in itself proof of the similarity of the two types. The single species preferential to D3 and declining in M1 is Ammophila arenaria (down from 70.5% in D3 to 29.7% in M1). This can be interpreted as increasing wetness or soil profile development, i.e. increase in stability and humus content. Probably both factors are active, because M1 contains a notably wide range of soil types, from beach deposits to peat! There are seven species preferential to M1 and and five of these can be interpreted as resulting from a straightforward increase in wetness - Agrostis stolonifera (up from 9.9% in D3 to 48.6% in M1), Equisetum palustre (0.2% to 24.3%), Filipendula ulmaria (4.7% to 27.0%), Lathyrus pratensis (4.7% to 32.4%) and Ranunculus repens (10.8% to 56.8%). The increase in Lolium perenne agg. (9.5% to 21.6%) and Rumex acetosa (9.7% to 24.3%) is neither so clear-cut nor interpretable. The former species may well be related to re-seeding and the latter does favour damper habitats.

When examined in terms of cover, M1 appears to be even more peculiar. The most important cover species turns out to be Petasites hybridus (10.4%). But this species only occurs in 10.8% of quadrats, i.e. it has virtually 100% cover in just 4 quadrats! The second most important cover species is Festuca rubra (8.8%), followed by Lolium perenne (7.9%), Agropyron repens (6.0%) and Ulex europaeus (5.8%). Apart from Festuca, which occurs in 51.4% of quadrats, the other species are to some degree similar to Petasites, i.e. achieving high cover in just a few quadrats. Lolium occurs in 21.6% of quadrats, Agropyron 24.3% and Ulex in 16.2%. Arrhenatherum elatius is more like Festuca rubra with 5.7% cover and a frequency of 40.5%. Other species with cover of 3% or more are Ammophila arenaria (cover 5.6% and frequency 29.7%), Agrostis stolonifera (4.8% and 48.6%), Holcus lanatus (4.5% and 54.1%), Cirsium arvense (4.4% and 56.8%) and Anthoxanthum odoratum (3.1% and 18.8%). The varied vegetation cover of M1 is further demonstrated by the list of potential dominants (species with 10% or more cover in a quadrat) which is long for a type with so few quadrats, 40 species in all and 20 in more than one quadrat. The list is typified by species which achieve extremely high cover as dominants, i.e. in those quadrats where their cover exceeds 10%. For example, Petasites has a mean cover as a dominant of 96.3%, Ammophila arenaria has 50.0% and Anthoxanthum odoratum has 50.0%.

Vascular plants achieve almost complete cover in this type, with a mean of 102.8%. Bryophytes and lichens are relatively unimportant, bryophytes occur in 51.4% of quadrats with a mean cover of 1.0%, whilst the equivalent figures for lichens are 2.7% and negligible cover. A wide range of non-living cover types was recorded in M1, the most important of these being undecomposed organic matter, with a frequency of 16.2% and cover of 2.9%, clay with 8.1% and 2.4%, bare sand with 37.8% and 9.2%, gravel with 8.1% and 0.9%, cobbles with 10.8% and 3.9% and boulders with 8.1% and 0.1%. Fresh water occurs in 10.8% of quadrats with a mean cover of 3.8%. Tidal litter was recorded in 10.8% of quadrats with a mean cover of 0.2%.

As far as soil types are concerned, damp, disturbed marsh M1 is singularly ill-defined. Only three soil types are significantly associated with M1, Beach Deposits BD3 (5.4%), Thin Soil TS3 (5.4%) and mature Deep Sandy Soil DS7 (24.3%), together accounting for only 35.1% of the type. Other common soil types are semi-mature, Deep Sandy Soils DS5 (21.6%) and DS6 (10.8%, this a negative correlation) and Thin Soil TS9 (10.8%). The addition of these three types accounts for a further 43.2% (total accounted for 78.3%). This really is a very mixed collection of soil types but examination of individual quadrats reveals the common trend as being damp, often humic or disturbed soils.

Grazing pressure on damp, disturbed marsh M1 is quite low, with 35.1% of quadrats being recorded as having no grazing, 35.1% as light, 18.9% as moderate and 10.8% as heavy. Domesticated herbivores, in particular, are much reduced, with cattle in 16.2% of quadrats and sheep in 8.1%. Rabbits are, however, fairly frequent at 56.8%. A wide range of disturbance factors are present in M1, usually at low frequency levels - wall (2.7%), fence (2.7%), tarmac road (2.7%), dirt road (2.7%), vehicle track (5.4%), unsurfaced path (2.7%), planted trees (5.4%), recent cultivation (2.7%), standing crop (2.7%) and rubbish (18.9%).

A proportion of quadrats contain aquatic habitats of various kinds - loch (5.4%), ditch (2.7%), stream (5.4%), river (5.4%), dried-up stream (2.7%).

Local aspect for M1 is fairly neutral but general aspect shows a slight preference for north and east (together 62.1%). Slopes are varied, with up to 1 degree in 24.3% of quadrats, 1-5 degrees in 45.9%, 5-15 degrees in 27.0% and over 15 degrees in 2.7%. Surface types are similarly varied, with the majority being plane or simple undulating (total of 81.0%). Most of the examples of M1 are under the 50ft contour (78.4%) but the type extends as high as the 150-200ft zone. Distance from the sea is extremely varied, with 5.4% in the 0-10m zone and 10.8% in the 10-50m. Such quadrats explain the presence of beach deposits and tidal litter. However, the modal distance for the type is 200-400m (27.0%) but one quadrat is over 1500m from the sea. The distribution of distance from the sea is rather similar to that for semi-stable dune grassland D3 but the mean distance is higher 325m (cf. 179m for D3).

The geographical distribution of damp, disturbed marsh M1 is quite distinctive. It occurs mainly on the east coast of Scotland, reaching its peak in sites bordering the Firth of Forth where Dumbarnie, Aberlady and Tyninghame all contain 10% of the type. It occurs less frequently on the north coast but there is another minor concentration on the northern tip of Lewis where Tolsta contains 13%. The rest of the Hebrides and west coast contribute only three examples of the type.

It is quite difficult to characterize damp, disturbed marsh M1 except to use the term, quite often used in Clapham, Tutin and Warburg to describe the habitat of certain species, such as Agropyron repens, i.e. "waste places". In this instance they are damp, waste places and include such disturbed habitats as rubbish dumps, track edges, embankments, ditch and stream beds and other areas that are disturbed by a variety of activities, some of them unknown. Species typical of this type of situation include Arrhenatherum elatius, Heracleum sphondylium, Urtica dioica, Agropyron repens, Rumex crispus, Potentilla anserina, Stellaria media, Rumex obtusifolius, Galium aparine, Poa annua, Capsella bursa-pastoris, Plantago major and Poa trivialis. There is also an element of scrub invasion, e.g. Ulex europaeus and Hippophae rhamnoides, and of course other invasion in the form of Petasites hybridus, although all quadrats dominated by this species occurred on Lewis (Barvas and Tolsta). Low grazing may also be a factor in the type which, on further examination, might prove to be rather transient, i.e. with a tendency to settle down and change into something else with time. This is something that could only be discovered by monitoring and, from a practical viewpoint, there are probably other more important vegetation types where the dynamics are in doubt.

M2 - Wet marsh

M2 - Wet marsh

(dominated by Agrostis stolonifera, Carex nigra and Hydrocotyle vulgaris)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 36)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	1	1	2 Macrihanish Dunes	1	0
6 Gruinart	1	1	7 Oronsay	1	2
9 Kiloran Bay	1	3	12 West Tiree	3	3
13 Ballevullin	1	3	15 Crossapol and Gunna	1	1
16 Totamore Dunes	1	3	17 Gallanach	1	2
18 Vatersay	1	3	21 Daliburgh	3	6
22 Oraiclate	5	11	23 Howbeg	1	5
25 Loch Bee	3	4	27 Stilligarry (South)	3	8
33 Vallay	1	3	35 Balranald	5	11
38 Pabbay	1	2	44 Eoropie	3	10
48 Scousburgh	2	7	51 Holland	2	6
54 Sheigra	3	11	58 Farr Bay	2	1
62 Dunnet	3	5	63 Freswick	1	3
64 Sandwood	2	4	65 Sinclairs Bay	1	3
75 Lossiemouth	1	0	76 Spey Bay (West)	7	26
77 Spey Bay (Central)	1	1	80 Strathbeg	12	19
89 Barry Links	3	3	90 Tentsmuir	3	4
92 Aberlady	5	16	93 Gullane	1	1

M2 - Wet marsh, dominated by Agrostis stolonifera, Carex nigra and (Hydrocotyle vulgaris)

This is the most common of the Marshland types, with 87 quadrats (2.3%) allocated to it. As already noted, it has no less than nine outlets in the key; step 12 (+ve) which isolates 1 quadrat, step 20 (-ve) with 44 quadrats, step 59 (+ve) with 7 quadrats, step 61 (-ve) with 25 quadrats, step 62 (+ve) with 4 quadrats, step 69 (+ve) with 2 quadrats, step 74 (+ve) with 1 quadrat, step 75 (+ve) with 1 quadrat and step 83 (+ve) with 2 quadrats. This list reveals that steps 20 (-ve) and 61 (-ve) together deal with 69 quadrats (79.3%) of the type. The nine outlets for M2 are a good deal more dispersed in the key than those for M1. In particular, step 20 (-ve), which isolates just over half of the type, is in a quite different part of the key (see Figure 6A), one which is chiefly concerned with splitting up the various forms of slightly acid, wet grassland G6 and acid, wet grassland G7 (also minority forms of D5 and P1). There is obvious logic about this because, as already noted in the introduction to the Marshland family, both G6 and G7 are considered to be borderline marshy types. The crucial step in the key is step 3, where the more acid types go to the negative side. This is followed by step 4 which removes the extreme acid element on the positive side. Following this, on the negative side, is step 5 which is concerned with wet and dry species, the wet indicators (+ve) being Caltha palustris, Cardamine pratense, Galium palustre, Hydrocotyle vulgaris and Ranunculus flammula. It is this step which determines the branch with step 20 in it. The other major outlet for type M2 is firmly rooted in the part of the key that deals with mainly Marshland types (see M1 above and Figure 6B). As with M1, the majority of outlets for M2 occur in the Duneland part of the key (7 of the 9) but one outlet is, in fact, on the maritime side of the key. This is step 83 (+ve) which, although it isolates only 2 quadrats, does serve to show the continuity of freshwater and brackish marshes (as does a form of G6 from which M2 is separated in this part of the key, see Figure 6C).

All nine forms of M2 are considered together for the rest of the description of the type but it is as well to remember that there are more and less acid forms of the type, and even a peripheral saltmarsh influence, included in the range of variation.

As already noted, wet marsh M2, like M1, is weak on constant species and only Agrostis stolonifera (86.2%) has a frequency of over 60%. Four other species have frequencies from 50%-60% - Galium palustre (55.2%), Carex nigra (54.0%), Holcus lanatus (52.9%) and Cardamine pratensis (51.7%). There are 52 species with a frequency of 10% or more (cf. 51 for M1).

Figure 4 shows a fairly close relationship between damp disturbed marsh M1 and wet marsh M2. The following table of preferential species makes the comparison between the two types.

Preferential Species for Type M1:-

Species Names	M1 %	M2 %
Achillea millefolium	32.4	0.0
Agropyron repens	24.3	2.3
Ammophila arenaria	29.7	2.3
Arrhenatherum elatius	40.5	4.6
Carex arenaria	21.6	3.4
Centaurea nigra	27.0	1.1
Cirsium arvense	56.8	9.2
Dactylis glomerata	35.1	1.1
Festuca rubra	51.4	19.5
Galium verum	27.0	0.0
Heracleum sphondylium	37.8	1.1
Lathyrus pratensis	32.4	12.6
Lolium perenne agg.	21.6	6.9
Lotus corniculatus	29.7	8.0
Plantago lanceolata	43.2	8.0
Rumex acetosa	24.3	9.2
Senecio jacobaea	43.2	3.4
Taraxacum spp.	24.3	3.4
Urtica dioica	27.0	4.6

Preferential Species for Type M2:-

Species Names	M1 %	M2 %
Caltha palustris	5.4	44.8
Cardamine pratensis	5.4	51.7
Carex nigra	0.0	54.0
Eleocharis palustris	5.4	27.6
Epilobium palustre	0.0	36.8
Equisetum fluviatile	0.0	28.7
Galium palustre	2.7	55.2
Hydrocotyle vulgaris	5.4	44.8
Juncus articulatus	5.4	44.8
Juncus effusus	2.7	21.8
Lychnis flos-cuculi	0.0	28.7
Mentha aquatica	8.1	31.0
Myosotis caespitosa	5.4	21.8
Potentilla anserina	18.9	41.4
Potentilla palustris	0.0	27.6
Ranunculus flammula	2.7	26.4

The ecological implications of the above table are fairly clear. Species preferential to M1 and reduced in M2 are mostly of a type that require dry or, at most, damp soil conditions but which cannot tolerate continued wetness. Some of these are typical dune species which can grow on more or less unmodified, dry sand, e.g. Achillea millefolium (down from 32.4% in M1 to 0.0% in M2), Ammophila arenaria (29.7% to 2.3%), Carex arenaria (21.6% to 3.4%), Festuca rubra (51.4% to 19.5%), Galium verum (27.0% to 0.0%) and Plantago lanceolata (43.2% to 8.0%). Several of the "coarser" grass species, which typically grow in waste places, are also on the decline in M2, e.g. Agropyron repens (24.3% to 2.3%), Arrhenatherum elatius (40.5% to 4.6%) and Dactylis glomerata (35.1% to 1.1%). One species which shows a slightly unexpected decline in M2 is Lathyrus pratensis (down from 32.4% to 12.6%). Conversely, species favouring M2 as opposed to M1 are exclusively those that grow in wet habitats, e.g. Caltha palustris (up from 5.4% in M1 to 44.8% in M2), Cardamine pratensis (5.4% to 51.7%), Carex nigra (0.0% to 54.0%), Galium palustre (2.7% to 55.2%), Hydrocotyle vulgaris (5.4% to 44.8%), Juncus articulatus (5.4% to 44.8%) and Epilobium palustre (0.0% to 36.8%). Species richness is very similar to M1, with 17.2 species per quadrat (cf. 18.2 for M1).

The main species contributing vascular plant cover to wet marsh M2 are Carex nigra (8.5%) and Agrostis stolonifera (7.9%). There are four more species with mean cover of 3% or more - Juncus effusus (4.8%, but only in 21.8% of quadrats), Juncus articulatus (4.5%), Carex rostrata (4.3%, but only in 13.8% of quadrats) and Hydrocotyle vulgaris (3.6%). As with M1, there is an extremely long list of potential dominants in M2 (species with 10% or more cover in a quadrat). There are 34 potential dominants in more than one quadrat and another 34 in one quadrat only (a total of 68 species). This is quite a high figure for a vegetation type with only 87 quadrats.

Total cover of vascular plants in M2 is less than complete, with a mean of 92.7% (cf. M1 with 102.8%). The difference in vascular plant cover is largely made up by a resurgence of bryophyte cover which occurs in 73.6% of quadrats with a mean cover of 8.0% (cf. 51.4% and 1.0% in M1). Lichens have little importance, occurring in only 5.7% of quadrats with a mean cover of 0.1%. The most important non-living cover categories are undecomposed organic matter in 11.5% of quadrats with a cover of 2.0%, decomposed organic matter (12.6% and 1.5%) and bare sand (19.5% and 8.4%, i.e. sand has a mean cover of about 40% in 20% of quadrats!). Freshwater was recorded in 33.3% of quadrats with a mean cover of 8.2% and saline water 2.3% and 1.2% (the saltmarsh element in the type).

In terms of soil types, wet marsh M2 is much better defined than M1. Highly associated soil types are Peaty Soils PS3 (10.3%), PS4 (5.7%) and PS5 (10.3%) and Thin Soils (peaty) TS8 (10.3%) and TS9 (31.0%). Together these five types account for 67.6% of quadrats. Other common soil types are semi-mature, Deep Sandy Soil DS6 (12.6%) and mature, Deep Sandy Soil DS7 (8.0%) but both these represent strong negative associations. This raises the total of quadrats accounted for to 88.2%. The overall relationship of M2 is with peaty soil types although, in view of the species composition, this might be better termed as highly organic soils. The soil classification based only on simple visual characteristics of the soil does not differentiate properly between acid peaty soils and the more base-rich, high organic, marshy soils.

Like damp, disturbed marsh M1, wet marsh M2 is lightly grazed. No grazing was recorded in 40.2% of quadrats (cf. 35.1% in M1), light grazing in 34.5% (cf. 35.1% in M1), moderate grazing in 19.5% (cf. 18.9% in M1) and heavy grazing in 5.7% (cf. 10.8% in M1). This low pressure is in sharp contrast to heavily grazed types such as damp, base-rich dune grassland D4, with grazing intensities of none (3.8%), light (30.8%), moderate (35.8%) and heavy (29.6%). The source of grazing pressure in M2 is fairly well balanced between cattle (35.6%), sheep (20.7%) and rabbit (32.2%). There is a certain amount of human disturbance in M2 - embankment (2.3%), vehicle track (5.7%), unsurfaced path (5.7%), fire evidence (2.3%), recent cultivation (1.1%) and old cultivation (2.3%). Rubbish was recorded from 31.0% of quadrats (cf. 18.9% for M1 or D2 43.1%).

Aquatic habitats are quite an important feature of wet marsh M2. Puddles were recorded in 2.3% of quadrats, ditch (5.7%), pond (5.7%), loch (16.1%), stream (2.3%), river (4.6%), dried-up puddle (1.1%), dried-up ditch (3.4%), dried-up stream (1.1%), dried-up pond (3.4%) and dried-up loch (3.4%).

In terms of local aspect, M2 shows a slight preference for northern aspects (32.2%) whereas general aspect has a strong tendency to west (46.0%). Slopes are very gentle with 62.1% under 1 degree and 33.3% in the 1-5 degree range (total 95.4%). Surface types show a similar trend, with 78.2% plane and 18.4% undulating simple (total 96.6%). Wet marsh M2 is an almost exclusively low elevation type, with 94.3% of quadrats under the 50ft contour (mean elevation 30.2ft OD). However, distance from the sea is very variable from the 0-10m zone up to over 1500m+. Mean distance from the sea is 778m (cf. 325m for M1).

The geographical distribution of wet marsh M2 shows no distinctive pattern. The type is well distributed round the Scottish coast, being present in 36 out of the 94 sites. Notable areas of absence are Harris and Lewis in the Outer Hebrides (although Europie has 10% of the type) and parts of the east coast, probably the result of site truncation. The type achieves its maximum importance in Spey Bay (West) on the Moray Firth, with 26%, and this is closely followed by Strathbeg (19%) and Aberlady (16%).

The reason for the type being so widely distributed, with no sign of the east/west differentation which characterizes so many other types, is probably because hydrological and edaphic conditions are the critical factors, overriding climate, substrate type and land-use factors. In this respect the type is similar to Colonist type C and semi-stable dune grassland D3, in which stability and disturbance are the dominant factors. A similar replacement of critical factors is particularly evident in the Saltmarsh family, where all but one of the five types show no marked geographical distribution. This is interpreted as the effect of saltwater inundation assuming the role of the critical environmental factor.

The remaining two members of the Marshland family M3 and M4 can be dealt with very briefly since, quantitatively, they are extremely unimportant, with 6 and 4 quadrats allocated to them respectively.

M3 - Shrub invaded marsh

M3 - Shrub invaded marsh

(dominated by Agrostis stolonifera, Ulex europaeus and Salix cinerea agg.)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 4)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	1	1	75 Lossiemouth	2	4
76 Spey Bay (West)	2	4	90 Tentsmuir	1	1

M3 - Scrub invaded marsh, dominated by (Agrostis stolonifera), Ulex europaeus and Salix cinerea agg.

This type has just 6 quadrats (0.2%) allocated to it and has two outlets in the key. Step 40 (+ve) isolates 2 quadrats and step 58 (-ve) 4 quadrats. Because of its position in the classification, the former is likely to represent a slightly more acid form of the type (see Figures 6A and B).

The most common species in scrub invaded marsh M3 is Holcus lanatus (100.0%), followed by Lotus corniculatus (66.7%). Five species occur in exactly 50% of quadrats - Ranunculus repens, Rubus fruticosus agg., Salix cinerea agg., Senecio jacobaea and Ulex europaeus. Even from this limited list of species, two of the main characteristics of the type are evident; firstly the occurrence of dry habitats and, secondly, the presence of scrub or woodland species. The third feature, that of wetness, is also present as is evidenced by the presence of a number of marsh species, e.g. Hydrocotyle vulgaris (33.3%), Myosotis caespitosa (33.3%), Alnus glutinosa (16.7%), Cardamine pratensis (16.7%), Carex rostrata (16.7%) and a whole list of other species occurring in one quadrat out of the six. Species richness is very similar to the other Marshland types with 16.2 species per quadrat (cf. M1 with 18.2 and M2 with 17.2).

As far as relationships with other vegetation types are concerned, shrub invaded marsh M3 is probably most similar to, and, indeed, may be developed from, damp, disturbed marsh M1. Wet marsh M2 is another candidate but, as this contains few drier habitats, the former relationship seems more likely. The following table shows the preferential species for the two types M1 and M3.

Preferential Species for Types M1:-

Species Names	M1 %	M3 %
Achillea millefolium	32.4	0.0
Agropyron repens	24.3	0.0
Ammophila arenaria	29.7	0.0
Centaurea nigra	27.0	0.0
Cerastium holosteoides	37.8	0.0
Cirsium arvense	56.8	16.7
Dactylis glomerata	35.1	0.0
Equisetum palustre	24.3	0.0
Festuca rubra	51.4	16.7
Filipendula ulmaria	27.0	0.0
Heracleum sphondylium	37.8	0.0
Lathyrus pratensis	32.4	0.0
Lolium perenne agg.	21.6	0.0
Plantago lanceolata	43.2	0.0
Rumex crispus	21.6	0.0
Taraxacum spp.	24.3	0.0
Trifolium repens	35.1	0.0
Urtica dioica	27.0	0.0

Preferential Species for Type M3:-

Species Names	M1 %	M3 %
Agrostis tenuis	16.2	33.3
Deschampsia flexuosa	0.0	33.3
Dryopteris dilatata agg.	0.0	33.3
Hydrocotyle vulgaris	5.4	33.3
Lotus corniculatus	29.7	66.7
Myosotis caespitosa	5.4	33.3
Pinus sylvestris	0.0	33.3
Rubus fruticosus agg.	2.7	50.0
Rumex acetosella	2.7	33.3
Salix cinerea agg.	0.0	50.0
Ulex europaeus	16.2	50.0

Species preferential to M1 and declining in M3 are rather an odd assortment of dry habitat species, disturbance species and even some wet species. Preferential to M3 there are several woody species, e.g. Pinus sylvestris (up from 0.0% in M1 up to 33.3% in M3), Rubus fruticosus agg. (2.7% to 50.0%), Salix cinerea agg. (0.0% to 50.0%) and Ulex europaeus (16.2% to 50.0%). Other woody species not yet mentioned but present in M3 are Myrica gale, Prunus spinosa, Rosa canina agg., Rosa pimpinellifolia, Sarothamnus scoparius, Betula spp. and Salix nigricans. In this respect, M3 can be likened to shrub invaded grassland D6. Both are very uncommon types but may represent the ultimate successional trend on their respective habitat types, woodland in the case of D6 and carr in the case of M3.

The three most important cover species in M3 are trees or shrubs - Ulex europaeus (23.4%), Salix cinerea agg. (14.3%) and Pinus sylvestris (14.2%). Other species contributing significant cover are Agrostis stolonifera (11.7%), Juncus articulatus (6.7%), Deschampsia flexuosa (6.0%) and Myrica gale (5.0%). There are 14 potential dominants (species with 10% or more cover in a quadrat) in the type.

Total cover of vascular plants is high at 109.7% and this is supplemented by bryophytes in 83.3% of quadrats with a mean cover of 10.1%. Lichens were only recorded from one quadrat with negligible cover. Important non-living cover categories include undecomposed organic matter in 50.0% of quadrats with mean cover of 20.0%, cobbles in 33.3% and 10.0% and freshwater in 33.3% and 4.2%.

There is very little to say about soil types except that they are mainly rich in organic matter. Soil types CS3 (16.7%), PS1 (16.7%) and TS9 (33.3%) are all significantly correlated with vegetation type M3.

Grazing is again fairly light in shrub invaded marsh M3, with cattle in one of the six quadrats (16.7%) and rabbit in five (83.3%). No sheep were recorded in the type. In terms of human disturbance, one quadrat had sand quarrying, one had an embankment and another contained planted trees. Rubbish was also found in one quadrat (16.7%).

Nothing can be concluded about aspect from so few samples. Slopes are moderate, with 1-5 degrees in 66.7% of quadrats, and the most common surface type is simple undulating (66.7%). All quadrats are under the 50ft contour and mean distance from the sea is 595m.

No real conclusion can be drawn about the geographical distribution of shrub invaded marsh M3 except that all 6 quadrats occur in four sites that belong to Site Type 9 - East Coast Main Type - namely Torrs Warren, Lossiemouth, Spey Bay (West) and Tentsmuir. As already discussed in relation to Grassland G4, which has a similar geographical distribution, these are the largest (and probably most complete) sites in the survey.

M4 - Terrestrial/aquatic transitional marsh

M4 - Terrestrial/aquatic transitional marsh

(too few quadrats to determine dominance).

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 2)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
27 Stillisarry (South)	3	2	56 Faraid Head	1	3

M4 - Terrestrial/aquatic transitional marsh, with no clear dominants (only one species, Ranunculus trichophyllus, has cover of 10% or more in one quadrat)

There is even less to be said about this type than there was for M3 above. Of the four quadrats allocated to the type, three were half in a loch and the fourth was on the dried-up bed of a loch. There are two outlets for the type in the key; step 47 (+ve) with 3 quadrats and step 62 (-ve) with 1. The difference between these is of little concern.

The most common species in M4 is Agrostis stolonifera (100.0%), followed by Littorella uniflora (75.0%) and Myriophyllum alterniflorum (75.0%) - the latter two aquatic species. Three other species occur with 50% frequency - Juncus articulatus, Ranunculus trichophyllus and Potamogeton filiformis. The remainder of species recorded in the type, of which there are 25, occur in one quadrat only and include a wide range of dry, damp and wet terrestrial species and several more aquatic ones, e.g. Lobelia dortmanna and Potamogeton gramineus.

As already noted, the only species with significant cover is Ranunculus trichophyllus (2.6%). Mean cover of vascular plants is low at 7.1% and is complmented by a 50.0% cover of bare sand, and 28.8% freshwater. Bryophytes occur in only one quadrat with negligible cover. Lichens were not recorded from the type.

Soil types are exclusively Thin Soils (highly organic) TS8 (25.0%) and TS9 (75.0%).

Grazing in terrestrial/aquatic transitional marsh M4 is low, with 50% ungrazed and 50% lightly grazed. Animals recorded were cattle (50.0%), sheep (50.0%) and rabbit (50.0%). There is no evidence of human disturbance apart from loch edge litter in 75.0% of quadrats. Aquatic habitats are obviously important in M4, with loch 75.0% and dried-up loch 50.0%, i.e. one quadrat had both wet and dried-up loch bed in it.

No conclusion can be drawn about aspect for M4. Slopes are gentle with under 1 degree 50.0% and 1-5 degrees 50.0%. Surface types are 75.0% plane and 25.0% simple undulating. All quadrats recorded in the type are under the 50ft contour and mean distance from the sea is 680m.

The four quadrats originate from just two sites, Stilligary (South) on South Uist (with 3 quadrats) and Faraid Head on the north coast (with one quadrat). No conclusion can be drawn from this distribution. Both sites were recorded in 1975 when the stratified sampling method with water edge as a linear stratum was in force. The exact position on the ground of the quadrat is caused by the method of sampling in the linear strata (see Section 4.2) and has very little chance of occurring where sampling intensity is proportional to total area occupied by a vegetation type, as was the case in 1976 and 1977.

7.6 Maritime Vegetation Types

There are two families in this part of the classification

Saltmarsh - with 5 types (S1-S5)

Foredune - with 2 types (F1-F2)

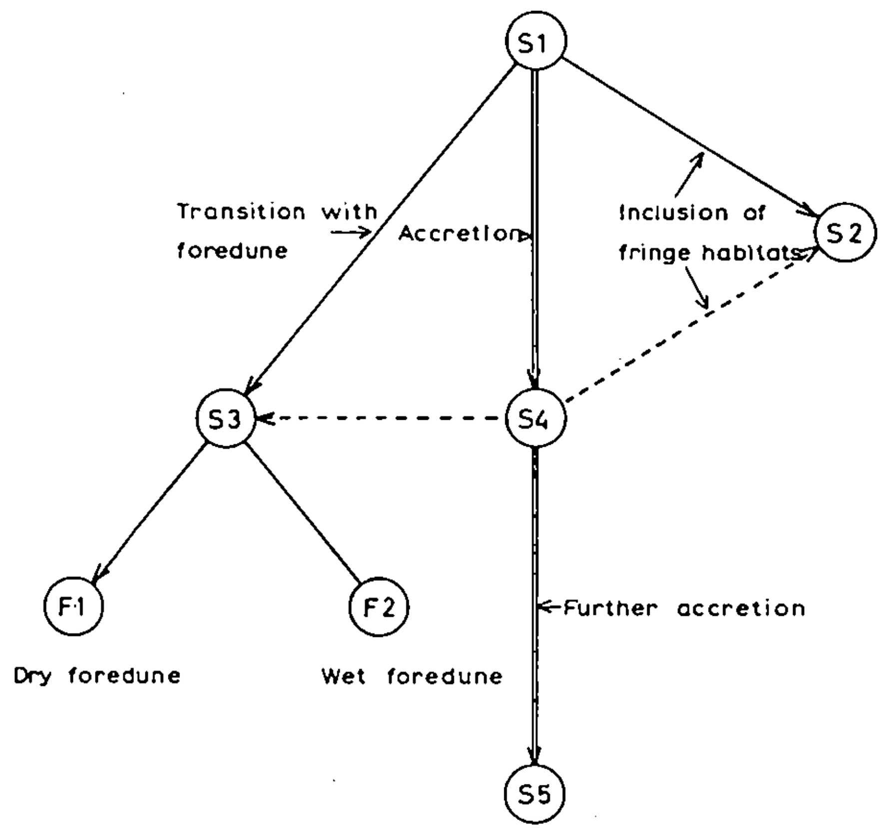
The putative relationships of these seven types are shown in Figure 5.

The common factor in the Maritime section of the classification is the influence of salt or brackish water, either in the form of periodical (tidal) inundation or as spray. The salt influence leads to the occurrence of a number of specially adapted species which do not occur in other vegetation types. The presence of these species is the basis of the first division in the vegetation classification: step 1 in the key with two negative indicators - Plantago lanceolata and Poa pratensis - and three positive indicators - Armeria maritima, Glaux maritima and Puccinellia maritima. A score of 1 or more, i.e. no negative indicators and one or more positive indicators or some balance of negative and positive indicators resulting in a score of 1 or more, leads to the positive (maritime) side with 176 quadrats out of 3,847 (3,843 minus the 4 unclassifiable quadrats) or 4.6% of quadrats. Of these 176 quadrats all but 11 are allocated to Saltmarsh types S1-S5 (the remainder go to G5 with 2 quadrats, G6 with 7 quadrats and M2 with 2 quadrats). Interestingly, step 1 fails to isolate 3 quite unambiguously maritime quadrats, all of which contain only Salicornia spp., i.e. real pioneer saltmarsh. This is because Salicornia is not common enough in the maritime types as a whole to constitute an indicator for them. However, step 2 of the classification deals with the problem and isolates these intractable quadrats from the remainder (3,501) using Salicornia spp. as the positive indicator and Festuca rubra, Plantago lanceolata, Poa pratensis and Trifolium repens as negative indicators. The remainder of divisions stemming from step 1 (+ve) are concerned with sorting out the differences between S1 to S5 and isolating the 11 (on balance) terrestrial quadrats.

Despite their inclusion in the Maritime group, the Foredune types F1 and F2 are isolated in the non-maritime part of the dichotomous key. At least, this is the case for the primary classification, but in the secondary (re-allocation) classification (see Section 6.2) the Saltmarsh and Foredune families are isolated together at the first division (see Figure 2). Although the evidence of the re-allocation classification is what has been used in the definition of the Maritime section of the classification, the Foredune family could probably be considered as non-maritime with equal validity. In this case it would probably have been merged with the Colonist family (containing the one type C).

Figure 5

Putative Relationships of Maritime Vegetation Types



7.6.1 Saltmarsh Family (S1-S5)

The putative relationships of the types in this family are shown in Figure 5. Types S1, S4 and S5 are shown as forming the more or less linear saltmarsh succession, whereas S2 and S3 are represented as deflections of this trend. In practice, most quadrats in S2 and S3 contain what are, in conventional terms, conflicting elements, i.e. saltmarsh species from several levels and non-saltmarsh species in the same quadrats. This condition is the combined result of quadrat size and the close proximity of different habitats on the ground. In some sites in the survey there are large areas of fairly uniform saltmarsh where there is little chance of a quadrat containing conflicting elements. In other sites, saltmarsh is restricted to small patches or fringes, often only a few metres across. In this type of situation there is a good chance that a 25 sq m quadrat will fall on a transition and that saltmarsh and non-saltmarsh species will be found within the same sample. The "impure" saltmarsh types are, therefore, very characteristic of a particular kind of site even though, in conventional terms, they may seem somewhat peculiar.

S1 - Lower saltmarsh

S1 - Lower saltmarsh

(dominated by Puccinellia maritima, Plantago maritima and Armeria maritima)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 19)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	1	1	6 Gruinart	2	3
12 West Tiree	1	1	18 Vatersay	2	7
25 Loch Bee	4	5	29 Kirkibost	1	4
36 Robach	1	3	37 Berneray	1	2
46 Tong	8	27	52 Achnahaird	2	7
53 Oldshore More	1	0	68 Dornoch	1	3
70 Morrich More	4	6	71 Whiteness	4	19
72 Culbin Bar	10	30	80 Strathbeg	1	2
86 St. Cyrus and Montrose	1	3	92 Aberlady	3	10
95 Tyninghame	7	17			

S1 - Lower saltmarsh, dominated by Puccinellia maritima, Plantago maritima and Armeria maritima

This is a reasonably common Saltmarsh type, with 55 quadrats (1.4%) in the survey. In common with all the members of the Saltmarsh family, S1 has multiple outlets in the vegetation classification key (see Figure 6C). In this case there are six outlets; step 2 (+ve) isolating 3 quadrats, 89 (-ve) with 35 quadrats, 90 (+ve) with 3 quadrats, 94 (+ve) with 3 quadrats, 98 (+ve) with 7 quadrats and 103 (-ve) with 4 quadrats. Thus it is seen that one outlet, step 89 (-ve), is responsible for nearly 64% of the type. As already noted, step 2 (+ve) isolates the most pioneer form of the type, with just Salicornia spp. present. All other outlets for S1 stem from step 80 (+ve) in the key, where the positive indicators are Salicornia spp. and Suaeda maritima, and the negative indicators are Agrostis stolonifera, Festuca rubra and Juncus gerardii, and a score of 0 or more goes positive. This branch of the classification is entirely devoted to differentiating the more pioneer types of S2 and S3 (impure types) from S1. In conventional terms, lower saltmarsh S1 embraces pioneer saltmarsh and low saltmarsh. Algae are quite commonly present in the type but were not recorded in this survey. The composite of all six forms of S1 forms the basis for the following type description.

The most common species in S1 is Puccinellia maritima (85.5%), followed by Salicornia spp. (65.5%), Armeria maritima (58.2%), Plantago maritima (56.4%), Suaeda maritima (52.7%) and Glaux maritima (50.9%). There are only four other species with a frequency of 10% or more - Aster tripolium (40.0%), Spergularia media (40.0%), Spergularia marina (20.0%) and Festuca rubra (12.7%). The type is conspicuously species-poor, with a mean number of species per quadrat of only 5.1. Only 19 species are recorded for the type as a whole. These figures are lower than for any other vegetation type in the survey.

The species contributing most cover to lower saltmarsh S1 is Puccinellia maritima (22.6%), followed by Plantago maritima (9.9%) and Armeria maritima (6.2%). Two other species have cover of 3% or more - Suaeda maritima (3.7%) and Glaux maritima (3.1%). The total number of potential dominants (species with 10% or more cover in a quadrat) recorded in the type is 12. Eight of them occur in more than one quadrat and are closely similar to the top cover species.

Total cover of vascular plants in S1 is quite low at 54.0%. No bryophytes are recorded from the type but lichens occur in 5.5% of quadrats with 2.0% cover (these are presumably rocks with lichens on them). The most important non-living cover categories are saltmarsh mud, in 41.8% of quadrats with a mean cover of 12.1%, bare sand (41.8% and 14.7%), gravel (9.1% and 1.5%), cobbles (7.3% and 1.3%) and solid rock (7.3% and 7.2%), i.e. 4 quadrats were substantially solid rock! Saline water was recorded in 40.0% of quadrats with a mean cover of 6.9%. Additional cover was contributed by tidal litter (41.8% and 1.4%) and other cover (36.4% and 8.3%), this latter category being mostly algae.

Lower saltmarsh S1 has the highest correlation with soil type of any member of the Saltmarsh family. It is strongly associated with Sandy Cobble Soil CS7 (3.6%), Thin (peaty) Soils TS1 (7.3%), TS9 (14.5%) and TS10 (7.3%) and Peaty Soils PS2 (12.7%) and PS3 (16.4%). Together, these account for 61.8% of quadrats allocated to the type (out of 92.7% for which soil data are available). Other common soil types are semi-mature, Deep Sandy Soil DS6 (16.4%) and mature, Deep Sandy Soil

DS7 (5.5%). This brings the proportion of S1 accounted for to 83.7%. The emphasis is on high organic or peaty soils with a high water table.

Grazing pressure in lower saltmarsh S1 is generally light, with no grazing in 45.5% of quadrats, light grazing in 30.9%, moderate grazing in 9.1% and heavy grazing in 14.5%. The source of grazing seems to be almost equally divided between the three main herbivores recorded in the survey - cattle (30.9%), sheep (27.3%) and rabbit (32.7%). The main human disturbance in S1 takes the form of vehicle tracks, which were recorded in 9.1% of quadrats, but presumably this is a very persistent effect in a "muddy" habitat. Rubbish was recorded from only 1.8% of quadrats, i.e. either people do not wander about on saltmarsh or their artefacts are washed away by the tide. However, it should be noted that tidal litter occurs in 41.8% of quadrats.

There is a wide range of aquatic habitats recorded for lower saltmarsh S1, most of them involving the presence of saltwater, e.g. saltmarsh pan (18.2%), saltmarsh creek (23.6%), dried-up saltmarsh pan or creek (29.1%) and rock pool (7.3%). A small minority of quadrats have some freshwater habitats present, e.g. puddle, rut, stream, and loch.

Local aspect in S1 shows a distinct preference for south (43.6%), whereas general aspect is even more strongly biased towards the north (52.7%). What this means in environmental terms it is difficult to say. As might be expected, slopes are gentle, with 78.2% under 1 degree. Similarly, surface type is mostly plane (81.8%). However, there is still the odd quadrat with steep slopes and broken surfaces and most of these occur close to HWMST on the more steeply shelving beaches and in amongst rocks. All quadrats of S1 are located under the 50ft contour and the mean distance from the sea is 22m. Most quadrats occur in the 0-10m zone (43.6%) or 10-50m zone (43.6%), i.e. 87.2% within 50m of HWMST, but a few are at greater distance (up to the 200-400m zone). The more inland examples of the type are the result of very gently shelving situations.

There appears to be no distinctive geographical distribution for lower saltmarsh S1, which occurs all round the Scottish coast in those sites that contain some saltmarsh habitat. In fact, saltmarsh is a more common habitat on the east coast of Scotland and, in particular, in sites on the Moray Firth and Firth of Forth. In the first of these areas, Morrich More contains 6% of the type, Whiteness 19% and Culbin 30%, whilst in the latter Aberlady contains 10% and Tyninghame 17%. On the west coast there are fewer sites with much saltmarsh but Vatersay has 7% of S1, Loch Bee has 5%, Tong (nearly whole site is saltmarsh of one type or another) has 27% and Achnahaird has 7%.

S2 - Fringing, mixed saltmarsh

S2 - Fringing, mixed saltmarsh

(dominated by Festuca rubra, Armeria maritima and Glaux maritima)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 8)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
35 Balranald	1	0	40 Luskintyre	2	6
57 Bettyhill	1	3	60 Melvich	1	2
67 Coul Links	1	1	70 Morrich More	3	5
71 Whiteness	4	16	72 Culbin Bar	1	2

S2 - Fringing, mixed saltmarsh, dominated by Festuca rubra, Armeria maritima and Glaux maritima

This type of saltmarsh vegetation is much less common than S1 above, with only 14 quadrats (0.4%) allocated to it. The type has three outlets in the key, step 89 (+ve) isolating 6 quadrats, step 102 (+ve) with 2 quadrats and step 105 (+ve) with 6 quadrats. The first of these steps is concerned with resolving the difference between S1 and S2 and the other two steps with differentiation between S2 and S4 (see Figure 6C). There is no reason to suppose that the three forms of S2 are ecologically very different but the type itself is fairly variable, depending on the exact nature of the habitat in which it occurs, i.e. the nature of the fringe, the slope, the type of terrestrial habitats included, etc.

The three most common species in fringing, mixed saltmarsh S2 are Festuca rubra (100.0%), Armeria maritima (92.9%) and Plantago maritima (92.9%). Other species with a frequency of 50% or more are Puccinellia maritima (85.7%), Glaux maritima (78.6%) and Spergularia media (57.1%). This means that there are only 6 species with a frequency of 50% or more (13 with 10% or more). A total of 23 species were recorded from the type and the mean number of species per quadrat is 7.5 (cf. S1 with 5.1).

The following table of preferential species summarizes the floristic difference between lower saltmarsh S1 and fringing, mixed saltmarsh S2.

Preferential Species for Type S1:-

Species Names	S1 %	S2 %
Aster tripolium	40.0	0.0
Salicornia spp.	65.5	0.0
Spergularia marina	20.0	0.0

Preferential Species for Type S2:-

Species Names	S1 %	S2 %
Agrostis stolonifera	0.0	35.7
Cochlearia officinalis	1.8	28.6
Festuca rubra	12.7	100.0
Juncus gerardii	1.8	21.4

This table shows the complete loss of certain low saltmarsh species from S1 to S2 and the gain of several upper marsh species. It is not suggested that this is a normal successional process, like the development of upper saltmarsh S4 from lower saltmarsh S1, because of the specialized habitats involved.

The species conferring most vegetative cover in S2 are Festuca rubra (33.0%), Puccinellia maritima (11.8%) and Armeria maritima (11.7%). Other species with mean cover of 3% or more are Glaux maritima (9.5%), Plantago maritima (8.9%) and Agrostis stolonifera (6.1%). Potential dominants (species with 10% or more cover in a quadrat) are 8 in number and their order of importance is closely similar to that for the high cover species above. Mean cover of vascular plants is 87.6% (cf. S1 with 54.0%), the main non-living cover types being saltmarsh mud in 7.1% of quadrats and with a mean cover of 2.1%, bare sand (57.1% and 5.8%), gravel (14.3% and 3.2%) and cobbles (21.4% and 0.1%). Saline water was recorded from 21.4% of quadrats with mean cover of 2.5%, tidal litter (28.6% and 0.8%) and other (21.4% and 3.6%, mostly algae). Bryophytes occur in 14.3% of quadrats but with negligible cover, and lichens do not occur at all.

Fringing, mixed saltmarsh S2 is only weakly associated with the soil types. Two types, Sandy Cobbles CS4 (14.3%) and Peaty Soil PS5 (14.3%), are significantly correlated with this vegetation type but only account for 28.6% of the quadrats. Other soil types range from nearly pure, Deep Sand DS3 (7.1%) to Peaty Soil PS2 (7.1%). This lack of correlation could have two distinct sources. Firstly, the exact position of the middle of the quadrat may be rather critical in a fringing habitat or, secondly, there may be a genuine indifference to soil type, with the saltwater factor dominating all else. As most of the Saltmarsh family (apart from S1) show rather weak associations with the soil types, the latter explanation seems to be the more likely.

Grazing pressure in S2 is increased compared with S1, with no grazing in 7.1% of quadrats (cf. S1 with 45.5%), light grazing in 14.3% (cf. S1 with 30.9%), moderate grazing in 50.0% (cf. S1 with 9.1%) and heavy grazing in 28.6% (cf. S1 with 14.5%). Records of grazing animals are similarly increased, with cattle in 57.1%, sheep in 35.7% and rabbit in 57.1% (cf. S1 with 30.9%, 27.3%, and 32.7% respectively). Vehicle tracks (28.6%) are again the main example of human disturbance. Spent cartridges and other armaments were recorded from 7.1% of quadrats and rubbish in 14.3% (to this must be added tidal litter in 28.6%).

Some aquatic habitats are present in fringing saltmarsh S2, all of them related to saltwater. Saltmarsh pan occurs in 21.4% of quadrats and saltmarsh creek in 7.1%.

There is a distinct tendency for northern aspects in fringing, mixed saltmarsh S2, with local aspect 42.9% north and general aspect 71.4% north. The main reason for this correlation with northerly aspects is that S2 is mainly a northern type (see below). Slopes in the type are gentle, with 85.7% of quadrats under 1 degree and the remainder in the 1-5 degrees category. Surface types are similar, with 85.7% plane and the remainder simple undulating. All 14 quadrats allocated to the type are under the 50ft contour, and they all also occur within 50m of the sea (57.1% in the 0-10m zone and 42.9% in the 10-50m zone). Mean distance from the sea is only 11m, the only type closer than this being S3 with a mean of 3m (to be described next).

In terms of geographical distribution, fringing, mixed saltmarsh S2 is very much a northern type. It occurs in two sites on the Outer Hebrides - Balranald (North Uist) and Luskintyre (Harris). On the north coast, it occurs at Bettyhill and Melvich and then, finally, in the Moray Firth it occurs at Coul Links, Morrich More, Whiteness and Culbin Bar (Whiteness has 16% of the type). This distribution of S2 is probably just a reflection of the presence of a particular type of fringing habitat in sites. This habitat usually occurs in a bayhead or estuarine situation where there is a relatively narrow strip of saltmarsh. The fringing habitat may occur in a much wider range of sites than is suggested by the distribution of S2 but, because it constitutes such a relatively small area of a site, the chance of it being sampled is commensurately low.

S3 - Saltmarsh/strandline transition

S3 - Saltmarsh/strandline transition

(dominated by Agropyron Junceiforme, Festuca rubra and Glaux maritima)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 9)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
7 Oronsay	1	2	12 West Tiree	1	1
27 Stilligarry (South)	1	0	54 Sheigra	1	0
68 Dornoch	2	2	71 Whiteness	3	8
74 Findhorn	1	0	92 Aberlady	1	3
93 Tyninghame	4	11			

S3 - Saltmarsh/strandline transition, dominated by (Agropyron junceiforme), Festuca rubra and (Glaux maritima)

The putative relationships of this type are shown in Figure 5, in which it is suggested that S3 is intermediate between the Saltmarsh types S1 or S4 and the Foredune types F1 and F2. There are 15 quadrats (0.4%) allocated to this type which has four outlets in the key. Step 60 (+ve) isolates 3 quadrats, step 81 (-ve) with 8 quadrats, step 91 (-ve) with 3 quadrats and step 103 (+ve) with 1 quadrat. The form of S3 isolated by step 81 (-ve) is seen as the most common type, with over 50% of quadrats. Attention should be drawn to step 60 (+ve) which is, in fact, in the non-maritime part of the key, i.e. the balance of species at step 1 is in favour of the negative side. However, with admirable logic, the 3 quadrats that take this route do so in company with the majority of Foredune F1, from which they are separated in steps 52 (+ve) and 60 (+ve) (see Figure 6B). This form of S3 merely has the balance of species in favour of the strandline element as opposed to saltmarsh. Like S2 above, saltmarsh/strandline transition S3 is a fairly variable type, depending on the zonation width of the saltmarsh, the rapidity with which the effects of salt water are diminished in an inland direction, i.e. the steepness of the terrain, and the exact position of the quadrat centre. Within these limits, there are thought to be no serious ecological differences between the various forms of S3 and the following description refers to a composite of all four forms.

The degree of variation in S3 is evidenced by the lack of "constant" (high frequency) species. The most common species is Festuca rubra (73.3%) but there is only one other species with a frequency of 50% or more, and this is Plantago maritima (66.7%). Five species lie in the 40%-50% range - Agropyron junceiforme (46.7%), Atriplex hastata (46.7%), Glaux maritima (46.7%), Armeria maritima (40.0%) and Puccinellia maritima (40.0%). There are a number of other species with intermediate frequencies and as a result, although there are only 2 species with a frequency of 50% or more, there are no less than 32 species occurring in 10% or more quadrats (cf. equivalent figures for S2 are 6 and 13). A total of 49 species were recorded from this type (cf. 19 for S1 and 23 for S2). Species richness, as measured by the mean number of species per quadrat, is still on the increase and is up to 9.5 (cf. 5.1 for S1 and 7.5 for S2).

The floristic comparison between lower saltmarsh S1 and saltmarsh/strandline transition S3 is summarized in the following table of preferential species for the two types.

Preferential Species for Type S1:-

Species Names	S1 %	S3 %
Aster tripolium	40.0	0.0
Puccinellia maritima	85.5	40.0
Salicornia spp.	65.5	13.3
Spergularia media	40.0	13.3

Preferential Species for Type S3:-

Species Names	S1 %	S3 %
Agropyron junceiforme	1.8	46.7
Agropyron repens	0.0	26.7
Agrostis stolonifera	0.0	33.3
Atriplex hastata	0.0	46.7
Atriplex laciniata	0.0	20.0
Atriplex littoralis	0.0	20.0
Atriplex patula	1.8	20.0
Cochlearia officinalis	1.8	26.7
Festuca rubra	12.7	73.3
Potentilla anserina	0.0	26.7
Rumex crispus	0.0	33.3
Senecio jacobaea	0.0	26.7
Stellaria media	0.0	20.0

In this table, low saltmarsh species are seen to be on the decline and a much larger number of species are on the increase. Some of the species favouring S3 as compared with S1 are typical strandline species, e.g. the four species of Atriplex and Rumex crispus. Agropyron junceiforme is more of a foredune species, whilst others, e.g. Agropyron repens, Potentilla anserina and Stellaria media, are more typical of disturbed habitats.

Alternatively, saltmarsh/strandline transition S3 may be compared with dry foredune F1 and the following table summarizes the floristic differences between these two types.

Preferential Species for Type S3:-

Species Names	S3 %	F1 %
Agropyron repens	26.7	0.0
Agrostis stolonifera	33.3	3.1
Armeria maritima	40.0	0.0
Atriplex littoralis	20.0	0.0
Atriplex patula	20.0	3.1
Cochlearia officinalis	26.7	0.0
Festuca rubra	73.3	0.0
Glaux maritima	46.7	0.0
Plantago maritima	66.7	0.0
Potentilla anserina	26.7	6.3
Puccinellia maritima	40.0	0.0
Rumex crispus	33.3	6.3
Senecio jacobaea	26.7	0.0
Stellaria media	20.0	0.0
Suaeda maritima	33.3	0.0

Preferential Species for Type F1:-

Species Names	S3 %	F1 %
Cakile maritima	6.7	31.3
Honkenya peploides	6.7	34.4

This comparison shows a general and fairly massive loss of species (15 in all) from S3 to F1, both saltmarsh and strandline species being involved. Only two species have an increased frequency, Cakile maritima (up from 6.7% in S3 to 31.3% in F1) and Honkenya peploides (6.7% to 34.4%). The common factor between the two types, in terms of species composition, is limited to Agropyron junceiforme (46.7% in S3 and 59.4% in F1) and Atriplex hastata (46.7% and 40.6% respectively).

The most important cover species in saltmarsh/strandline transition S3 is Festuca rubra (15.5%) and this is followed by Puccinellia maritima (8.8%), Agropyron junceiforme (8.8%) and Agropyron repens (3.8%). A total of 11 potential dominants (species with 10% or more cover in a quadrat) were recorded from the 15 quadrats allocated to the type (cf. 8 species for S2). Total cover of vascular plants is reduced in S3 (49.3%) compared with S2 (87.6%) and even S1 (54.0%). Bryophytes occur in 20.0% of quadrats, but with negligible cover, and lichens were not recorded at all. Even saltmarsh mud, in 13.3% of quadrats with 0.7% cover, does little to make up the difference and it is bare sand (73.3% and 25.8%), gravel (26.7% and 5.4%), cobbles (13.3% and 10.7%), boulders (13.3% and 6.7%) and solid rock (6.7% and 5.7%) that are most important (hence the term "strandline" in the type name). These figures indicate that non-living cover in individual quadrats is very varied as to type and quantity, i.e. cobbles in 2 quadrats have about 70% cover! Saline water occurs in 6.7% of quadrats but with only 0.3% cover, whilst tidal litter occurs in 66.7% with 5.5% cover.

Again, saltmarsh/strandline transition S3 is very poorly related to the soil types it occupies. Only two soil types are significantly associated, Thin Soil TS4 (6.7%) and Sandy Cobble Soil CS7 (6.7%), and these together account for only 13.4%. Other soils vary from raw beach deposits, i.e. cobbles and gravel, to shallow peaty soils. As with S2, it is assumed that it is the saline conditions that determine the type rather than the type of soil substrate.

Grazing pressure in S3 is fairly light, with no grazing recorded in 40.0% of quadrats, light grazing in 26.7%, moderate grazing in 26.7% and heavy grazing in 6.7%. Cattle and sheep are at a fairly low level (26.7% and 13.3% respectively), whilst rabbits are increased (73.3%). Human disturbance is more varied compared with the previous saltmarsh types, with dirt road (6.7%), vehicle tracks (20.0%), unsurfaced paths (6.7%) and spent cartridge (20.0%). No rubbish was recorded in this type but tidal litter has a frequency of 66.7%.

A few aquatic habitats were also recorded in saltmarsh/strandline transition S3 but only one, rock pool (6.7%), is related to saltwater. Other aquatic habitats present are rut (6.7%), river (6.7%), flush/spring (6.7%), dried-up puddle (6.7%) and dried-up rut (6.7%).

Local and general aspect are contradictory, with the former favouring west (40.0%) and the latter north (53.3%). No explanation is offered for this observation, but it should be noted that a similar relationship was found in S1 (see above). As might be expected, slope is an important feature of S3, with only 26.7% of quadrats in the under 1 degree category (cf. 78.2% for S1 and 85.7% for S2). Slopes of 1-5 degrees occur in 46.7% if quadrats, 5-15 degrees in 20.0% and over 15 degrees in 6.7%. This is interpreted as meaning that the transition from saltmarsh to foredune is often quite sharp with relatively steep slopes. Surface types are also characteristic, with 53.3% plane, 33.3% simple undulating, none undulating complex and 13.3% broken, i.e. slopes are steepish but relatively plane. All examples of the type lie under the 50ft contour, which is not surprising for a type in which 73.3% of quadrats are within 10m of HWMST and the remaining 26.7% are within 50m. In fact mean distance from the sea is an incredibly low at 3m (cf. 22m for S1 and 11m for S2). Again, this points towards the relationship of S3 with fairly steeply sloping ground just above HWMST.

Saltmarsh/strandline transition S3 is a fairly uncommon but widespread vegetation type, in the sense that it occurs in small quantities all round the Scottish Coast. As with the other members of the Saltmarsh family, it is found only in those sites which include the saltmarsh habitat and, for this reason, it tends to be most concentrated in the large estuary systems on the east coast - the Moray Firth and Firth of Forth. Whiteness has 8% of the type and Tyninghame 11%. There are odd occurrences of the type on the mainland west coast and on the Inner and Outer Hebrides. Only the north coast and Orkney and Shetland have no examples of S3 but, with such a relatively uncommon type and a low probability of being sampled, not too much significance should be attached to this observation, i.e. it is not good evidence that these areas are outside the range of S3.

S4 - Upper saltmarsh

S4 - Upper saltmarsh

(dominated by Festuca rubra, Glaux maritima and Juncus gerardii)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 24)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
6 Gruinart	3	4	11 Sanna	1	3
15 Crossapol and Gunna	1	1	25 Loch Bee	2	2
28 Baleshare	2	4	29 Kirkibost	3	11
31 Paible	2	13	35 Balranald	1	2
36 Robach	1	3	39 Northton	3	8
40 Luskintyre	8	26	41 Uig	1	3
45 Tolsta	1	3	46 Tong	18	60
49 Breckin	1	4	50 Redpoint	1	0
52 Achnahaird	4	15	67 Coul Links	2	1
68 Dornoch	14	44	70 Morrich More	7	11
77 Spey Bay (Central)	1	2	80 Strathbeg	1	2
92 Aberlady	2	6	95 Tyninghame	1	1

S4 - Upper saltmarsh, dominated by Festuca rubra, Glaux maritima and Juncus gerardii

This really is the "mainline" saltmarsh vegetation type, forming the zone between the lower (and pioneer) saltmarsh S1 and the upper saltmarsh/dune transition S5. The type is quite common, with 81 quadrats (2.1%) of quadrats allocated to it, but has no less than 13 outlets in the key! Step 84 (+ve) isolates 1 quadrat, step 87 (+ve) with 2, step 88 (+ve) with 3, step 91 (+ve) with 3, step 92 (+ve) with 3, step 96 (+ve) with 7, step 97 (+ve) with 2, step 99 (-ve) with 24, step 100 (+ve) with 3, step 101 (+ve) with 2, step 102 (-ve) with 7, step 104 (+ve) with 1 and step 105 (-ve) with 23. Thus just two outlets, steps 99 (-ve) and 105 (-ve), are seen to deal with 57 quadrats or 70% of the type. These two outlets are in analogous parts of adjacent stems of the hierarchy which are separated by step 77 (see Figure 6C). In this step, the more maritime part goes negative and the less maritime part goes positive. The negative side is defined by the presence of Puccinellia maritima and the positive side by a series of non-maritime species, of which at least 2 have to be present (3 if Puccinellia is present also) for the positive step to be chosen. This leads to the conclusion that outlets 84 (+ve), 88 (+ve), 96 (+ve), 97 (+ve), 101 (+ve), 102 (-ve) and 105 (-ve) define forms of S4 in which saltmarsh is dominant, whereas steps 87 (+ve), 92 (+ve), 99 (-ve), 100 (+ve) and 104 (+ve) define forms in which the non-maritime element is stronger. The following description is based on a composite of all 13 forms of S4.

The most common species in upper saltmarsh S4 are Festuca rubra (96.3%) and Glaux maritima (93.8%). Four further species have frequencies of 50% or more - Plantago maritima (88.9%), Armeria maritima (87.7%), Juncus gerardii (86.4%) and Agrostis stolonifera (66.7%). This gives a total of 6 species with a frequency of 50% or more and 21 with 10% or more (cf. S1 with 6 and 10 species respectively). The total number of species recorded in S4 is 88 (cf. S1 with 19). Species richness, as measured by the mean number of species per quadrat, is also increased in S4 (10.9) as compared with S1 (5.1).

Figure 5 indicates a strong relationship between lower saltmarsh S1 and upper saltmarsh S4 and this could hardly be otherwise if the names given to the two types are correct. The suggestion is that the relationship is largely successional in nature. The main process involved is the accretion of material by the lower saltmarsh. This leads to a raising in level of the marsh and diminished influence of saltwater as tidal inundation becomes of progressively less frequent occurrence. The following table compares the two types in terms of their preferential species.

Preferential Species for Type S1:-

Species Names	S1 %	S4 %
Puccinellia maritima	85.5	38.3
Salicornia spp.	65.5	1.2
Spergularia marina	20.0	4.9

Spergularia media	40.1	11.1
Suaeda maritima	52.7	1.2

Preferential Species for Type S4:-

Species Names	S1 %	S4 %
Agrostis stolonifera	0.0	66.7
Carex flava agg.	0.0	30.9
Cochlearia officinalis	1.8	40.7
Euphrasia officinalis agg.	0.0	22.2
Festuca rubra	12.7	96.3
Juncus gerardii	1.8	86.4
Leontodon autumnalis	0.0	29.6
Plantago coronopus	0.0	44.4
Trifolium repens	0.0	23.5
Triglochin maritima	9.1	48.1

Species common in S1, but declining in S4, are mainly genuine saltmarsh species such as Puccinellia maritima (down from 85.5% in S1 to 38.3% in S4), Salicornia spp. (65.5% to 1.2%) and Suaeda maritima (52.7% to 1.2%). Conversely, species on the increase in S4 are upper saltmarsh species such as Juncus gerardii (up from 1.8% in S1 to 86.4% in S4) and Triglochin maritima (9.1% to 48.1%). Other species occupy a more fringing habitat, i.e. not in the saltmarsh proper, such as Cochlearia officinalis (up from 1.8% in S1 to 40.7% in S4), and Carex flava agg. (in this case almost certainly Carex extensa - see Appendix 3 - 0.0% to 30.9%). Plantago coronopus, mainly a spray zone species, is up from 0.0% to 44.4%. Festuca rubra and Agrostis stolonifera are both wide ranging species, which also have saltmarsh ecotypes, and these are also on the increase (12.7% to 96.3% and 0.0% to 66.7% respectively). Genuine, non-maritime species make an appearance in S4 (they go a stage further in S5), such as Leontodon autumnalis (0.0% in S1 to 29.6% in S4), Trifolium repens (0.0% to 23.5%) and Euphrasia officinalis agg. (0.0% to 22.2%).

The most important cover species in upper saltmarsh S4 is Festuca rubra (28.2%), followed by Juncus gerardii (15.4%), Plantago maritima (13.7%) and Glaux maritima (11.2%). Two other species have mean cover of 3% or more - Armeria maritima (6.5%) and Agrostis stolonifera (3.8%). Only one species that had high cover in S1 shows a marked decline of cover in S4 and that is Puccinellia maritima (22.6% in S1 to 2.2% in S4). Other species have more or less maintained their cover status, e.g. Plantago maritima (9.9% in S1 and 13.7% in S4) and Armeria maritima (6.2% and 6.5%). Finally, there are the species that show markedly increased cover in S4 as compared with S1, e.g. Festuca rubra (2.5% in S1 and 28.2% in S4), Juncus gerardii (less than 0.5% to 15.4%) and Glaux maritima (3.1% to 11.2%). There is quite a long list of potential dominants (species with 10% or more cover in a quadrat) in S4, 13 species in more than one quadrat and a further 15 in one quadrat only. In general, the most common potential dominants are the same as the top cover species but there are some interesting exceptions, e.g. Carex flacca occurs in 19.8% of quadrats but is dominant in 6.2%, Ammophila arenaria (6.2% and 4.9%), and Juncus articulatus (11.1% and 3.7%). This shows that in a minority of quadrats it is possible to have quite a large area of non-saltmarsh habitat without deflecting the overall affinities of the sample, i.e. it remains a saltmarsh type as far as the classification is concerned.

Mean cover of vascular plants in upper saltmarsh S4 (93.6%) is markedly increased compared with lower saltmarsh S1 (54.0%). Bryophytes are present in 48.1% of quadrats with a mean cover of 0.6% and equivalent figures for lichens are 4.9% and 0.4%. Non-living cover categories are now much reduced in importance, with saltmarsh mud present in 22.2% of quadrats and with a mean cover of 0.9% (cf. 41.8% and 12.1% for S1), bare sand 19.8% and 2.4% (cf. 41.8% and 14.7% for S1) and saline water 22.2% and 2.8% (cf. 40.0% and 6.9% for S1). Tidal litter is present in 23.5% of quadrats with a mean cover of 0.2% (cf. 41.8% and 1.4% for S1).

Upper saltmarsh S4 shows a slightly improved relationship with the soil types. It is strongly associated with Thin Soil TS2 (2.5%) and the two Peaty Soil types PS3 (11.1%) and PS5 (22.2%). Together these account for 35.8% of the quadrats. Other common types are immature, Deep Sandy Soil DS2 (6.2%), semi-mature, Deep Sandy Soil DS6 (14.8%, this a negative association) and mature, Deep Sandy Soil DS7 (11.1%). Together these raise the proportion of quadrats accounted for to 67.9% (out of 91.4% for which soil data are available). As with S1, the main emphasis of soil types in S4 is on those with a high humus content or peat-like profiles.

Grazing pressure shows a distinct increase in upper saltmarsh S4, presumably as a result of the increased "grassyness" of the vegetation. No grazing was recorded in 2.5% of quadrats (cf. S1 with 45.5%), light grazing in 33.3% (cf. S1 with 30.9%), moderate grazing in 37.0% (cf. S1 with 9.1%) and heavy grazing in 27.2% (cf. S1 with 14.5%). Grazing animals recorded show a similar trend, with cattle in 61.7% (cf. S1 with 30.9%), sheep in 58.0% (cf. S1 with 27.3%) and rabbit in 58.0% (cf. S1 with 32.7%). Human disturbance is fairly limited in the type, with vehicle tracks in 7.4% of quadrats, unsurfaced path in 4.9%, spent cartridge in 3.7%, other armament in 3.7% and oil deposit in 3.7%. Interestingly, turf cutting was recorded from 6.2% of quadrats in S4 (the traditional source of sea-washed turf?). Rubbish was recorded from 22.2% of quadrats.

Aquatic habitats are fairly common in the type, with various types of puddles, ruts and ditches but the main types are saltmarsh pan 28.4%, saltmarsh creek 4.9% and dried-up saltmarsh pan or creek 29.6%.

In terms of local aspect, S4 shows a tendency to northern or eastern aspects (66.6% combined), whereas general aspect is shifted through 90 degrees to east and south (59.3% combined). As might be expected in upper saltmarsh S4, slopes are fairly gentle, with 71.6% of quadrats under 1 degree and 23.5% in 1-5 degree range, i.e. only 4.9% steeper than 5 degrees. This is very similar to lower saltmarsh S1 with 78.2% and 16.4% respectively. Surface type is mostly plane (85.2%) or simple undulating (9.9%). All quadrats lie under the 50ft contour but mean distance from the sea shows a sharp increase over the previous saltmarsh types to 137m (cf. S1=22m, S2=11m and S3=3m). Modal distance is 10-50m with 28.4% of quadrats but greater distances are quite common, e.g. 400-600m with 6.2%. One quadrat is over 1500m from HWMST! Most of the quadrats which occur at distance from the sea occupy low slacks which, although they extend well inland, are still subject to periodic flooding with saltwater.

Being a fairly common, generalized saltmarsh type, upper saltmarsh S4 has a widespread geographical distribution in the survey. It occurs in virtually all sites with extensive saltmarshes within their surveyed boundary. The only geographical areas where the type is conspicuous by its absence is the north coast (small, fringing saltmarshes with S2 present mostly occur in this region) and the east coast between the Moray Firth and Firth of Forth (there is very little saltmarsh of any type present in these sites). The type reaches its peak in Tong on the Isle of Lewis, where no less than 60% of the quadrats are S4. Also on the west side of Scotland, Luskintyre (Harris) contains 26%, Kirkibost and Paible (North Uist) 11% and 13% respectively and Achnahaird (north-western mainland) 15%. On the east coast, two sites in the Moray Firth, Dornoch 44% and Morrich More 11%, contain large amounts of S4.

S5 - Upper saltmarsh/dune transition

S5 - Upper saltmarsh/dune transition

(dominated by Festuca rubra, Carex flacca and Agrostis stolonifera)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 11)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
19 West Barra	3	8	28 Baleshare	1	2
29 Kirkibost	2	7	39 Northton	2	5
49 Breckin	1	4	70 Morrich More	1	1
72 Culbin Bar	1	2	74 Findhorn	1	2
77 Spey Bay (Central)	1	1	86 St. Cyrus and Montrose	1	3
92 Aberlady	1	3			

S5 - Upper saltmarsh/dune transition, dominated by Festuca rubra, (Carex flacca) and Agrostis stolonifera

This is a relatively uncommon type with only 15 quadrats (0.4%) allocated to it. It has six outlets in the key which are notable for being scattered all over the place. The reason for this is that, although the upper saltmarsh component of the type is fairly consistent, the dune part is extremely variable depending on what type of habitat abuts on the saltmarsh. Thus step 15 (+ve) isolates 1 quadrat, step 31 (+ve) has 4 quadrats (both of these outlets are mixed with D2, G3 and G4 and therefore contain acid elements - see Figure 6A), step 72 (+ve) with 4 quadrats (this outlet is mixed with D1 and D4 and contains more base-rich elements - see Figure 6B), step 86 (+ve) with 1 quadrat, step 99 (+ve) with 1 quadrat and step 104 (-ve) with 4 quadrats. These last three outlets occur in the maritime part of the key (see Figure 6C) thus indicating that the saltmarsh element is dominant. Outlets 86 (+ve) and 99 (+ve) isolate quadrats that are transitional with fairly conventional dune vegetation but the four quadrats in outlet 104 (-ve) contain a freshwater marsh element. Despite the fairly wide degree of variation in the type, the following description refers to a composite of all six forms.

The most common species in upper saltmarsh/dune transition S5 is Festuca rubra (93.3%), followed by Armeria maritima (86.7%) and Plantago maritima (80.0%). Five other species have frequencies of 50% or more - Agrostis stolonifera (60.0%), Plantago coronopus (60.0%), Poa pratensis (60.0%), Trifolium repens (60.0%), and Juncus gerardii (53.3%). There are 8 species with a frequency of 50% or more and 42 with 10% or more. The total number of species recorded in the type is 87, high for a type with only 15 quadrats. Species richness, as measured by the mean number of species per quadrat, at 17.4 is the highest in the Saltmarsh family (S1=5.1, S2=7.5, S3=9.5 and S4=10.9).

Upper saltmarsh/dune transition S5 is seen as being a more or less direct successional development from upper saltmarsh S4, it being the result of further sedement accretion (either by water or sand blow). The type also occurs in low slacks with tidal access to the sea. Changes in accessibility to saltwater may lead to movement, either in the direction of S5 or reversion to S4. The following table of preferential species summarizes the differences between S4 and S5 in terms of species content.

Preferential Species for Type S4:-

Species Names	S4 %	S5 %
Aster tripolium	21.0	0.0
Carex flava agg.	30.9	6.7
Glaux maritima	93.8	40.0
Puccinellia maritima	38.3	0.0

Preferential Species for Type S5:-

Species Names	S4 %	S5 %
Agrostis tenuis	8.6	40.0
Ammophila arenaria	6.2	40.0
Bellis perennis	3.7	26.7
Carex arenaria	0.0	46.7
Carex flacca	19.8	46.7
Cerastium atrovirens	7.4	20.0
Cerastium holosteoides	6.2	20.0
Cirsium arvense	1.2	20.0
Dactylis glomerata	0.0	26.7
Eleocharis quinqueflora	4.9	26.7
Festuca ovina	1.2	20.0
Honkenya peploides	1.2	20.0
Hypochoeris radicata	0.0	26.7
Lotus corniculatus	2.5	46.7
Plantago lanceolata	2.5	33.3
Poa pratensis	17.3	60.0
Potentilla anserina	3.7	20.0
Sagina procumbens	9.9	20.0
Senecio jacobaea	0.0	26.7
Taraxacum spp.	4.9	26.7
Trifolium repens	23.5	60.0

Species on the decline in S5 as compared to S4 are restricted to saltmarsh species, e.g. Aster tripolium (down from 21.0% in S4 to 0.0% in S5), Glaux maritima (93.8% to 40.0%), Puccinellia maritima (38.3% to 0.0%) and Carex flava agg. (probably Carex extensa, 30.9% to 6.7%). On the increase in S5 are a whole range of non-maritime species indicative of a range of conditions - more acidophilous species such as Agrostis tenuis and Festuca ovina, more typical dune species such as Ammophila arenaria, Cerastium atrovirens, Cerastium holosteoides, Lotus corniculatus, Poa pratensis, Senecio jacobaea and Trifolium repens and marshy species such as Eleocharis quinqueflora.

The most important cover species in upper saltmarsh/dune transition S5 is Festuca rubra (33.1%). Below this, there is a considerable drop to Plantago maritima (6.2%), Plantago coronopus (4.9%), Juncus gerardii (4.6%), Agrostis stolonifera (4.5%), Carex flacca (4.5%), Ammophila arenaria (3.3%) and Armeria maritima (3.2%). There are 12 potential dominants (species with cover of 10% or more in a quadrat) recorded for S5, 8 of them in more than one quadrat. The potential dominants are in close accord with the top cover species. Just to indicate how varied the "dune part" of the vegetation can be, one quadrat is dominated by Calluna vulgaris (20% cover). Total cover of vascular plants (86.8%) is slightly reduced compared with S4 (93.6%), the difference being made up largely by non-living cover types, such as bare sand with a frequency of 33.3% and mean cover of 8.1% (cf. 19.8% and 2.4% for S4), gravel 20.0% and 3.4% (cf. 3.7% and 0.4% for S4) and solid rock 13.3% and 7.7% (cf. 2.5% and 2.3% for S4). Bryophytes occur in 86.7% of quadrats in S5 with a mean cover of 2.0% and the equivalent figures for lichens are 26.7% and 4.1%, i.e. high cover of lichens in relatively few quadrats. Saline water is present in 13.3% of quadrats with a mean cover of 1.7% (cf. 22.2% and 2.8% for S4) and tidal litter is also reduced to 6.7% of quadrats and negligible cover (cf. 23.5% and 0.2% for S4).

Upper saltmarsh/dune transition S5 is not well correlated with the soil types. Only Peaty Soil PS3 (13.3%) and Thin Soil (rock near the surface) TS10 (13.3%) are significantly associated with this vegetation type (a total of 26.6% of quadrats accounted for). Other soil types range from immature, Deep Sand Soil DS2, through various other sandy types with different degrees of maturity, i.e. humus content, to various types of peaty soil. The exact position of the quadrat centre, in what is a transitional type, may be responsible for some of this variation.

Grazing pressure in S5 is quite high, with no grazing in 13.3% of quadrats (cf. 2.5% in S4), light grazing in 26.7% (cf. 33.3% in S4), moderate grazing in 26.7% (cf. 37.0% in S4) and heavy grazing in 33.3% (cf. 27.2% in S4). The main grazing animals recorded were cattle (33.3%), sheep (40.0%) and rabbit (46.7%). Human disturbance in the type is limited to vehicle tracks (13.3%) and unsurfaced path (20.0%). Rubbish was recorded from 53.3% of quadrats, an unusually high figure.

A few aquatic habitats are also present in S5 - puddle (6.7%), saltmarsh pan (6.7%), ditch (6.7%), dried-up saltmarsh pan or creek (6.7%) and rock pool (6.7%).

Local aspect for upper saltmarsh/dune transition S5 is slightly biased towards north (40.0%), whilst general aspect favours west (53.3%). There is a marked increase in slope compared with the other Saltmarsh types with less than 1 degree 40.0%, 1-5 degrees 40.0% and 5-15 degrees 20.0%. Surface type is mostly plane (53.3%) and simple undulating (26.7%) but with a minority of more complex types. All quadrats of S5 are located under the 50ft contour and mean distance from the sea is 65m, rather less than for S4 at 137m. This difference is a little unexpected and may or may not be a significant feature of the type. Most quadrats of S5 occur in the 10-50m zone (53.3%).

Upper saltmarsh/dune transition S5 shows no distinct geographical distribution. It is most common on sites in the Outer Hebrides, West Barra (8%), Kirkibost (7%) and Northton (5%).

In summary of the Saltmarsh family, it is interesting to note the occurrence of the main saltmarsh species in the various stages of successional development, i.e. S1 to S2 (possibly) to S4 to S5 (but ignoring the rather aberrant S3). The following table shows percentage frequency of various species in the four types listed above.

Species Name	Saltmarsh Types (% frequency)			
	S1	S2	S4	S5
Salicornia spp.	65.5	-	1.2	-
Suaeda maritima	52.7	42.9	1.2	6.7
Spergularia media	40.0	57.1	11.1	-
Spergularia marina	20.0	-	4.9	-
Aster tripolium	40.0	-	21.0	-
Armeria maritima	58.2	92.9	87.7	86.7
Plantago maritima	56.4	92.9	88.9	80.0
Puccinellia maritima	85.5	85.7	38.3	-
Glaux maritima	50.9	78.6	93.8	40.0
Festuca rubra	12.7	100.0	96.3	93.3
Juncus gerardii	1.8	21.4	86.4	53.3
Agrostis stolonifera	-	35.7	66.7	60.0

This list of species is roughly ordered according to the level of the saltmarsh from low to high. The first five species, Salicornia, Suaeda, the two Spergularias and Aster, are low marsh species and the remainder come in higher up. Armeria maritima and Plantago maritima are particularly interesting, because both occur with moderate frequency in the low marsh types, are at their peak in the upper marsh, but there is little decline even in S5. Indeed, both species extend beyond the saltmarsh family, Plantago maritima being common in a wide range of damp vegetation types, e.g. D4=54.1%, G1=46.8%, and G2=78.8%, but is rarely present in genuine freshwater marshes, e.g. M2=1.1%. Armeria occurs occasionally in a range of vegetation types, but only at low frequencies, and it is usually associated with rocky habitats allied to some minor spray effect. Festuca rubra and Agrostis stolonifera both occur in the upper saltmarsh types and these are presumably specialized ecotypes of the two species.

7.6.2 Foredune Family (F1-F2)

This is not a particularly important family, with only 37 quadrats (1.0%) in the survey. There are two types in this family which covers the range of habitats occurring at the terrestrial/maritime boundary when it is not in the form of a saltmarsh. The determining factors for the Foredune, as opposed to the Saltmarsh, family are probably slope, exposure and substrate type which themselves tend to be strongly interdependent. Basically, a saltmarsh requires gentle slopes (unless it is very narrow and fringing), fine particle size substrates, e.g. sand, silt, clay and organic matter, and shelter - or the fine substrates will be quickly eroded. The steeper, more exposed beaches composed of sand, gravel and cobble mixtures are where the Foredune types occur. The type also covers what is often called the strandline, i.e. the zone immediately above HWMST which is not regularly washed with sea water but can receive quite a large amount of spray. This zone may be washed away entirely during winter storms.

F1 - Dry foredune

F1 - Dry foredune

(dominated by Agropyron junceiforme, Elymus arenarius and Atriplex hastata)

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 21)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
10 Calgary Dunes	1	4	13 Ballevullin	1	3
19 West Barra	1	3	23 Howbeg	1	5
26 Borve	1	4	27 Stilligarry (South)	4	1
32 Hosta	1	3	33 Vallay	1	3
34 Leathann	1	3	35 Balranald	3	1
50 Redpoint	1	1	53 Oldshore More	1	0
54 Sheigra	2	1	56 Faraid Head	1	3
66 Ferry Links	1	0	67 Coul Links	1	1
68 Dornoch	4	6	72 Culbin Bar	2	5
74 Findhorn	1	0	82 Cruden Bay	1	3
90 Tentsmuir	2	3			

F1 - Dry foredune, dominated by Agropyron junceiforme, (Elymus arenarius and Atriplex hastata)

This vegetation type, with 32 quadrats (0.8%) allocated to it, is the most common of the Foredune types (F2 has only 5 quadrats). The type has four outlets in the key, step 48 (+ve) isolates 1 quadrat, step 51 (+ve) with 1 quadrat, step 52 (-ve) with 23 quadrats and step 60 (-ve) with 7 quadrats. Obviously the form of F1 isolated by step 52 (-ve) is in the majority and, as steps 51 (+ve) and 60 (-ve) are closely related in the key, these forms are unlikely to be seriously different. However, step 48 (+ve) is in the part of the key that deals with Marshland types and the single quadrat isolated here is somewhat wetter than the more typical form of F1 (see Figure 6B). The following description refers to a composite of all four forms of the type.

Dry foredune F1 is poorly characterized in terms of constant species, with only Agropyron junceiforme (59.4%) with a frequency of 50% or more. In fact, there are only seven species with a frequency of 10% or more, the others being Atriplex hastata (40.6%), Honkenya peploides (34.4%), Cakile maritima (31.3%), Atriplex laciniata (18.8%), Atriplex glabriuscula (15.6%) and Elymus arenarius (15.6%). Of all the genuine vegetation types, i.e. excluding bare ground B, F1 is the most species-poor type with only 19 species recorded from 32 quadrats and a mean number of species per quadrat of 2.6 (cf. 6.1 for C).

The comparison between F1 and, what is possibly its most closely related type, saltmarsh/strandline transition S3 has already been discussed in relation to the latter type. In a comparison between F1 and S3, the former has only two preferential species, Cakile maritima and Honkenya peploides. Most other species having been seriously depleted or lost altogether.

There are no species in dry foredune F1 with a mean cover of 3% or more, the two most important species being Elymus arenarius (2.4%) and Agropyron junceiforme (1.5%). One of the most characteristic features of the type is, therefore, low cover of vascular plants, only 6.6% (cf. C with 35.5%). Bryophytes do not occur in the type and lichens are only present in 3.1% of quadrats with negligible cover. Looking at plant cover in more detail through the potential dominants, it is clear that some quadrats have quite high cover of individual species, e.g. 9.4% of quadrats contain Agropyron junceiforme with 10% or more cover and the equivalent figure for Elymus arenarius is 6.3%. In fact, in the two quadrats that contain Elymus as a dominant, its mean cover is 37.5%. The only other potential dominants are Atriplex hastata and Cakile maritima in one quadrat each.

Clearly dry foredune F1 represents a fairly inhospitable habitat for plant growth. The remaining cover is made up by the non-living categories - bare sand in 96.9% of quadrats with a mean cover of 77.2%, gravel (9.4% and 0.5%), cobbles (25.0% and 9.5%), boulders (21.9% and 5.2%) and solid rock (6.3% and 2.5%). Tidal litter is present in 78.1% of quadrats with 2.3% cover.

Dry foredune F2 is quite well correlated with its soil types which, as might be expected, are characterized by being immature (little humus). Associated soil types are Beach Deposit BD3 (6.3%), immature, Deep Sandy Soils DS2 (25.0%) and DS3 (28.1%) and Thin Soil (sand overlying rock) TS6 (6.3%). Together these four types account for 65.7% of quadrats. The only other common type is semi-mature, Deep Sandy Soil DS6 (15.6%).

As might be expected from the species list and the amount of vegetation cover, grazing pressure in F1 is minimal, with no grazing in 78.1% of quadrats, light grazing in 15.6%, moderate grazing in 6.3% and heavy grazing in none. Signs of grazing animals are similarly sparse, with cattle in 9.4%, sheep in 3.1% and rabbit in 21.9%. Human disturbance in the type is not very great (presumably because it is periodically obliterated but, in any case, this would be insignificant compared with natural disturbance), with vehicle track (6.3%) and spent cartridge (6.3%). Rubbish was recorded from 6.3% of quadrats. Some aquatic habitats are present in the type - river (3.1%), flush/spring (3.1%), saltmarsh creek (3.1%), and rock pool (3.1%).

Local aspect for F1 is fairly neutral but general aspect shows quite a strong preference for south or west (together 78.1%). As suggested in the introduction to the family, slope is an important factor in a vegetation type which occurs on the steeper beaches. Only 12.5% of quadrats have slopes under 1 degree, 50.0% with 1-5 degrees, 31.3% with 5-15 degrees and 6.3% with 15 degrees or over. Surface types are generally plane or simple undulating, together 81.3%. Only one of the 32 quadrats is over the 50ft contour and mean distance from the sea is low at 15m. In fact, 53.1% of quadrats are within 10m of the sea and a further 37.5% in the 10-50m zone. The furthest this type can get from the sea is 100-200m (just one quadrat).

Despite the fact that dry foredune F1 does not conform to the usual east/west division of vegetation types, it does have quite a distinctive geographical distribution. This is presumably related to sites which have particular types of beaches. The type is relatively common in three distinct areas - the southern half of the Outer Hebrides, the west coast of the mainland and the Moray Firth region. In all it occurs in 21 out of 94 sites but only one site, Dornoch (6%), contains more than 5% of the type.

F2 - Wet foredune

F2 - Wet foredune

(dominated by Phalaris arundinacea, Agropyron junceiforme and Agrostis stolonifera

LIST OF SITES WITH RECORDS:-

QUADRAT SURVEY (NO. OF RECORDS = 4)

NO./NAME	QDS.	FREQ.%	NO./NAME	QDS.	FREQ.%
1 Torrs Warren	1	1	42 Valtos	1	4
48 Scousburgh	1	3	77 Spew Bay (Central)	2	5

F2 - Wet foredune, dominated by (Phalaris arundinacea, Agropyron junceiforme) and Agrostis stolonifera

This is a rather uncommon vegetation type, with only 5 quadrats (0.1%) allocated to it. Because the information is so limited, the type can only be described summarily. F2 has but one outlet in the key, step 53 (+ve), which occurs in a part of the key where the main concern is with Marshland types, i.e. the distinction between M1 and M2 (see Figure 6B). This position is entirely consistent with the most important characteristic of the type, i.e. freshwater seeping through the strandline.

The most common species in F2 are Agrostis stolonifera (100.0%) and Cochlearia officinalis (100.0%). Two additional species have frequencies of 50% or more - Stellaria media (60.0%) and Tripleurospermum maritimum (60.0%). There are in all 26 species with a frequency of 10% or more (this is also the total number of species recorded for the type). The mean number of species per quadrat is greatly increased compared with F1 at 8.8 (cf. 2.6 in F1).

The main cover species in wet foredune F2 are Phalaris arundinacea (15.0%), Agropyron junceiforme (12.0%) and Agrostis stolonifera (4.1%). The same three species are the only potential dominants (species with 10% or more cover in a quadrat) in the type. Mean cover of vascular plants is also increased as compared with F1 at 34.9% (cf. 6.6% for F1 and 35.5% for C). Bryophytes were recorded in 40.0% of quadrats but with negligible cover. Lichens do not occur at all. The main non-living cover categories are saltmarsh mud in 40.0% of quadrats with 20.0% cover, bare sand (60.0% and 43.0%), gravel (40.0% and 2.0%), cobbles (40.0% and 1.1%) and tidal litter (40.0% and 3.0%).

Few conclusions can be drawn about the relationship of F2 to soil types. The main characteristic appears to be dampness with 1 quadrat on Sandy Cobble Soil CS2, three on semi-mature, Deep Sandy Soil DS6 and one on Thin Soil TS9.

No conclusions can be drawn about aspect. Slopes tend to be moderate with all quadrats in the 1-5 degrees class. Surface types are mostly plane or simple undulating (80%). All five quadrats allocated to the type are under the 50ft contour and mean distance from the sea is 24m.

There are too few examples of this type to make any sensible comment about geographical distribution, except that it appears to be widespread, with 1 quadrat in the south-west, 1 on the Outer Hebrides, 1 on Shetland and 2 on the Moray Firth.

7.7 Two-Way Tables

The following tables summarize the 28 vegetation types (Bare ground B is excluded for obvious reasons) in terms of percentage species frequency (Table 2) and percentage cover (Table 3). Table 3, in fact, shows percentage cover x 10 in order to restrict entries to the table to three characters without losing the first decimal place (i.e. 25.1% cover = 251 or 0.2% = 2). In both tables a dash (-) means that a particular species is absent from that vegetation type and a plus sign (+) means that it is present but with a frequency of less than 0.5% in Table 2 or with a cover of less than 0.05% in Table 3.

The tables are set out with the vegetation type (using their mnemonics) across the top and species down the side. The ordering of the rows and columns (as in phytosociological tables) is important.

The vegetation types (columns) have been blocked in families, the order within a family being according to their first axis ordination score (ordination of percentage frequency data for the twenty-eight vegetation types). The order of families from left to right can be broken down into three parts. First of all there are the three main families shown in Figure 3 (the non-maritime vegetation types) which run from P2 in the Peatland family (wet, acid) to Colonist type C (dry, unstable and usually base-rich). As already discussed, this range of types is the result of a mixture of successional and environmental trends. Next in the tables are the vegetation types influenced by freshwater (the Marshland family, see Figure 4). For the sake of clarity, these types have been separated off from the families to their left although, in terms of the first axis score, they fall somewhere between the Grassland and Duneland families. This is justified by the wide separation of the more extreme types in the Marshland family on other axes of the ordination (axes 2, 3 and 4 in fact). As already noted, the most common type M1 has close affinities with D3 in the Duneland family, and, indeed, M1 must be considered as a transitional Marshland type. Similar arguments also apply to the Foredune and Saltmarsh families (maritime vegetation types, see Figure 5) which appear on the extreme right of the tables. The more extreme maritime types, e.g. S1, are totally different from any other vegetation types but some Saltmarsh types are transitional with other families, e.g. S5 with D3. As with the total separation of the Marshland family from its more closely related non-marshy types, the isolation of the Foredune and Saltmarsh families is an arbitrary decision designed to make the two-way tables more easily interpreted.

The method of species ordering (the rows) - they are listed in 33 blocks varying from 2 to 16 species per block - is much more complex. This ordering is based on a species classification, the species within a block being highly associated in the sense that they normally occur close together on the ground. The species classification was derived from the smallest quadrat size (1 sq m) that was recorded in the survey. This small size is a more stringent test of which species will grow in immediate proximity to one another than the larger 25 sq m quadrat which was used for the vegetation classification. The number of quadrats used in the species classification is somewhat reduced compared with the vegetation classification, i.e. 2,590 quadrats as compared with 3,677, and there are two reasons for this difference. Firstly, the 1 sq m quadrat was not recorded in the first year of survey (1975) and, secondly, the smaller quadrat results in a higher proportion containing no plants at all (at that size). It is not thought that the absence of data from the sites surveyed in 1975 will produce any bias in a species classification. To avoid classifying species for which there was little information (and would not figure much in the tables anyway), only species with a frequency of 10 or more in the 1 sq m quadrat (equivalent to a frequency of 0.4%) were included. The classification procedure used comprised four distinct processes.

(a) A reciprocal averaging ordination of the 2,590 quadrats using a downweight for all species with a frequency of less than 100. The first four axes were extracted.

(b) Weighting of the four axes by standardization to unit mean square deviation of species scores within stands.

(c) Calculation of interstand distance (Euclidean distance) between species, based on the standardized axes scores.

(d) Minimum variance clustering, using the distance matrix described above.

The clustering process was taken right through to its conclusion (of one cluster) and a hierarchical diagram constructed. There was a reasonably well marked discontinuity at 33 species classes so the (arbitrary) decision was taken to use this as the level of interpretation. The species classes were now placed in first axis order (analogous to what was done with the vegetation types) but, in doing so, they were not permitted to violate the main stems of the species classification which are analogous to the vegetation type families. Eleven species families were recognized in this process. The net result is a species ordering which matches the vegetation type ordering as closely as possible, albeit at a different scale, i.e. 1 sq m quadrat instead of 25 sq m. Within a class the species order is alphabetical.

Because variation between the vegetation types is at least two-dimensional, and arguably four dimensions are required to describe it comprehensively, it is clear that there can be no ideal method of ordering the rows and columns (an ideal method of ordering would give clear-cut blocking of entries with a strong diagonal trend). The method described is thus seen as something of a compromise but one that is designed to be as useful as possible.

Examination of the tables reveals some good blocking of entries and a quite marked right to left diagonal trend in the non-maritime columns (Peatland, Grassland, Duneland and Colonist), which extends from species class 1 (Agropyron repens, Bromus mollis agg., etc) down to class 25 (Myrica gale and Trichophorum cespitosum). Further down the tables, species class 26 (Angelica sylvestris, Carex nigra, etc.) to class 30 (Epilobium palustre, Equisetum fluviatile, etc.) are particularly associated with the Marshland family, species class 31 (Agropyron junceiforme, Atriplex hastata and Elymus arenarius) is associated with the Foredune family and, finally, classes 32 and 33 are associated with the Saltmarsh family.

The tables are a compact means of summarizing the vegetation types in terms of species frequency and cover. Despite the previous warnings about the use of species cover in identifying vegetation types, Table 3 is obviously more clear-cut in terms of the size of entries (there is greater polarization in terms of +'s and high numerical values) than that for frequency.

TABLE 2. TWO-WAY TABLE OF SPECIES FREQUENCY (%) - VEGETATION TYPE FAMILIES AND SPECIES CLASSES

SPECIES NAMES	VEGETATION TYPE FAMILIES																															
	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1
Agropyron repens	-	-	-	-	-	1	2	-	3	-	-	14	9	7	4	16	1	-	-	2	24	-	-	13	1	27	-	-
Bromus mollis agg.	-	-	-	-	-	+	-	-	1	-	-	5	1	4	-	+	-	-	-	-	8	-	-	-	-	-	-	-
Crepis capillaris	-	-	-	-	-	+	-	-	1	-	-	5	4	7	1	2	-	-	-	-	3	-	-	-	-	-	-	-
Geranium molle	-	-	-	-	-	1	-	-	+	-	-	3	1	11	7	5	2	-	-	-	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	4	-	1	2	7	-	-	27	8	22	3	24	2	-	-	1	38	-	-	7	-	-	-	-
Myosotis arvensis	-	-	-	-	-	-	-	-	1	-	-	2	1	10	4	4	1	-	-	1	5	-	-	-	-	-	-	-
Petasites hybridus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	+	-	-	-	-	11	-	-	-	-	-	-	-
Plantago major	-	-	-	-	-	1	1	-	2	-	-	12	8	6	2	2	-	-	-	2	11	-	-	-	-	-	-	-
Polygonum aviculare agg.	-	-	-	-	-	-	1	-	+	-	-	5	1	2	-	2	-	-	-	1	8	-	-	-	-	7	7	-
Saxifraga tridactylites	-	-	-	-	-	-	-	-	-	-	-	-	1	3	1	-	+	-	-	-	-	-	-	-	-	-	-	-
Sonchus arvensis	-	-	-	-	-	-	-	-	+	-	-	2	3	3	2	5	1	17	-	3	3	-	-	7	1	7	-	-
Valerianella locusta	-	-	-	-	-	-	-	-	-	-	-	-	1	2	5	+	1	-	-	-	-	-	-	-	-	-	-	-
Anthyllis vulneraria	-	-	1	-	-	1	-	14	7	-	-	3	13	17	2	5	-	-	-	-	-	-	-	-	-	-	-	-
Arabis hirsuta	-	-	-	-	-	-	-	-	-	-	-	-	3	4	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Arenaria serpyllifolia agg.	-	-	-	-	-	+	-	-	1	-	-	-	5	15	4	3	3	-	-	-	-	-	-	-	1	-	-	-
Dactylis glomerata	-	-	-	-	4	3	2	-	7	-	29	44	6	11	7	25	1	-	-	1	35	-	-	27	-	-	-	-
Daucus carota	-	-	-	-	-	-	-	8	9	-	-	7	20	25	2	7	-	-	-	-	5	-	-	7	-	-	-	-
Erodium cicutarium agg.	-	-	-	-	-	-	-	-	+	-	-	-	1	6	3	3	6	-	-	-	-	-	-	-	-	7	-	-
Erophila verna	-	-	-	-	-	+	-	-	-	-	-	-	-	2	2	+	1	-	-	-	-	-	-	-	-	-	-	-
Geranium sanguineum	-	-	-	-	-	-	-	-	+	-	-	-	1	3	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum minus	-	-	-	-	-	1	-	2	6	-	-	2	10	35	2	20	1	-	-	-	3	-	-	-	-	-	-	-
Viola tricolor	-	-	-	-	-	3	-	-	2	-	-	-	5	17	13	3	4	-	-	-	3	-	-	-	-	-	-	-
Ammophila arenaria	-	-	-	3	-	32	-	7	7	50	-	-	23	56	86	70	96	-	-	2	30	-	-	40	6	13	14	-
Cerastium atrovirens	-	-	2	-	-	6	-	10	6	50	14	-	11	25	28	17	16	-	-	2	8	-	-	20	7	13	-	-
Cirsium arvense	-	-	-	-	-	4	-	1	6	-	-	53	11	13	33	34	16	17	-	9	57	-	20	20	1	-	-	-
Galium aparine	-	-	-	-	-	-	1	-	+	-	-	8	-	1	1	6	+	-	-	3	14	3	-	-	-	13	-	-
Honkenya peploides	-	-	-	-	-	+	-	-	+	-	-	-	-	2	1	2	4	-	-	-	3	34	-	20	1	7	-	2
Rumex crispus	-	-	-	-	-	1	1	2	5	-	-	19	12	7	8	11	7	-	-	13	22	6	-	-	2	33	-	-
Sedum acre	-	-	1	-	-	-	-	1	1	-	14	-	4	6	4	3	2	-	-	-	3	-	-	7	1	7	-	-
Sonchus asper	-	-	-	-	-	-	-	-	1	-	-	7	1	3	9	10	5	-	-	1	8	-	-	7	-	13	-	-
Taraxacum spp.	-	-	11	3	-	5	10	11	18	-	-	29	16	32	46	33	12	-	-	3	24	-	-	27	5	-	-	-
Torilis japonica	-	-	-	-	-	-	-	-	+	-	-	-	-	1	4	3	-	-	-	-	5	-	-	7	-	-	-	-
Tussilago farfara	-	-	-	-	-	-	-	1	+	-	-	7	2	+	+	5	3	-	-	1	5	-	20	-	-	-	-	-
Achillea millefolium	-	-	7	17	4	21	2	44	31	-	29	47	33	66	17	36	5	-	-	-	32	-	-	7	-	-	-	-
Arrhenatherum elatius	-	13	1	-	13	2	2	-	7	-	14	25	5	13	15	21	1	33	-	5	41	-	-	7	-	-	-	-
Centaurea nigra	-	-	4	-	4	1	3	20	21	-	29	34	11	22	2	15	+	-	-	1	27	-	-	13	-	-	-	-
Cirsium vulgare	-	-	1	10	4	5	2	8	11	-	14	7	9	19	22	21	12	17	-	-	14	-	-	-	-	-	-	-
Galium sterneri	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galium verum	-	-	6	-	-	15	1	55	30	-	14	8	75	82	77	53	15	17	-	-	27	-	-	-	1	-	-	-
Lolium perenne agg.	-	-	1	3	-	1	10	14	25	-	14	46	23	39	6	9	1	-	-	7	22	-	-	7	-	-	-	-
Matricaria matricarioides	-	-	-	-	-	-	-	-	+	-	-	2	1	1	1	+	-	-	-	-	5	-	-	-	-	-	-	-
Odontites verna	3	-	1	-	-	-	-	-	6	-	-	3	11	17	+	1	-	-	-	1	5	-	-	13	6	-	-	-
Poa trivialis	-	-	-	-	-	1	9	2	5	-	14	7	9	8	+	3	-	-	-	13	11	-	-	-	-	-	-	-
Ranunculus bulbosus	-	-	-	-	-	2	-	6	9	-	14	3	14	21	8	6	1	-	-	-	-	-	-	-	-	-	-	-
Senecio Jacobaea	-	-	4	28	13	17	11	19	20	50	14	7	57	67	70	56	24	50	25	3	43	-	-	27	-	27	-	-
Stellaria media	-	-	-	-	-	1	2	-	6	-	14	20	6	9	4	7	1	-	-	6	19	-	40	-	-	20	-	-
Urtica dioica	-	13	-	-	-	2	-	-	1	-	14	20	2	2	4	14	1	-	-	5	27	-	-	7	-	-	-	-
Veronica arvensis	-	-	-	7	-	5	-	2	1	-	-	2	6	14	12	3	1	-	-	-	3	-	-	-	-	-	-	-
Astragalus danicus	-	-	-	-	-	1	-	-	-	-	-	-	-	1	17	5	1	-	-	-	-	-	-	7	-	-	-	-
Bellis perennis	-	-	6	-	-	4	56	60	64	-	14	49	79	88	29	16	3	-	25	15	16	-	-	27	4	-	-	-
Briza media	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Centaurium erythraea	-	-	-	-	-	-	1	5	2	-	-	-	9	2	1	+	1	-	-	-	-	-	-	-	-	7	-	-
Cerastium holosteoides	-	-	15	24	4	29	47	58	70	50	14	75	76	79	64	39	4	-	-	21	38	3	-	20	6	-	-	-
Gentianella amarella	-	-	3	-	-	-	-	8	8	-	-	2	12	9	4	4	-	-	-	-	-	-	-	-	-	-	-	-
Helictotrichon pubescens	-	-	2	-	-	1	-	5	7	-	-	7	6	11	6	2	-	17	-	-	-	-	-	-	-	-	-	-
Leontodon taraxacoides	-	-	-	-	-	1	-	6	5	-	-	3	3	5	3	1	+	-	-	-	-	-	-	-	-	-	-	-
Linum catharticum	-	-	8	-	-	3	3	56	35	-	-	10	61	45	25	7	3	-	25	1	3	-	-	-	4	-	7	-
Ononis repens	-	-	-	-	-	+	-	-	-	-	-	-	1	1	7	7	2	-	-	-	3	-	-	7	-	-	-	-
Plantago lanceolata	-	-	36	-	4	15	43	90	88	-	57	83	87	95	56	58	6	-	25	8	43	-	-	33	2	-	-	-
Poa annua	-	-	1	3	4	3	-	1	4	-	-	14	7	7	4	2	2	-	-	7	14	-	-	-	-	13	-	-
Campanula rotundifolia	-	-	2	-	4	25	-	22	10	-	14	7	11	15	32	21	8	-	-	-	11	-	-	-	-	-	-	-
Cerastium semidecandrum	-	-	-	-	-	3	-	-	-	-	-	-	-	1	4	1	+	-	-	-	-	-	-	-	-	-	-	-
Chamaenerion angustifolium	-	-	-	14	9	5	-	1	1	-	-	2	-	-	10	4	4	17	-	1	8	-	-	7	-	-	-	-
Cochlearia officinalis	-	-	1	-	-	-	1	2	3	-	-	-	3	1	-	2	+	-	-	-	-	-	100	47	41	27	29	2
Koeleria cristata	-	-	15	-	-	15	-	58	20	-	-	7	18	28	33	12	4	-	-	1	8	-	-	7	-	-	-	-
Trifolium dubium	-	-	-	3	-	1	-	-	1	-	-	-	1	2	4	1	-	-	-	-	-	-	-	-	-	-	-	-
Veronica chamaedrys	-	-	1	-	4	13	-	9	6	-	-	20	3	8	46	19	3	-	-	1	16	-	-	-	-	-	-	-
Vicia lathyroides/sativa	-	-	-	-	4	6	-	-	2	50	-	-	-	1	17	5	2	-	-	1	-	-	-	7	1	-	-	-
Chrysanthemum leucanthemum	-	-	-	-	-	-	1	1	5	-	-	8	2	2	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Coeloglossum viride	-	-	-	-	-	-	1	11	14	-	-	2	22	8	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Euphrasia officinalis agg.	-	-	39	3	-	5	38	75	65	-	-	14	79	75	16	7	3	-	25	8	-	-	-	40	22	-	7	-
Festuca rubra	10	38	46	52	39	46	78	75	93	50	71	85	96	96	88	82	25	17	-	20	51	-	-	93	96	73	100	13
Leontodon autumnalis	-	-	19	3	17	3	60	39	58	-	-	44	55	36	9	12	2	-	-	8	-	-	-	33	30	-	-	-
Lotus corniculatus	-	13	50	17	4	36	30	95	82	50	-	29	82	76	74	40	13	67	-	8	30	-	-	47	2	-	-	-
Plantago coronopus	-	-	2	-	-	-	1	13	10	50	14	2	20	9	3	2	2	-	-	-	-	-	-	60	44	-	7	-
Poa pratensis	-	-	15	86	39	57	48	43	74	-	100	75	87	88	86	77	9	33	-	25	41	-	-	60	17	7	-	-
Primula veris	-	-	1	-	-	-	+	-	2	3	-	2	1	2	3	2	+	-	-	-	3	-	-	-	-	-	-	-
Primula vulgaris	-	-	6	-	-	-	-	-	7	3	-	8	4	5	+	1	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculus acris	-	-	21	7	17	2	71	56	77	-	-	75	85	75	5	11	1	17	-	25	22	-	-	13	2	-	-	-
Rhinanthus minor agg.	-	-	9	-	17	3	27	11	27	-	-	24	34	20	5	4	-	-	25	14	8	-	-	7	2	-	-	-
Thymus drucei	-	-	25	-	-	11	-	85	28	100	-	8	28	33	56	8	11	-	-	-	3	-	-	-	-	-	-	-
Trifolium pratense	-	-	17	-	-	1	33	40	51	-	-	29	55	41	1	1	-	-	-	3	5	-	-	13	-	-	-	-
Trifolium repens	-	-	51	28	30	22	82	79	89	50	29	90	93	96	53	39	2	-	25	30	35	-	-	60	23	-	-	-
Vicia sepium	-	-	1	-	-	4	-	-	2	-	-	3	1	4	+	7	-	-	-	-	5	-	-	-	-	-	-	-
Agrostis stolonifera	3	25	25	34	61	9	80	28	57	50	86	47	90	42	8	10	8	33	100	86	49	3	100	60	67	33	36	-
Carex flacca	-	-	20	10	4	6	28	29	30	50	-	29	45	20	7	4	1	-	25	16	-	-	-	47	20	-	-	-
Cynosurus cristatus	-	-	18	-	-	2	44	41	47	-	-	53	41	25	6	3	-	-	-	9	3	-	-	-	-	-	-	-
Gentianella campestris	-	-	-	-	-	-	-	19	7	-	-	-	8	2	-	+	-	-	-	1	-	-	-	-	-	-	-	-
Hieraceum pilosella	-	-	6	3	-	14	-	31	10	50	-	3	8	12	32	6	5	-	-	-	-	-	-	-	-	-	-	-
Holcus lanatus	5	63	63	49	87	49	78	70	87	-	86	93	84	44	56	33	7	100	25	53	54	-	-	7	-	-	-	-
Luzula campestris	10	13	24	45	22	41	33	44	43	-	29	27	47	44	57	7	5	-	-	3	3	-	-	-	1	-	-	-
Ophioglossum vulgatum	-	-	-	-	-	+	3	-	10	-	-	-	21	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Phleum bertolonii/pratense	-	-	1	-	-	3	1	-	1	-	-	2	1	2	1	3	-	-	-	2	5	-	-	-	-	-	-	-
Polygala vulgaris	26	-	26	-	-	3	1	37	15	-	-	3	26	21	6	2	1	-	-	-	-	-	-	-	-	-	-	-
Prunella vulgaris	-	-	35	3	17	4	63	75	74	-	-	47	75	49	10	2	1	-	25	10	3	-	-	-	-	-	-	-
Rumex acetosa	-	63	8	55	22	13	12	28	33	50	43	76	20	23	4	10	2	17	25	9	24	-	-	-	-	-	-	-
Sagina nodosa	-	-	-	3	-	+	17	4	5	-	-	-	9	2	1	1	-	-	-	5	-	-	-	13	19	-	14	-
Viola riviniana	-	-	29	3	13	28	1	69	28	50	29	19	25	19	43	7	7	17	-	1	11	-	-	7	-	-	-	-
Equisetum arvense	-	-	2	7	4	3	25	5	20	-	-	24	19	7	2	6	2	-	-	14	8	-	20	7	-	-	-	-
Juncus bufonius	-	-	1	-	9	1	7	-	5	-	-	7	8	2	1	+	1	-	-	13	3	-	-	-	7	7	-	-
Potentilla anserina	-	-	2	7	9	1	48	7	35	-	14	34	64	13	1	4	3	-	25	10	19	6	-	20	4	27	-	-
Ranunculus repens	-	-	2	17	26	5	52	4	27	-	14	53	38	19	7	11	2	50	25	41	57	-	-	-	-	-	-	-
Vicia cracca	-	-	3	7	4	1	33	2	29	-	-	14	28	9	1	6	1	-	-	11	8	-	-	7	-	-	-	-
Deschampsia cespitosa	-	13	-	-	22	1	1	-	2	-	-	15	4	1	1	3	-	17	-	14	8	-	-	-	-	-	-	-
Lathyrus pratensis	-	-	3	3	4	1	18	-	11	-	14	17	9	1	1	5	-	-	-	13	32	-	-	-	-	-	-	-
Parnassia palustris	-	-	4	-	-	+	10	8	7	-	-	2	9	2	-	+	-	-	-	3	-	-	-	-	-	-	-	-
Sagina procumbens	-	-	6	14	22	3	38	9	20	50	-	36	13	5	6	1	-	-	25	15	-	-	-	20	10	-	-	-
Senecio aquaticus	-	-	3	-	4	-	34	-	6	-	-	17	4	2	-	+	-	-	-	9	3	-	-	-	-	-	-	-

(Table 2. Species Frequency (%) continued)

	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1
Aira praecox	3	-	10	3	-	14	3	16	7	-	29	2	4	3	26	4	6	-	-	-	-	-	-	7	-	-	-	-
Carex arenaria	-	-	2	69	4	70	3	9	18	-	-	5	51	40	79	33	20	17	-	3	22	3	-	47	-	7	7	-
Hieraceum spp.	3	-	3	-	-	2	-	4	1	-	-	2	3	1	8	4	+	17	-	-	-	-	-	-	-	-	-	-
Myosotis ramosissima	-	-	-	-	-	2	-	-	+	-	-	-	-	-	11	2	1	-	-	-	3	-	-	-	-	-	-	-
Sedum anglicum	3	-	11	-	-	+	-	4	4	50	-	-	1	1	-	+	1	-	-	-	-	-	-	-	1	-	-	-
Ulex europaeus	-	-	-	7	26	19	2	6	1	-	57	7	-	-	4	6	1	50	-	1	16	-	-	7	-	-	-	-
Viola canina	-	-	-	-	-	9	-	1	2	-	-	8	1	2	16	2	3	-	-	-	5	-	-	-	-	-	-	-
Agrostis tenuis	-	13	34	86	35	84	9	68	39	50	57	66	8	12	37	12	8	33	-	3	16	-	-	40	9	-	-	-
Rumex acetosella	-	-	2	10	4	22	-	1	3	-	14	10	-	1	20	4	3	33	-	6	3	-	-	13	-	-	-	-
Teesdalia nudicaulis	-	-	-	-	-	3	-	-	-	-	-	-	-	-	2	+	3	-	-	-	-	-	-	-	-	-	-	-
Veronica officinalis	-	-	2	10	-	25	1	12	2	50	-	5	2	1	22	2	4	-	-	-	-	-	-	-	-	-	-	-
Anthoxanthum odoratum	44	50	87	79	52	57	56	77	67	50	86	76	11	9	28	7	1	33	-	9	19	-	-	-	-	-	-	-
Hypochoeris radicata	-	-	21	7	-	19	3	36	11	-	29	14	1	2	40	8	9	-	-	1	8	-	-	27	-	-	-	-
Luzula multiflora	13	25	35	52	22	15	20	21	18	-	-	12	6	5	4	2	1	-	-	6	5	-	-	-	-	-	-	-
Scilla verna	-	-	5	-	-	-	-	9	3	-	-	-	2	1	+	-	-	-	-	-	-	-	-	7	1	-	-	-
Achillea ptarmica	-	13	4	24	30	2	6	9	9	-	-	17	2	-	1	+	-	-	-	6	3	-	-	-	-	-	-	-
Antennaria dioica	-	-	10	-	-	+	-	16	4	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex pulicaris	-	13	42	3	-	+	27	45	15	-	-	2	11	+	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Cirsium palustre	-	38	4	21	61	2	1	6	5	-	-	14	2	+	-	+	+	17	-	11	5	-	-	-	-	-	-	-
Dactylorchis spp.	33	-	28	3	-	1	52	17	22	-	-	5	23	6	+	+	-	-	-	18	-	-	-	-	-	-	-	-
Sieglingia decumbens	-	-	77	21	9	11	18	71	34	50	-	-	16	1	2	+	-	-	-	-	3	-	-	7	5	-	-	-
Festuca ovina	13	25	47	90	-	70	8	49	15	100	-	7	1	4	39	3	8	17	-	-	-	-	-	20	1	-	-	-
Galium saxatile	5	25	13	90	35	53	1	11	6	-	14	12	1	1	16	3	2	17	-	1	3	-	-	-	-	-	-	-
Holcus mollis	-	38	-	34	13	5	-	-	1	-	-	8	-	+	+	3	-	-	-	3	14	-	-	-	-	-	-	-
Pteridium aquilinum	8	13	4	-	13	10	-	12	4	-	29	10	1	1	2	2	3	-	-	-	-	-	-	-	-	-	-	-
Anagallis tenella	-	-	27	3	4	-	44	13	16	-	-	-	9	+	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Carex flava agg.	3	-	26	3	4	1	26	18	4	-	-	-	1	+	-	-	-	-	-	1	-	-	-	7	31	-	-	-
Carex panicea	46	13	69	10	9	3	57	47	26	-	-	5	21	4	2	+	-	-	-	2	3	-	-	-	1	-	-	-
Eleocharis quinqueflora	3	-	7	-	-	-	16	-	2	-	-	-	1	-	-	-	-	-	-	1	-	-	-	27	5	-	-	-
Potentilla palustris	3	50	4	3	35	+	29	-	+	-	-	2	1	-	-	-	-	17	-	28	-	-	-	-	-	-	-	-
Ranunculus flammula	3	-	28	10	22	+	81	8	16	-	-	14	4	+	-	+	-	-	-	26	3	-	-	-	1	-	-	-
Succisa pratensis	33	13	85	3	17	6	62	64	42	-	14	22	8	5	1	1	-	-	-	5	3	-	-	-	-	-	-	-
Agrostis canina	38	50	43	90	22	10	9	11	8	-	14	2	2	3	1	2	1	-	-	7	3	-	-	7	-	-	-	-
Hypericum pulchrum	-	-	11	-	-	4	2	10	1	-	-	3	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Salix repens	15	13	32	31	17	17	9	21	7	-	-	2	3	+	6	+	1	-	-	2	3	-	-	-	-	-	-	-
Juncus effusus	13	63	23	72	83	5	21	6	10	-	-	29	1	+	+	+	-	17	-	22	3	-	-	-	-	-	-	-
Pedicularis palustris	-	13	14	-	-	-	30	2	4	-	-	2	3	-	-	-	-	-	-	7	-	-	-	-	1	-	-	-
Viola palustris	-	63	10	31	61	1	3	3	2	-	-	2	2	+	-	-	-	17	-	7	-	-	-	-	-	-	-	-
Festuca vivipara	8	13	28	-	4	1	2	23	5	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus acutiflorus	-	38	5	28	17	1	2	1	2	-	-	2	2	+	+	-	-	-	-	5	-	-	-	-	1	-	-	-
Pedicularis sylvatica	10	-	29	3	-	1	19	8	4	-	-	-	1	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Schoenus nigricans	-	-	7	-	-	-	3	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Carex echinata	21	50	56	3	22	+	27	9	5	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-
Juncus bulbosus/kochii	5	13	12	3	-	+	20	3	4	-	-	-	1	+	-	-	-	-	25	1	-	-	-	-	-	-	-	-
Carex pilulifera	5	-	8	3	-	3	-	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus squarrosus	26	13	23	38	4	11	-	6	2	-	-	2	-	-	2	-	+	-	-	-	-	-	-	-	-	-	-	-
Nardus stricta	13	63	69	97	22	16	12	24	11	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Potentilla erecta	100	88	97	97	65	32	24	79	25	-	14	15	2	-	3	-	+	-	-	-	3	-	-	-	-	-	-	-
Eriophorum angustifolium	69	38	44	-	9	+	46	7	6	-	-	-	1	-	-	-	-	-	-	5	-	-	-	-	1	-	-	-
Molinia caerulea	95	50	87	7	13	2	43	27	21	-	-	3	5	-	-	+	+	17	-	-	-	-	-	-	1	-	-	-
Calluna vulgaris	95	50	92	45	17	61	9	65	12	50	-	-	-	-	5	+	7	-	-	-	-	-	-	7	-	-	-	-
Deschampsia flexuosa	13	-	4	17	4	11	-	1	+	-	-	-	-	-	+	+	+	33	-	-	-	-	-	-	-	-	-	-
Empetrum nigrum	15	25	10	7	-	15	-	14	2	-	-	2	-	+	4	1	2	-	-	-	-	-	-	-	-	-	-	-
Erica cinerea	31	13	33	-	9	36	3	10	1	-	-	2	-	-	3	1	5	-	-	-	3	-	-	-	-	-	-	-
Luzula pilosa	5	13	1	3	4	4	-	-	-	-	14	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Erica tetralix	90	63	82	41	17	10	13	22	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Narthecium ossifragum	31	-	41	-	-	+	4	3	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myrica gale	54	25	17	-	9	+	2	1	-	-	-	-	-	-	-	-	-	17	-	1	-	-	-	-	-	-	-	-
Trichophorum cespitosum	51	13	22	-	-	+	-	1	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Angelica sylvestris	-	25	5	-	26	1	18	13	12	-	-	25	4	1	1	8	1	17	-	23	14	-	-	-	-	-	-	-
Carex nigra	26	63	58	86	74	8	92	51	77	-	-	19	58	16	2	2	-	-	25	54	-	-	-	7	5	-	-	-
Equisetum palustre	-	25	-	10	-	1	16	1	9	-	-	7	4	+	-	+	-	-	-	15	24	-	-	-	-	-	-	-
Juncus balticus	-	-	3	-	-	1	8	4	14	-	-	-	9	+	-	+	-	-	-	-	-	-	-	-	1	-	-	-
Plantago maritima	-	-	44	-	-	1	24	79	47	50	29	10	54	9	7	5	2	-	-	1	-	-	40	80	89	67	93	56
Polygala serpyllifolia	8	-	14	17	-	4	2	5	2	-	-	2	3	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Selaginella selaginoides	-	-	22	-	-	-	9	29	21	-	-	2	26	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Triglochin maritima	-	-	-	-	-	-	33	-	6	-	-	-	3	-	-	+	-	-	-	11	-	3	-	33	48	-	7	9
Cardamine pratensis	-	-	3	3	17	1	70	4	15	-	-	31	26	2	1	1	-	17	-	52	5	-	-	-	-	-	-	-
Iris pseudacorus	-	-	2	-	4	-	13	-	6	-	-	3	1	+	-	+	-	-	-	15	8	3	-	-	-	-	-	-
Lychnis flos-cuculi	-	-	5	-	13	-	44	2	16	-	-	15	14	+	-	-	-	-	-	29	-	-	-	7	2	-	-	-
Oenanthe lachenalii	-	-	-	-	-	-	21	-	4	-	-	5	1	-	-	-	-	-	-	3	-	-	-	-	1	-	-	-
Polygonum amphibium	-	-	-	-	-	+	12	-	4	-	-	-	3	1	-	-	-	-	-	20	-	-	-	-	-	-	-	-
Triglochin palustris	-	-	2	-	-	-	15	2	6	-	-	3	6	+	-	-	-	-	-	9	-	-	-	13	1	7	7	-
Caltha palustris	-	-	1	-	4	-	76	3	12	-	-	17	8	-	-	1	-	-	25	45	5	-	-	-	-	-	-	-
Eleocharis palustris	-	-	-	-	-	-	26	-	3	-	-	7	6	-	-	+	+	-	-	28	5	-	-	-	-	-	-	-
Mentha aquatica	-	-	-	-	-	-	27	-	1	-	-	5	4	-	-	1	-	-	-	31	8	-	-	-	-	-	-	-
Filipendula ulmaria	-	-	4	-	4	2	16	5	15	-	-	32	7	1	-	5	-	-	-	24	27	-	-	-	-	-	-	-
Hydrocotyle vulgaris	3	13	21	10	61	1	82	7	18	-	-	2	23	+	-	+	-	33	25	45	5	-	-	-	-	-	-	-
Juncus articulatus	3	-	19	7	22	1	62	15	32	-	-	32	33	1	+	+	+	17	50	45	5	-	20	20	11	-	7	-
Pinguicula vulgaris	8	-	19	-	-	-	25	9	18	-	-	2	11	+	-	-	-	-	-	-	-	-	-	7	1	-	-	-
Epilobium palustre	-	13	3	10	57	+	33	-	7	-	-	8	4	-	+	+	-	17	25	37	-	-	20	-	-	-	-	-
Equisetum fluviatile	-	-	2	-	22	-	18	-	3	-	-	8	4	-	-	-	-	17	-	29	-	-	-	-	-	-	-	-
Galium palustre	-	-	2	7	61	1	46	1	5	-	-	19	6	-	-	+	-	17	-	55	3	-	-	-	-	-	-	-
Agropyron junceiforme	-	-	-	-	-	+	-	1	+	-	-	2	3	8	6	17	33	-	-	2	-	59	20	7	4	47	14	2
Atriplex hastata	-	-	-	-	-	-	-	-	-	-	14	-	-	1	1	3	7	-	-	1	5	41	40	7	-	47	-	-
Elymus arenarius	-	-	-	-	-	-	-	-	-	-	-	2	-	1	2	6	9	-	-	-	5	16	-	-	2	13	7	-
Armeria maritima	-	-	-	-	-	1	-	4	4	100	-	3	1	3	4	3	+	-	-	-	-	-	-	87	88	40	93	58
Glaux maritima	-	-	-	-	-	-	15	1	3	-	-	-	5	+	-	1	-	-	-	5	3	-	-	40	94	47	79	51
Juncus gerardii	-	-	-	3	-	+	3	-	2	-	-	-	4	+	-	+	-	-	-	2	-	-	-	53	86	13	21	2
Aster tripolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	40
Puccinellia maritima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	38	40	86	85

TABLE 3. TWO-WAY TABLE OF SPECIES COVER (% X 10) - VEGETATION TYPE FAMILIES AND SPECIES CLASSES

SPECIES NAMES	VEGETATION TYPE FAMILIES																											
	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1
Agropyron repens	-	-	-	-	-	+	2	-	1	-	-	2	3	3	5	11	+	-	-	+	60	-	-	1	1	38	-	-
Bromus mollis agg.	-	-	-	-	-	+	-	-	1	-	-	+	+	1	-	+	-	-	-	-	3	-	-	-	-	-	-	-
Crepis capillaris	-	-	-	-	-	+	-	-	+	-	-	+	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-	-
Geranium molle	-	-	-	-	-	+	-	-	+	-	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	+	-	+	+	2	-	-	3	2	11	+	8	+	-	-	1	12	-	-	1	-	-	-	-
Myosotis arvensis	-	-	-	-	-	-	-	-	+	-	-	+	+	+	+	+	+	-	-	+	+	-	-	-	-	-	-	-
Petasites hybridus	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	2	-	-	-	-	104	-	-	-	-	-	-	-
Plantago major	-	-	-	-	-	+	+	-	+	-	-	1	+	1	+	+	-	-	-	+	6	-	-	-	-	-	-	-
Polygonum aviculare agg.	-	-	-	-	-	-	+	-	+	-	-	+	+	1	-	2	-	-	-	+	1	-	-	-	-	1	+	-
Saxifraga tridactylites	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-
Sonchus arvensis	-	-	-	-	-	-	-	-	+	-	-	1	+	+	+	1	+	+	-	3	+	-	-	+	+	1	-	-
Valerianella locusta	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Anthyllis vulneraria	-	-	+	-	-	+	-	2	+	-	-	+	1	1	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Arabis hirsuta	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Arenaria serpyllifolia agg.	-	-	-	-	-	+	-	-	+	-	-	-	+	1	+	+	+	-	-	-	-	-	-	-	+	-	-	-
Dactylis glomerata	-	-	-	-	+	1	+	-	1	-	15	22	4	5	1	13	+	-	-	+	13	-	-	2	-	-	-	-
Daucus carota	-	-	-	-	-	-	-	1	1	-	-	+	2	3	+	1	-	-	-	-	+	-	-	+	-	-	-	-
Erodium cicutarium agg.	-	-	-	-	-	-	-	-	+	-	-	-	+	1	+	1	1	-	-	-	-	-	-	-	-	+	-	-
Erophila verna	-	-	-	-	-	+	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Geranium sanguineum	-	-	-	-	-	-	-	-	+	-	-	-	+	1	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum minus	-	-	-	-	-	+	-	+	1	-	-	+	3	11	1	5	+	-	-	-	+	-	-	-	-	-	-	-
Viola tricolor	-	-	-	-	-	+	-	-	+	-	-	-	1	1	1	+	+	-	-	-	+	-	-	-	-	-	-	-
Ammophila arenaria	-	-	-	+	-	39	-	3	11	1	-	-	12	94	226	249	192	-	-	+	56	-	-	33	9	4	7	-
Cerastium atrovirens	-	-	+	-	-	+	-	+	+	5	+	-	1	4	1	1	1	-	-	+	+	-	-	1	+	+	-	-
Cirsium arvense	-	-	-	-	-	1	-	+	1	-	-	30	3	4	4	6	3	8	-	1	44	-	2	1	+	-	-	-
Galium aparine	-	-	-	-	-	-	+	-	+	-	-	1	-	+	+	+	+	-	-	+	1	+	-	-	-	+	-	-
Honkenya peploides	-	-	-	-	-	+	-	-	+	-	-	-	-	1	+	+	+	-	-	-	15	4	-	7	+	+	-	+
Rumex crispus	-	-	-	-	-	+	+	+	+	-	-	2	+	+	1	1	+	-	-	+	1	+	-	-	+	1	-	-
Sedum acre	-	-	+	-	-	-	-	+	+	-	+	-	+	+	+	+	+	-	-	-	+	-	-	1	+	+	-	-
Sonchus asper	-	-	-	-	-	-	-	-	+	-	-	+	+	+	+	+	+	-	-	+	+	-	-	+	-	+	-	-
Taraxacum spp.	-	-	+	+	-	+	+	+	1	-	-	2	+	2	1	2	+	-	-	+	1	-	-	4	1	-	-	-
Torilis japonica	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	1	-	-	-	-	+	-	-	+	-	-	-	-
Tussilago farfara	-	-	-	-	-	-	-	1	+	-	-	1	1	+	+	1	1	-	-	+	1	-	1	-	-	-	-	-
Achillea millefolium	-	-	+	1	+	2	+	3	3	-	1	3	3	11	1	6	1	-	-	-	4	-	-	3	-	-	-	-
Arrhenatherum elatius	-	6	1	-	7	1	1	-	2	-	+	18	4	7	11	24	+	9	-	10	57	-	-	+	-	-	-	-
Centaurea nigra	-	-	+	-	+	+	+	2	6	-	2	5	2	6	+	5	+	-	-	+	3	-	-	+	-	-	-	-
Cirsium vulgare	-	-	+	+	+	+	+	+	+	-	1	1	1	1	1	2	+	+	-	-	2	-	-	-	-	-	-	-
Galium sterneri	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galium verum	-	-	+	-	-	1	+	5	7	-	+	+	18	36	21	20	3	+	-	-	3	-	-	-	+	-	-	-
Lolium perenne agg.	-	-	+	+	-	1	2	4	14	-	+	38	6	25	2	10	4	-	-	2	79	-	-	1	-	-	-	-
Matricaria matricarioides	-	-	-	-	-	-	-	-	+	-	-	+	+	+	+	+	-	-	-	-	3	-	-	-	-	-	-	-
Odontites verna	+	-	+	-	-	-	-	-	+	-	-	+	1	1	+	+	-	-	-	+	+	-	-	4	+	-	-	-
Poa trivialis	-	-	-	-	-	+	1	+	+	-	+	1	2	2	+	1	-	-	-	2	2	-	-	-	-	-	-	-
Ranunculus bulbosus	-	-	-	-	-	+	-	+	1	-	7	+	1	3	+	1	+	-	-	-	-	-	-	-	-	-	-	-
Senecio jacobaea	-	-	+	3	+	2	1	1	1	1	+	+	9	16	7	6	2	3	1	+	4	-	-	2	-	1	-	-
Stellaria media	-	-	-	-	-	+	+	-	1	-	+	4	+	2	1	1	+	-	-	1	3	-	5	-	-	1	-	-
Urtica dioica	-	+	-	-	-	1	-	-	+	-	7	3	+	1	+	6	+	-	-	4	11	-	-	+	-	-	-	-
Veronica arvensis	-	-	-	+	-	+	-	+	+	-	-	+	+	1	+	+	+	-	-	-	+	-	-	-	-	-	-	-
Astragalus danicus	-	-	-	-	-	+	-	-	-	-	-	-	-	+	3	2	+	-	-	-	-	-	-	3	-	-	-	-
Bellis perennis	-	-	1	-	-	1	13	14	22	-	+	11	39	35	5	2	1	-	1	2	4	-	-	11	1	-	-	-
Briza media	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Centaurium erythraea	-	-	-	-	-	-	+	+	+	-	-	-	+	+	+	+	+	-	-	-	-	-	-	-	-	+	-	-
Cerastium holosteoides	-	-	1	2	+	2	2	2	4	1	+	4	4	5	3	2	+	-	-	1	1	+	-	4	+	-	-	-
Gentianella amarella	-	-	+	-	-	-	-	+	+	-	-	+	1	1	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Helictotrichon pubescens	-	-	+	-	-	+	-	+	1	-	-	+	2	4	+	1	-	+	-	-	-	-	-	-	-	-	-	-
Leontodon taraxacoides	-	-	-	-	-	+	-	1	+	-	-	+	+	1	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Linum catharticum	-	-	+	-	-	+	+	3	2	-	-	+	4	3	2	+	+	-	1	+	+	-	-	-	+	-	+	-
Ononis repens	-	-	-	-	-	+	-	-	-	-	-	-	+	1	7	4	1	-	-	-	3	-	-	1	-	-	-	-
Plantago lanceolata	-	-	4	-	+	2	4	35	34	-	1	24	34	56	10	11	+	-	1	1	2	-	-	8	+	-	-	-
Poa annua	-	-	+	+	7	+	-	+	1	-	-	3	+	3	+	1	+	-	-	2	6	-	-	-	-	7	-	-
Campanula rotundifolia	-	-	+	-	+	2	-	1	1	-	+	+	1	1	2	1	+	-	-	-	1	-	-	-	-	-	-	-
Cerastium semidecandrum	-	-	-	-	-	+	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Chamaenerion angustifolium	-	-	-	+	1	1	-	+	+	-	-	+	-	-	2	4	2	+	-	5	1	-	-	+	-	-	-	-
Cochlearia officinalis	-	-	+	-	-	-	+	+	+	-	-	-	+	+	-	+	+	-	-	-	-	-	6	5	3	1	3	+
Koeleria cristata	-	-	2	-	-	3	-	13	5	-	-	5	3	9	9	3	1	-	-	+	6	-	-	1	-	-	-	-
Trifolium dubium	-	-	-	+	-	+	-	-	+	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Veronica chamaedrys	-	-	+	-	+	1	-	+	+	-	-	1	+	1	4	2	+	-	-	+	6	-	-	-	-	-	-	-
Vicia lathyroides/sativa	-	-	-	-	+	+	-	-	+	1	-	-	-	+	1	+	+	-	-	+	-	-	-	1	+	-	-	-
Chrysanthemum leucanthemum	-	-	-	-	-	-	+	+	1	-	-	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Coeloglossum viride	-	-	-	-	-	-	+	+	+	-	-	+	1	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Euphrasia officinalis agg.	-	-	2	+	-	+	2	5	7	-	-	1	11	12	2	1	+	-	1	+	-	-	-	6	2	-	+	-
Festuca rubra	8	32	28	41	35	49	58	149	159	25	221	101	219	276	203	191	25	+	-	13	88	-	-	331	282	155	330	25
Leontodon autumnalis	-	-	1	+	+	+	3	3	4	-	-	4	4	3	1	1	+	-	-	+	-	-	-	12	5	-	-	-
Lotus corniculatus	-	+	4	1	+	6	3	19	21	5	-	7	29	26	21	11	2	3	-	+	3	-	-	10	+	-	-	-
Plantago coronopus	-	-	+	-	-	-	+	2	1	1	+	2	3	1	+	+	+	-	-	-	-	-	-	49	24	-	4	-
Poa pratensis	-	-	2	22	3	15	14	12	31	-	5	64	34	43	13	24	2	1	-	4	11	-	-	9	2	+	-	-
Primula veris	-	-	+	-	-	+	-	+	+	-	-	+	+	+	+	+	+	-	-	-	+	-	-	-	-	-	-	-
Primula vulgaris	-	-	1	-	-	-	-	+	+	-	-	1	+	3	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculus acris	-	-	1	+	1	+	15	7	16	-	-	12	21	19	+	1	1	+	-	5	5	-	-	4	+	-	-	-
Rhinanthus minor agg.	-	-	1	-	1	+	1	1	2	-	-	4	2	3	+	+	-	-	1	1	+	-	-	+	+	-	-	-
Thymus drucei	-	-	2	-	-	2	-	24	6	26	-	1	4	16	20	4	6	-	-	-	+	-	-	-	-	-	-	-
Trifolium pratense	-	-	1	-	-	+	3	3	9	-	-	2	14	10	+	+	-	-	-	1	+	-	-	1	-	-	-	-
Trifolium repens	-	-	6	23	6	7	23	15	45	5	1	59	51	58	11	11	1	-	3	14	6	-	-	29	9	-	-	-
Vicia sepium	-	-	+	-	+	-	-	-	+	-	-	+	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-	-
Agrostis stolonifera	6	8	6	18	133	3	68	14	41	5	11	66	66	26	3	4	2	117	4	79	48	+	41	45	38	11	61	-
Carex flacca	-	-	10	4	+	1	11	16	15	5	-	3	30	7	1	1	1	-	1	1	-	-	-	45	14	-	-	-
Cynosurus cristatus	-	-	2	-	-	1	7	10	20	-	-	22	10	6	1	+	-	-	-	2	1	-	-	-	-	-	-	-
Gentianella campestris	-	-	-	-	-	-	-	1	+	-	-	-	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-
Hieracium pilosella	-	-	+	+	-	1	-	2	1	1	-	+	1	1	4	1	+	-	-	-	-	-	-	-	-	-	-	-
Holcus lanatus	+	26	13	39	41	21	32	41	48	-	61	109	37	26	18	12	4	12	3	29	45	-	-	1	-	-	-	-
Luzula campestris	+	+	3	11	1	5	2	3	4	-	1	1	3	3	5	+	+	-	-	+	+	-	-	-	+	-	-	-
Ophioglossum vulgatum	-	-	-	-	-	+	+	-	1	-	-	-	1	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Phleum bertolonii/pratense	-	-	+	-	-	+	+	-	+	-	-	+	+	1	+	1	-	-	-	3	+	-	-	-	-	-	-	-
Polygala vulgaris	1	-	1	-	-	+	+	1	1	-	-	+	1	1	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Prunella vulgaris	-	-	2	+	+	1	6	8	13	-	-	5	20	8	1	+	+	-	3	1	+	-	-	-	-	-	-	-
Rumex acetosa	-	3	1	4	2	1	1	2	4	1	9	10	1	2	+	1	+	2	1	1	3	-	-	-	-	-	-	-
Sagina nodosa	-	-	-	+	-	+	1	+	+	-	-	-	+	+	+	+	-	-	-	+	-	-	-	1	1	-	+	-
Viola riviniana	-	-	2	+	+	1	+	4	2	5	8	2	2	2	5	+	+	+	-	+	+	-	-	+	-	-	-	-
Equisetum arvense	-	-	+	+	+	+	3	+	2	-	-	2	1	1	+	2	1	-	-	3	+	-	1	1	-	-	-	-
Juncus bufonius	-	-	+	-	2	+	+	-	+	-	-	+	1	+	+	+	+	-	-	5	+	-	-	-	+	+	-	-
Potentilla anserina	-	-	1	2	+	1	17	1	16	-	+	13	44	10	+	2	3	-	3	18	5	+	-	4	2	1	-	-
Ranunculus repens	-	-	1	1	3	1	13	+	6	-	+	10	7	8	+	1	+	3	1	11	10	-	-	-	-	-	-	-
Vicia cracca	-	-	+	+	2	+	2	+	3	-	-	2	2	1	+	+	+	-	-	2	+	-	-	+	-	-	-	-
Deschampsia cespitosa	-	19	-	-	18	+	2	-	1	-	-	3	3	+	+	1	-	+	-	21	2	-	-	-	-	-	-	-
Lathyrus pratensis	-	-	+	+	+	+	2	-	1	-	+	1	+	+	+	+	-	-	-	3	2	-	-	-	-	-	-	-
Parnassia palustris	-	-	+	-	-	+	+	1	1	-	-	+	1	+	-	+	-	-	-	1	-	-	-	-	-	-	-	-
Sagina procumbens	-	-	+	+	2	+	1	+	2	1	-	3	2	1	1	+	-	-	3	2	-	-	-	1	1	-	-	-
Senecio aquaticus	-	-	+	-	+	-	4	-	+	-	-	1	1	1	-	+	-	-	-	1	+	-	-	-	-	-	-	-

(Table 3. Species Cover (% x 10) continued)

	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1
Aira praecox	+	-	+	+	-	1	+	1	+	-	15	+	+	+	2	1	1	-	-	-	-	-	-	3	-	-	-	-
Carex arenaria	-	-	+	32	+	68	1	1	2	-	-	+	8	9	32	8	10	+	-	+	3	2	-	9	-	+	+	-
Hieraceum spp.	+	-	+	-	-	+	-	+	+	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Myosotis ramosissima	-	-	-	-	-	+	-	-	+	-	-	-	-	-	1	+	+	-	-	-	+	-	-	-	-	-	-	-
Sedum anglicum	+	-	1	-	-	+	-	+	+	5	-	-	+	+	-	+	+	-	-	-	-	-	-	-	+	-	-	-
Ulex europaeus	-	-	-	+	83	58	+	9	+	-	200	18	-	-	4	28	1	234	-	1	58	-	-	1	-	-	-	-
Viola canina	-	-	-	-	-	+	-	+	+	-	-	+	+	+	1	+	+	-	-	-	+	-	-	-	-	-	-	-
Agrostis tenuis	-	1	19	52	38	70	1	39	32	1	30	73	3	5	27	13	2	2	-	3	18	-	-	5	2	-	-	-
Rumex acetosella	-	-	+	1	+	2	-	+	1	-	+	1	-	+	1	+	+	2	-	+	+	-	-	+	-	-	-	-
Teesdalia nudicaulis	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Veronica officinalis	-	-	+	+	-	1	+	1	+	5	-	+	+	+	3	+	+	-	-	-	-	-	-	-	-	-	-	-
Anthoxanthum odoratum	10	15	35	52	17	31	21	48	40	25	17	46	5	2	9	2	+	3	-	2	31	-	-	-	-	-	-	-
Hypochoeris radicata	-	-	1	+	-	2	+	4	1	-	1	1	+	+	3	1	1	-	-	+	+	-	-	1	-	-	-	-
Luzula multiflora	1	3	1	13	1	1	1	1	1	-	-	+	+	+	+	+	+	-	-	+	+	-	-	-	-	-	-	-
Scilla verna	-	-	+	-	-	-	-	+	+	-	-	-	+	+	+	-	-	-	-	-	-	-	-	+	+	-	-	-
Achillea ptarmica	-	1	+	1	1	+	+	+	+	-	-	1	+	-	+	+	-	-	-	+	+	-	-	-	-	-	-	-
Antennaria dioica	-	-	1	-	-	+	-	1	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex pulicaris	-	+	4	+	-	+	2	5	2	-	-	+	1	+	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cirsium palustre	-	7	+	1	5	+	+	+	+	-	-	1	+	+	-	+	+	2	-	1	1	-	-	-	-	-	-	-
Dactylorchis spp.	3	-	1	+	-	+	2	1	1	-	-	+	1	+	+	+	-	-	-	1	-	-	-	-	-	-	-	-
Sieglingia decumbens	-	-	24	3	1	2	3	40	17	5	-	-	3	+	+	+	-	-	-	-	+	-	-	+	2	-	-	-
Festuca ovina	3	3	42	125	-	88	4	84	13	30	-	2	4	5	66	3	7	+	-	-	-	-	-	21	1	-	-	-
Galium saxatile	1	2	1	30	1	10	+	1	2	-	7	1	+	+	1	+	+	25	-	+	+	-	-	-	-	-	-	-
Holcus mollis	-	9	-	27	7	7	-	-	+	-	-	4	-	+	+	4	-	-	-	+	11	-	-	-	-	-	-	-
Pteridium aquilinum	32	13	3	-	91	34	-	11	7	-	93	23	+	2	6	9	1	-	-	-	-	-	-	-	-	-	-	-
Anagallis tenella	-	-	2	+	2	-	3	1	1	-	-	-	1	+	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Carex flava agg.	+	-	5	2	+	+	12	5	1	-	-	-	1	+	-	-	-	-	-	+	-	-	-	1	3	-	-	-
Carex panicea	16	+	34	4	2	1	58	33	19	-	-	1	14	1	+	+	-	-	-	+	+	-	-	-	4	-	-	-
Eleocharis quinqueflora	6	-	3	-	-	-	2	-	+	-	-	-	+	-	-	-	-	-	-	1	-	-	-	8	5	-	-	-
Potentilla palustris	+	33	+	2	15	+	15	-	+	-	-	+	+	-	-	-	-	2	-	11	-	-	-	-	-	-	-	-
Ranunculus flammula	+	-	1	1	1	+	6	1	1	-	-	1	+	+	-	+	-	-	-	2	+	-	-	-	+	-	-	-
Succisa pratensis	2	1	22	+	1	1	15	27	22	-	1	2	2	2	+	+	-	-	-	+	1	-	-	-	-	-	-	-
Agrostis canina	11	9	11	50	35	5	4	2	1	-	+	+	1	3	+	+	+	-	-	12	+	-	-	1	-	-	-	-
Hypericum pulchrum	-	-	+	-	-	+	+	+	+	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Salix repens	5	+	13	34	16	25	12	10	6	-	-	1	1	+	18	+	1	-	-	6	1	-	-	-	-	-	-	-
Juncus effusus	4	33	3	48	160	4	10	5	10	-	-	14	3	+	+	+	-	8	-	48	1	-	-	-	-	-	-	-
Pedicularis palustris	-	+	1	-	-	-	2	+	+	-	-	+	+	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-
Viola palustris	-	4	1	5	14	+	+	+	+	-	-	+	+	+	-	-	-	2	-	1	-	-	-	-	-	-	-	-
Festuca vivipara	18	6	15	-	2	+	+	3	4	-	-	2	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus acutiflorus	-	32	1	11	20	2	2	+	+	-	-	+	+	+	+	-	-	-	-	1	-	-	-	-	+	-	-	-
Pedicularis sylvatica	+	-	1	+	-	+	1	+	+	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Schoenus nigricans	-	-	8	-	-	-	3	4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Carex echinata	6	3	10	+	2	+	3	1	+	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	+	-	-	-
Juncus bulbosus/kochii	+	+	5	+	-	+	5	+	+	-	-	-	+	+	-	-	-	-	1	+	-	-	-	-	-	-	-	-
Carex pilulifera	1	-	1	+	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus squarrosus	3	1	12	8	+	3	-	1	+	-	-	1	-	-	1	-	+	-	-	-	-	-	-	-	-	-	-	-
Nardus stricta	17	33	42	220	9	21	7	19	5	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Potentilla erecta	17	16	25	43	10	4	3	14	4	-	1	1	+	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-
Eriophorum angustifolium	53	45	13	-	+	+	15	+	1	-	-	-	+	-	-	-	-	-	-	4	-	-	-	-	+	-	-	-
Molinia caerulea	277	275	230	1	35	3	54	28	36	-	-	+	1	-	-	+	+	17	-	-	-	-	-	-	1	-	-	-
Calluna vulgaris	304	231	162	65	31	162	3	62	6	1	-	-	-	-	7	+	24	-	-	-	-	-	-	13	-	-	-	-
Deschampsia flexuosa	8	-	3	9	+	11	-	+	1	-	-	-	-	-	+	+	+	60	-	-	-	-	-	-	-	-	-	-
Empetrum nigrum	2	13	2	4	-	31	-	5	+	-	-	+	-	+	2	+	3	-	-	-	-	-	-	-	-	-	-	-
Erica cinerea	9	1	9	-	+	25	+	3	+	-	-	+	-	-	2	+	3	-	-	-	+	-	-	-	-	-	-	-
Luzula pilosa	1	+	+	+	+	+	-	-	-	-	1	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Erica tetralix	41	10	35	14	9	4	1	14	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Narthecium ossifragum	4	-	7	-	-	+	1	1	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myrica gale	75	25	20	-	11	+	4	+	-	-	-	-	-	-	-	-	-	50	-	4	-	-	-	-	-	-	-	-
Trichophorum cespitosum	39	+	14	-	-	+	-	+	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Angelica sylvestris	-	2	+	-	6	+	1	1	1	-	-	1	+	+	+	1	+	2	-	5	2	-	-	-	-	-	-	-
Carex nigra	5	27	25	47	40	21	51	33	64	-	-	12	72	4	+	+	-	-	3	85	-	-	-	1	2	-	-	-
Equisetum palustre	-	2	-	+	-	+	6	3	2	-	-	1	1	1	-	+	-	-	-	8	2	-	-	-	-	-	-	-
Juncus balticus	-	-	+	-	-	+	1	+	5	-	-	-	1	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-
Plantago maritima	-	-	5	-	-	+	4	35	21	5	1	3	19	4	+	1	+	-	-	+	-	-	1	62	137	16	89	99
Polygala serpyllifolia	+	-	+	+	-	+	+	+	+	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Selaginella selaginoides	-	-	1	-	-	-	+	2	1	-	-	+	2	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Triglochin maritima	-	-	-	-	-	-	5	-	1	-	-	-	1	-	-	+	-	-	-	1	-	+	-	2	9	-	1	2
Cardamine pratensis	-	-	+	+	+	+	3	+	+	-	-	1	1	+	+	+	-	+	-	2	+	-	-	-	-	-	-	-
Iris pseudacorus	-	-	+	-	+	-	11	-	4	-	-	8	+	+	-	+	-	-	-	24	4	+	-	-	-	-	-	-
Lychnis flos-cuculi	-	-	+	-	+	-	2	+	1	-	-	1	1	+	-	-	-	-	-	2	-	-	-	1	+	-	-	-
Oenanthe lachenalii	-	-	-	-	-	-	2	-	+	-	-	+	+	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-
Polygonum amphibium	-	-	-	-	-	+	1	-	2	-	-	-	1	+	-	-	-	-	-	7	-	-	-	-	-	-	-	-
Triglochin palustris	-	-	+	-	-	-	1	+	+	-	-	+	1	+	-	-	-	-	-	+	-	-	-	1	+	+	+	-
Caltha palustris	-	-	3	-	+	-	18	+	2	-	-	3	2	-	-	+	-	-	3	16	1	-	-	-	-	-	-	-
Eleocharis palustris	-	-	-	-	-	-	4	-	1	-	-	5	3	-	-	1	+	-	-	16	+	-	-	-	-	-	-	-
Mentha aquatica	-	-	-	-	-	-	3	-	+	-	-	1	+	-	-	+	-	-	-	6	1	-	-	-	-	-	-	-
Filipendula ulmaria	-	-	+	-	+	1	5	+	11	-	-	8	3	+	-	4	-	-	-	23	26	-	-	-	-	-	-	-
Hydrocotyle vulgaris	+	+	3	16	12	+	24	1	4	-	-	+	8	+	-	+	-	35	3	36	2	-	-	-	-	-	-	-
Juncus articulatus	+	-	7	2	18	+	24	1	9	-	-	18	10	+	+	+	+	67	3	45	3	-	1	2	6	-	+	-
Pinguicula vulgaris	+	-	1	-	-	-	1	+	1	-	-	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Epilobium palustre	-	+	+	+	2	+	1	-	+	-	-	+	+	-	+	+	-	+	1	6	-	-	1	-	-	-	-	-
Equisetum fluviatile	-	-	+	-	2	-	1	-	+	-	-	2	1	-	-	-	-	2	-	29	-	-	-	-	-	-	-	-
Galium palustre	-	-	+	+	5	+	3	+	+	-	-	1	1	-	-	+	-	2	-	12	+	-	-	-	-	-	-	-
Agropyron junceiforme	-	-	-	-	-	+	-	+	+	-	-	1	+	1	1	7	14	-	-	1	-	15	120	3	1	88	4	+
Atriplex hastata	-	-	-	-	-	-	-	-	-	-	+	-	-	+	1	1	2	-	-	+	+	9	1	+	-	5	-	-
Elymus arenarius	-	-	-	-	-	-	-	-	-	-	-	6	-	+	1	6	8	-	-	-	7	24	-	-	+	1	+	-
Armeria maritima	-	-	-	-	-	+	-	6	1	10	-	3	+	1	1	1	+	-	-	-	-	-	-	32	65	12	117	62
Glaux maritima	-	-	-	-	-	-	1	+	+	-	-	-	1	+	-	+	-	-	-	+	+	-	-	4	112	24	95	31
Juncus gerardii	-	-	-	+	-	+	1	-	1	-	-	-	1	+	-	+	-	-	-	+	-	-	-	46	154	10	23	1
Aster tripolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	12
Puccinellia maritima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	22	88	118	226

The tables may also be used to examine the distribution of particular species in relation to the vegetation types. In this context, there are a number of different types of behaviour patterns but these fall into two main categories.

(i) Species which occur in a wide range of vegetation types. Usually these are common species with a wide range of environmental tolerance (which is why they are common in the first place). Some of these species are usually regarded as having a series of ecotypes, some of which may even be morphologically distinct to the extent that they are accorded subspecific status. The prime examples of this type of species are the three common grasses Festuca rubra, Poa pratensis, and Agrostis stolonifera. In the species classification, such species tend to be grouped together along with species which occupy the middle of their range. Class 7 of the species classification (Chrysanthemum leucanthemum - Vicia sepium) is the best example of the type of situation. Other conspicuously wide ranging, common species include Cerastium holosteoides, Plantago lanceolata, Lotus corniculatus and Trifolium repens. There are other less common, wide ranging species which are dependant on the presence of certain more specialized habitats which can themselves occur in almost any vegetation type, i.e. Urtica dioica, Poa annua and Sagina nodosa.

(ii) Species which occur in quite a narrow range of vegetation types. These are inevitably species of intermediate frequency and are the ones which produce the blocking effect in the two tables. The best examples are those species which require very specialized habitats and may even be restricted to one vegetation type family, e.g. Aster tripolium and Puccinellia maritima in the Saltmarsh family. Species classes 1-3 (Agropyron repens to Tussilago fafara) tend to be fairly well restricted to the Duneland family whereas, moving down the tables, species classes 14-25 (Achillea ptarmica to Trichophorum cespitosum) show a strong preference for the Grassland and Peatland families (becoming progressively more restricted to the lefthand columns the higher the class number). Classes 26-30 (Angelica sylvestris to Galium palustre) are supposed to be Marshland species but, as can be seen, most of them stray over into the wetter types in the Duneland and Grassland families. Class 31 is supposed to consist of Foredune species and classes 32 and 33 Saltmarsh species and these are, indeed, fairly well restricted. It should be noted that, in general, those species that show restricted distribution in the two-way tables also serve as indicators to the vegetation types in the key.

Certain species show very interesting, and perhaps unexplained, distributions in terms of the vegetation types. The behaviour of Plantago maritima has already been discussed in relation to the Saltmarsh family. Other species worthy of note are Honkenya peploides (class 3) and Cochlearia officinalis (class 6), both of which are more wide ranging than might perhaps be expected. The presence of these species in widely differing vegetation types is thought to be a reflection of spray zone effects. Plantago coronopus (class 7) is probably behaving in a similar manner. A comparison between the distribution of Triglochin maritima and T. palustris is also very interesting, the latter extending to a wider range of vegetation types and the two species being far more similar (at least on the coast) than might be expected from their conventional flora descriptions. The tables are of little use for studying rare species as these are not usually included for just this reason.

7.8 Use of the Vegetation Type Key

The final part of this section of the report consists of instructions for the use of the synthetic key to vegetation types which, for reasons of space, has been separatley bound. The key derives 28 vegetation types and is composed of 105 steps which are shown diagramatically in Figures 6, 6A, 6B and 6C. The entries in the rectangular boxes are the numbers of quadrats out of 3,847 (or 3,677 when the 166 bare quadrats and the 4 which were unclassifiable have been removed) which took this route in the original classification, those in the oval boxes are the step numbers (same as the written key) and each termination is indicated by a vegetation type mnemonic beneath the rectangular box.

As already noted, use of the key to assign vegetation types is completely accurate in the sense that, when applied to the same sample of the population on which it is based, the result is identical in all respects to that produced in the computer analysis. Because the vegetation classification is based on such a large sample, its application to new individuals drawn from the same population is extremely unlikely to produce an unsatisfactory assignment. Indeed, such a result is almost certain to be caused by poor field recording or mistakes in the use of the key (see below).

Use of the key is simple, albeit somewhat laborious if a number of steps with a high number of indicators is involved. The number of steps required to determine a vegetation type varies between 2 and 10. Calculation of the indicator scores, i.e. the sum of negative and positive indicators present in a quadrat, and the correct transfer from one step to the the next require some care if mistakes are not to be made. It is good practice to record the keying-out process on paper and the following species list is used to illustrate one method by which this can be done.

Carex panicea	Festuca rubra
Trifolium repens	Lotus corniculatus
Bellis perennis	Sieglingia decumbens
Linum catharticum	Plantago lanceolata
Thymus drucei	Koeleria cristata
Selaginella selaginoides	Euphrasia officinalis agg.
Prunella vulgaris	Centaurea nigra
Viola riviniana	Plantago maritima
Anthyllis vulneraria	Agrostis stolonifera
Daucus carota	Carex arenaria
Festuca ovina	Achillea millefolium
Leontodon taraxacoides	Carex serotina
Succisa pratensis	Hieracium pilosella
Gentianella amarella	Coeloglossum viride
Juncus articulatus	Senecio jacobaea
Trifolium pratense	Erica tetralix

The steps in the key are examined as follows, noting the step number in brackets (), the sum of negative and positive indicators (- and +), the total score (=), the threshold value for the indicator score and the resulting step number to be taken (or vegetation type allocation if an outlet is reached).

Figure 6

Vegetation Classification - Higher Levels of Division

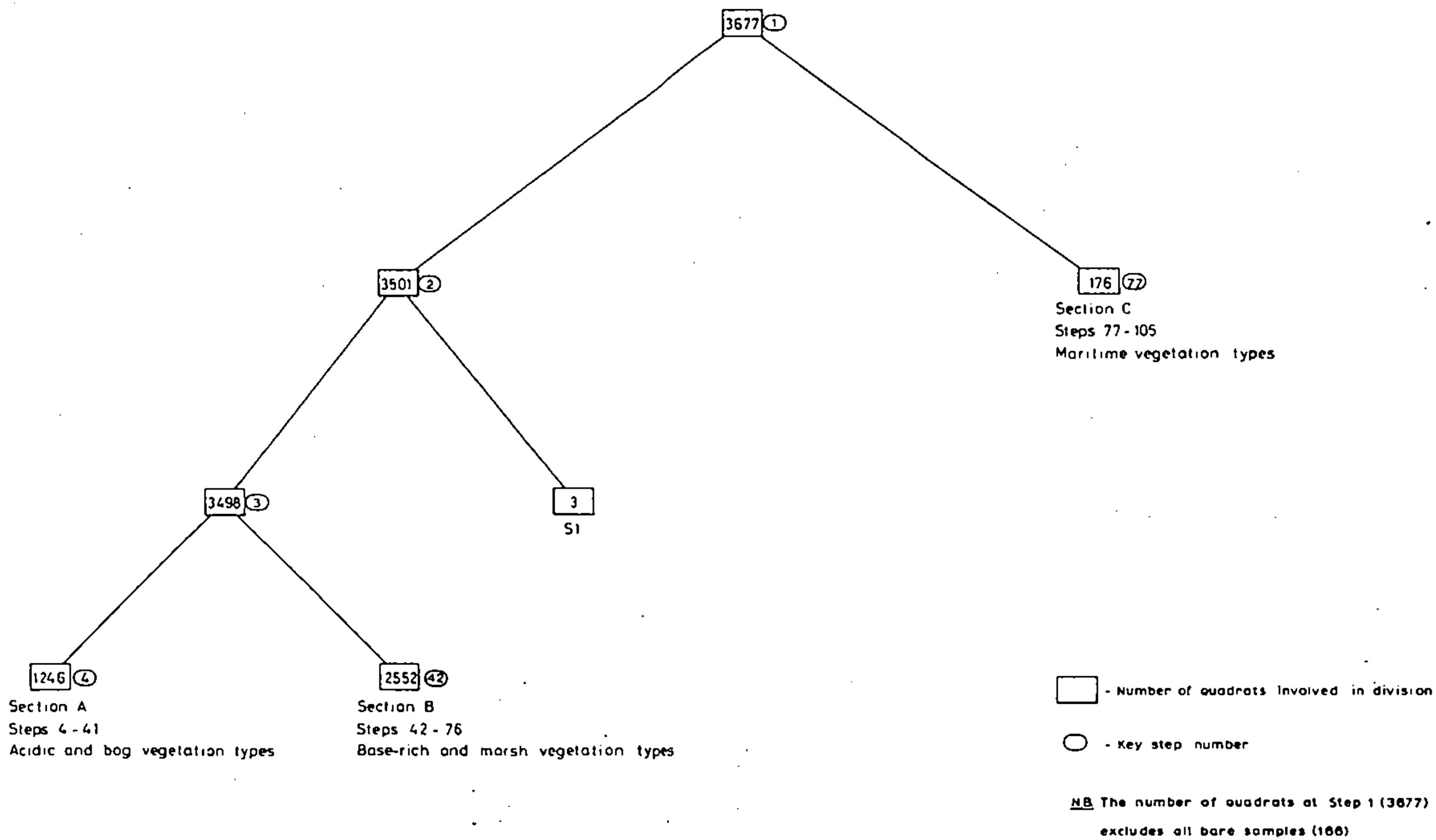


Figure 6A

Steps 4-41 Acidic and Bog Vegetation Types

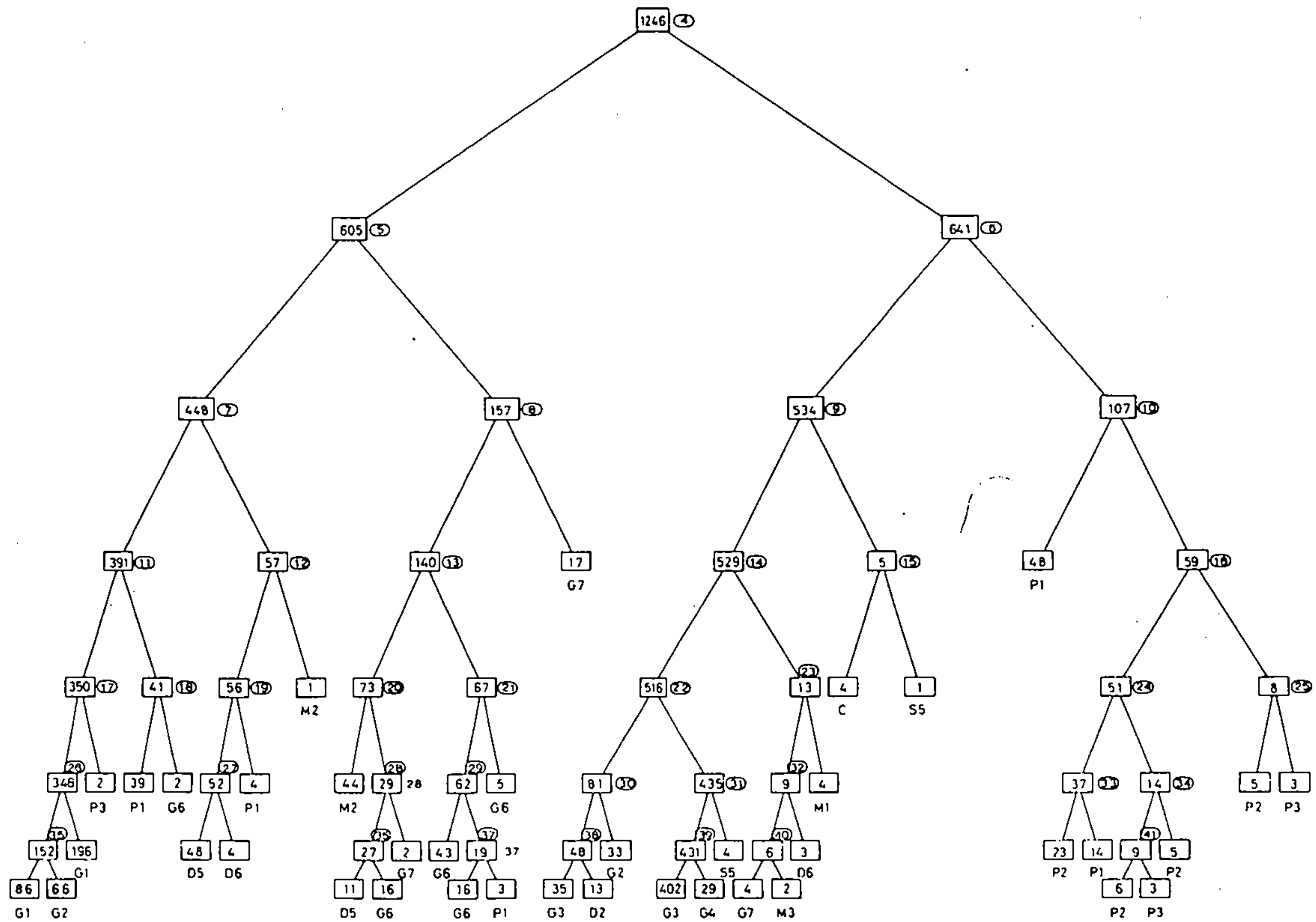


Figure 6B

Steps 42-76 Base-rich and Marsh Vegetation Types

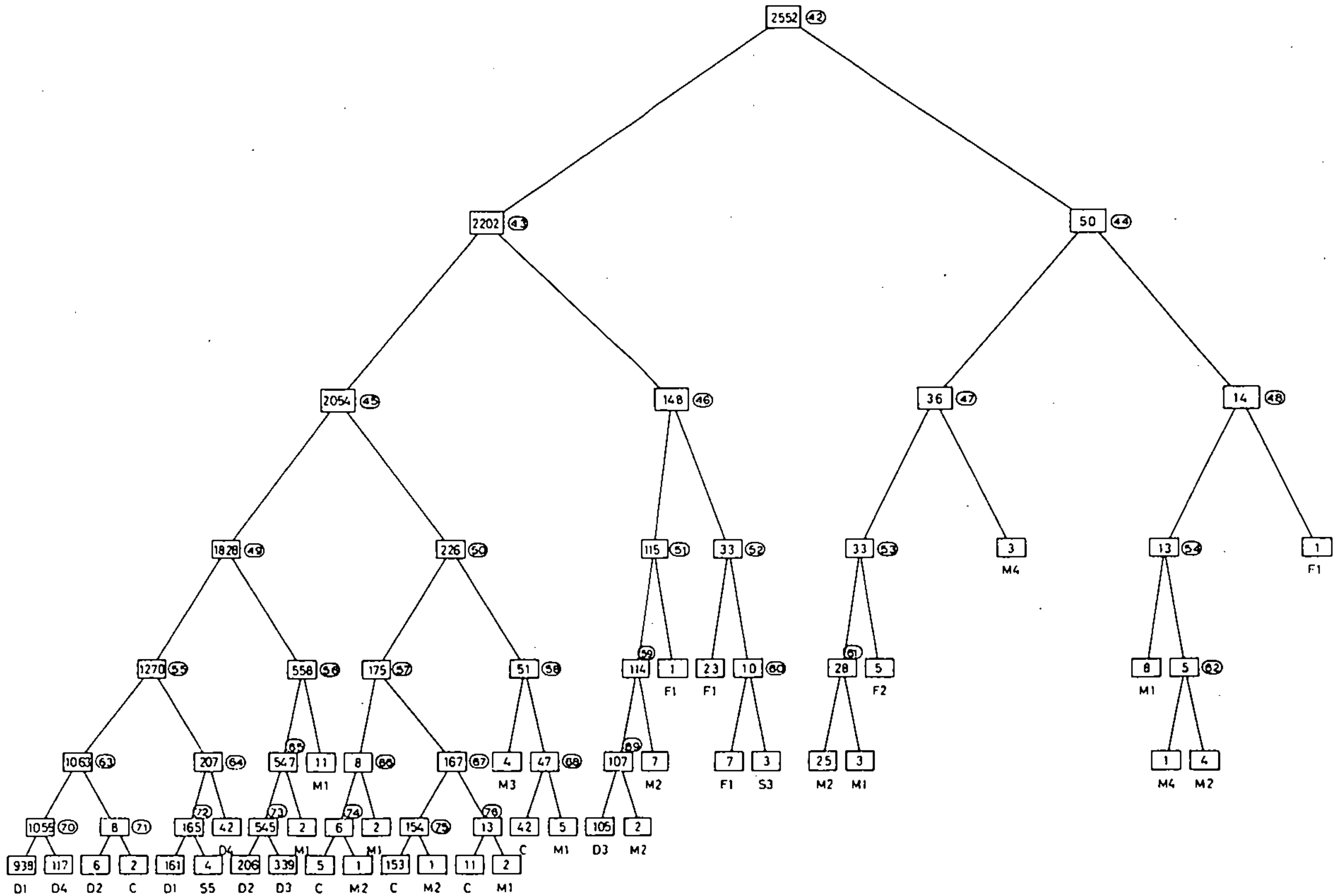
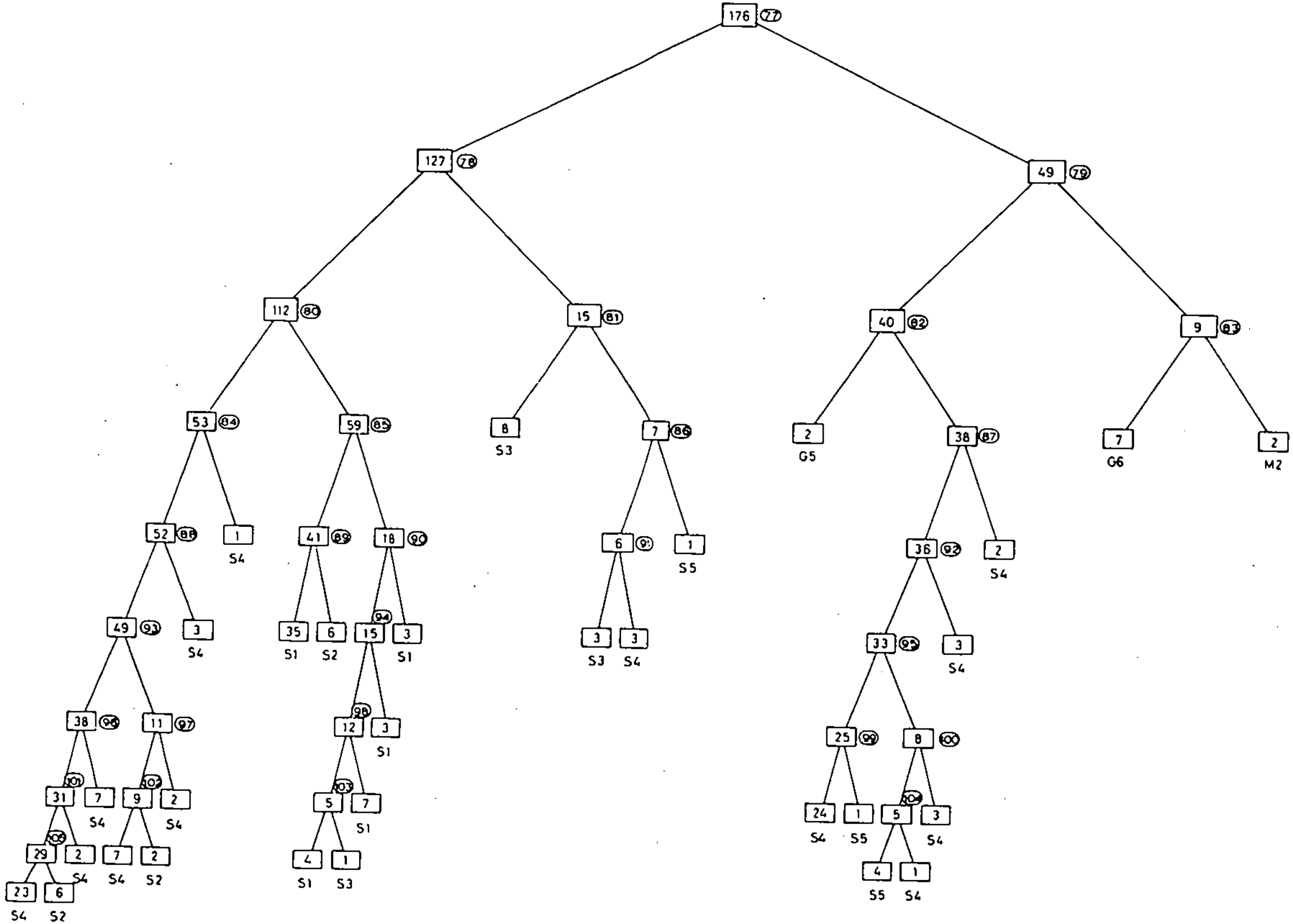


Figure 6C

Steps 77-105 Maritime Vegetation Types



In step 1 of the key only one of the two negative indicators is present (Plantago lanceolata), giving a score of -1 which, when compared with a threshold value of 0, leads to step 2. N.B. The convention that is used for the threshold score is that threshold or less goes negative and greater than threshold goes positive. This is clearly indicated in the key itself. The process of keying-out a species list may be summarized as follows:

(1) -1=-1 to be compared with a -ve threshold of 0, go to step 2

In step 2 there are three of the four negative indicators present (Festuca rubra, Plantago lanceolata and Trifolium repens) and no positive ones, giving a score of -3 which, when compared with a threshold of 0, leads to step 3 (this is now unlikely to be a maritime vegetation type, i.e. it cannot get into the part of the hierarchy shown in Figure 6C). Again, this may be summarized as follows:

(2) -1-1-1=-3 to be compared with a -ve threshold of 0, go to step 3

In step 3 there are two negative indicators present (Festuca ovina and Succisa pratensis) and one positive (Senecio jacobaea), giving a score of -1 which, when compared with a threshold of -1, leads to step 4 (this has now narrowly avoided going into the part of the hierarchy shown in Figure 6B and is thus not going to be assigned to one of the more base-rich Duneland types).

(3) -1-1+1=-1 to be compared with a -ve threshold of -1, go to step 4

In step 4 there are three negative indicators present (Agrostis stolonifera, Prunella vulgaris and Trifolium repens) and two positive (Carex arenaria and Festuca ovina), giving a score of -1 which, when compared with a threshold of -1, leads to step 5 (this means that the quadrat is now destined to be allocated to one of the more acid or bog types in Figure 6A).

(4) -1-1-1+1+1=-1 to be compared with a -ve threshold of -1, go to step 5.

In step 5 there are five negative indicators present (Lotus corniculatus, Plantago lanceolata, Plantago maritima, Sieglingia decumbens and Thymus drucei) and no positive ones, giving a score of -5 which, when compared with a threshold of 0, leads to step 7.

(5) -1-1-1-1-1=-5 to be compared with a -ve threshold of 0, go to step 7

In step 7 there are three negative indicators present (Euphrasia officinalis agg., Lotus corniculatus and Sieglingia decumbens) and no positive ones, giving a score of -3 which, when compared with a threshold of -1, leads to step 11.

(7) -1-1-1=-3 to be compared with a -ve threshold of -1, go to step 11

In step 11 there is one positive indicator present (Bellis perennis) and one negative (Erica tetralix), giving a score of 0 which, when compared with a threshold of 4, leads to step 17 (there have to be at least 5 positive indicators and no negative ones to get to the alternative step 18).

(11) -1+1=0 to be compared with a -ve threshold of +4, go to step 17

In step 17 there are two negative indicators present (Plantago lanceolata and Trifolium repens) and one positive (Erica tetralix), giving a score of -1 which, when compared with a threshold of 1, leads to step 26.

(17) -1-1+1=-1 to be compared with a -ve threshold of +1, go to step 26

In step 26 there are five negative indicators present (Achillea millefolium, Koeleria cristata, Linum catharticum, Thymus drucei and Viola riviniana) and one positive (Juncus articulatus), giving a score of -4 which, when compared with a threshold of -2, leads to step 35.

(26) -1-1-1-1-1+1=-4 to be compared with a -ve threshold of -2, go to step 35

Finally, in step 35 there are no negative indicators (none are listed in the key) and one positive one (Carex panicea), giving a score of +1 which, when compared with a threshold of 1, causes the quadrat in question to be allocated to vegetation type G1 (slightly acid, damp grassland). One more positive indicator would put the quadrat in vegetation type G2 (acid, damp grassland).

(35) +1=+1 to be compared with a -ve threshold of +1, allocated to vegetation type G1.

In the above example, only the abbreviated calculations, showing how the indicator scores were calculated, the threshold and the step numbers need be recorded to assist accuracy and checking. It is often useful to enter these directly on to the field sheet.

In fact, in the preparation of this example a mistake was made at step 4 in the key, where the presence of Prunella vulgaris was initially missed (but found in checking). This mistake resulted in an indicator score of 0 instead -1, leading to step 6 instead of 5. Following this new route through the key, the quadrat was eventually allocated to vegetation type G2 in step 30 which, as we have just seen, by the near miss in step 35, is quite a reasonable result. This demonstrates the inherent robustness of the key to minor mistakes in field recording and even, to some extent, in the use of the key itself. Nevertheless, as a considerable effort is usually expended in the collection of good field data, it is only appropriate that an equivalent amount of care should be taken in the use of the key in order to ensure the most accurate results possible. The time taken to use the key and check the result is comparatively small compared with that usually devoted to recording the field data.

The above description only covers the procedure for using the vegetation type key. There are, however, some other important considerations, such as the population definition and the sampling methods which may be used to obtain data. These points are covered in some detail in the introduction to Appendix 2 of the Handbook of Field Methods (pages 1-5). The two main points to be noted are:

(a) that the vegetation type key must only be applied to samples taken from the same population as that on which it is based, i.e. soft coast in Scotland, and
(b) that, if site classification or the estimation of relative amounts of different vegetation types on a site is one of the

aims of recording, then an objective sampling procedure must be employed.

Simple identification of the vegetation type occurring within a particular area of a site or the determination of vegetation type boundaries for mapping can freely utilize subjectively chosen samples.

8. SITE CLASSIFICATION

8.1 Introduction

The hierarchical diagram of the site classification is shown in Figure 7. It will be noted that, in contrast to the vegetation classification, this is a conventional ISA with four levels of division. Normally this would result in 16 classes (the geometrical progression 2-4-8-16) but in practice two stems have terminated at the third level of division with just one site remaining in each class (Site Types 11 and 14 on the righthand side of the hierarchy).

Much has already been said about the derivation of the site classification (see Section 6.3). The results of various investigations into the type of data on which to base the site classification have been discussed and it was concluded that species frequency % was likely to yield the most satisfactory result. This type of data summarization has a low information loss and the key, by which it can be generalized, is robust. Of the various summarization methods tested, species frequency gave the most clear-cut geographical distribution of site types - an outcome that could not have been contrived and is not likely to have occurred by chance. The overall similarities between the classifications produced by different methods of summarization suggest that the population (of sites) has a genuine structure that will emerge whatever method of analysis (within reason) is employed. It now only remains to give the details of the methods actually used.

Species frequency was calculated using the 25 sq m quadrat. This size of quadrat was used in preference to the larger 200 sq m quadrat (which in theory contains more information) so that the site and vegetation classifications were more closely comparable. In practice, it is extremely unlikely that it makes any difference which of the two quadrat sizes is used. In the case of the sites surveyed in 1975, when a stratified sampling procedure was used (see Section 4.2), species frequency had to be corrected appropriately. This correction involved the calculation of weighted frequencies in which each sample was given weight according to the relative intensity of sampling in the stratum to which it belonged. This means that strata with a high sampling intensity, e.g. usually the linear strata, such as strandline and water edge, have a low weight in the calculation of the % frequency of species for the site.

Having calculated the frequency of species within sites, these data need to be transformed into pseudo-species before they can be used in indicator species analysis. The concept behind this curious name is very simple, that one treats different quantities of a species almost as though they were separate subspecies of the species concerned. In the present case of the site classification, five pseudo-species were defined with upper limits of 20, 40, 60, 80 and 100% frequency. For convenience, these may be called pseudo-species 1-5 and it should be noted that the exact definition of ranges is: 1 = ,19.9, 2 = 20.0-39.9, 3 = 40.0-59.9, 4 = 60.0-79.9 and 5 = 80.0-100.0. Thus it is now possible to consider five species of <u>Ammophila arenaria</u> in a site: 1 = <u>A. arenaria</u> (0%+), 2 = <u>A. arenaria</u> (20%+), 3 = <u>A. arenaria</u> (40%+), 4 = <u>A. arenaria</u> (60%+) and 5 = <u>A. arenaria</u> (80%+). The most difficult feature to understand is that, according to this rule, pseudo-species are mutually inclusive, so that when a given pseudo-species is present so are its numerical subordinates. For example, if pseudo-species 2 is present so is 1 or, again, if the frequency of a species is 52% then pseudo-species 1, 2 and 3 will all automatically be present. As far as the user is concerned, this is less complicated than it sounds, as will be demonstrated in the instructions for the use of the key (see Section 8.5). Use of the key only requires a comparison to be made between the actual frequency of a species in the site and the frequency that is implied by the pseudo-species that is listed as an indicator. If the frequency is the same or greater than that required to generate the pseudo-species indicator (and it does not matter how much greater, even to the extent that superior pseudo-species are present) then that indicator is recorded as present and is scored -1 or +1 according to allegiance. Subordinate pseudo-species have no function in the keying-out process. In the computer analysis, the use of mutually inclusive pseudo-species has the effect of giving a quantitative weighting to the data, i.e. pseudo-species 5 has five times the weight of pseudo-species 1 in determining the ordination that is the basis for each division in ISA.

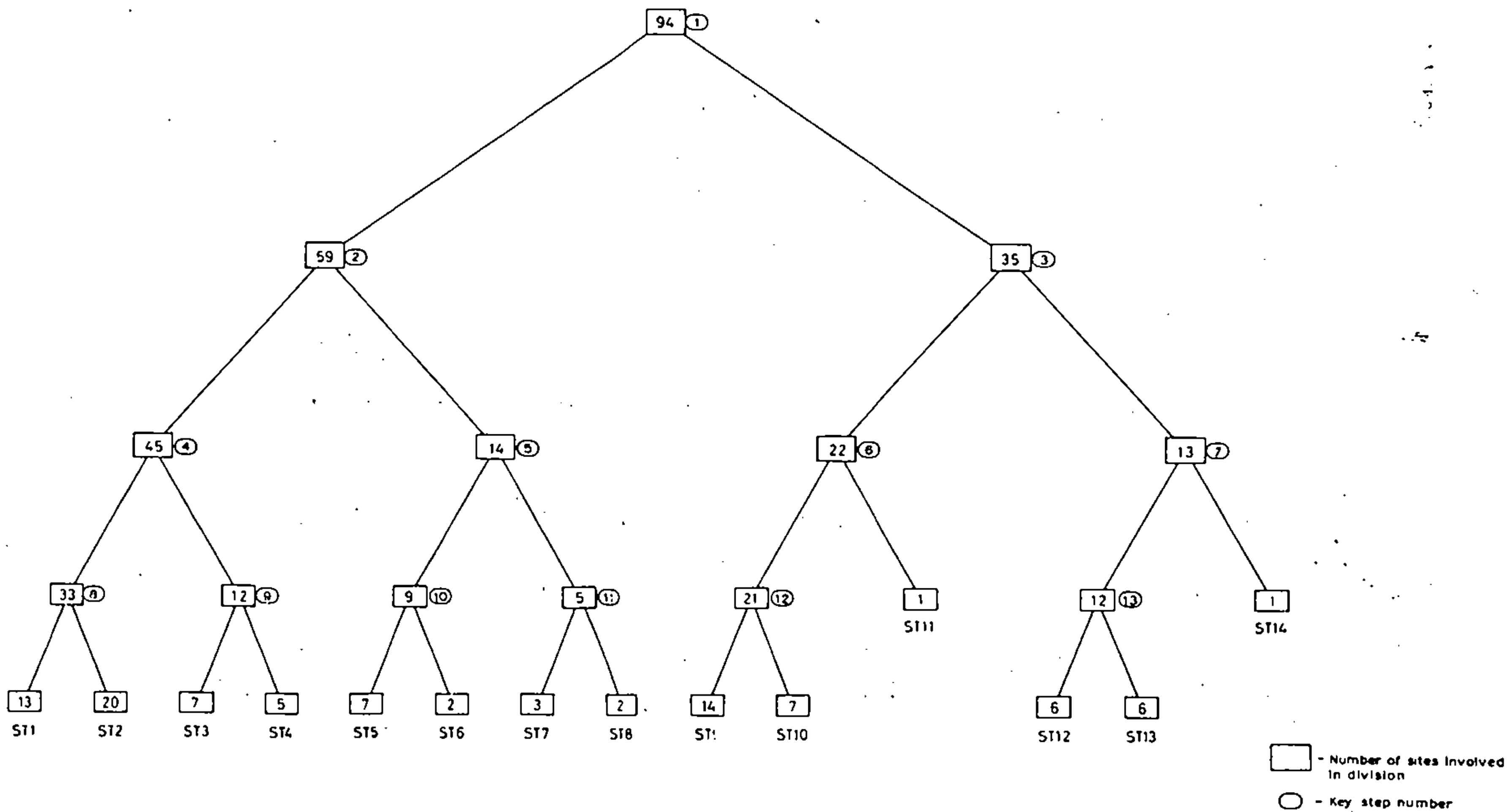
In the ISA that derived the site classification, all species were used and no downweighting of rare species (see Hill et al., 1975, pages 603 and 612) was employed.

The simplicity of the site classification, as compared with that for the vegetation types, is such that there is no need to employ elaborate measures to avoid misclassifications in the key, i.e. no re-allocation and multi-path keys are required. This simplicity stems from several features of the data from which it is derived. Firstly, the effect of the minority of aberrant quadrats is minimized by the method of data summarization, i.e. the taking of a mean (% species frequency) for all the quadrats in a site. Secondly, the site data are better "conditioned" than those for the vegetation, i.e. there are more or less equal numbers of sites over the range of variation (cf. the vegetation data in which nearly 29% of quadrats were allocated to one out of 29 types (including bare ground B), namely base-rich dune grassland D1). This does not mean that the site data are perfectly balanced because there are, for example, 29 sites on the Outer Hebrides where the range of variation is quite small. By contrast, there are only 11 sites on the north coast where the variation is comparatively large. Nevertheless, ISA has been able to deal with this degree of imbalance without any apparent difficulty. Even the two sites that are very different from all others in the survey, namely Tong (on Lewis) and Spey Bay (Central) (on the Moray Firth), have been dealt with satisfactorily without adversely affecting other parts of the classification. Finally, there is some evidence that there is a genuine structure to the site classification and that the range of variation can be reasonably well accounted for in two dimensions of a reciprocal averaging ordination (the first and second axes). This was not possible with the vegetation classification.

Nomenclature of the site types follows similar principles to those for the vegetation classification (see Section 7.2), except that no division into named families has been attempted. However, it is a marked feature of the site classification that the site types on the negative side of the first division (Site Types 1-8) have a western and northern distribution, whilst those on the positive side (Site Types 9-14) have a mostly eastern distribution (with the exception of Site Type 10 - of which more later). These two groups of site types tend to be losely referred to as the western (and northern) and eastern groups of site types. Each of the site types has been given a number (1-14), running from left to right on the hierarchical diagram (Figure 7), which can be expressed either as Site Type No. or by the abbreviation ST No. Each site type has also been given a brief name

Figure 7

Site Type Classification



which it is hoped encapsulates the main characteristics of the type. It has proved impossible to be entirely consistent in the naming process but each name begins with a geographical reference and this is usually followed by some sort of habitat description. There is no appended list of of dominant plant species as in the vegetation classification. The following is a list of the 14 site type names giving the number of sites in each type.

ST1 - West Coast, Hebridean, Machair type (13 sites)
ST2 - West Coast, Hebridean, dune type (20 sites)
ST3 - North and West Coast, truncated type (7 sites)
ST4 - Northern Isles type (5 sites)
ST5 - North and West Coast, acid heath type (7 sites)
ST6 - North Coast, bayhead, well drained type (2 sites)
ST7 - North-west Coast, bog type (3 sites)
ST8 - North-west Coast, montane type (2 sites)

ST9 - East Coast, Main type (14 sites)
ST10 - West Coast, acid, dwarf shrub type (7 sites)
ST11 - Hebridean Saltmarsh type (1 site)
ST12 - East Coast, truncated type (6 sites)
ST13 - East Coast, Firth type (6 sites)
ST14 - East Coast, estuarine shingle type (1 site)

8.2 Methods of Interpretation

The methods used to understand the site classification and the types of information upon which this interpretation is based are similar to those for the vegetation classification (see Section 7.1) The same categories of data - floristic, biotic, land-use, environmental, soils and geographical distribution - have been used and it is mainly the type of summarization that is different, i.e. the main concern is now with sites and site types rather than vegetation types.

The main difficulty in interpretation is the presence of confounding factors. Unfortunately, survey data are not like those produced by designed experiments, where there are proper controls and the factors (treatments) can be varied orthogonally to measure their effects. The lack of balance, or orthogonality, in survey data frequently makes it impossible to separate the possible effects of two or more factors. Even simple comparisons may be weakened by the very different numbers of observations falling within classes defined by discrete factors. There may even be a complete lack of replication for some comparisons.

In survey data, as opposed to those derived from designed experiments, factors tend to be highly correlated but this does not mean that they are necessarily causally related. Also, the range of combinations available for study may be limited. This limitation is well illustrated by the first division of the site classification (see Section 8.6 - the maps with step 1 of the site key) in which there is a fairly clean split between Site Types 1-8, on the west and north coasts (including the western islands), and 9-14, on the east coast. This split, which, it must be emphasized, represents the major trend of between-site (floristic) variation, divides Scotland on a line running south-west to north-east (almost along the Great Glen). The most obvious explanation of this division is that it is based on climatic differences, with an oceanic regime in the west and north and a more continental regime in the east. Maps of most climatic variables and synthesized climatic classifications (e.g. Birse and Dry, 1970;

Birse and Robinson, 1970; and Birse 1971) show similar trends. Climate may indeed be the most important factor in determining the site classification but this is difficult to establish because so many other factors follow roughly the same geographical pattern. Good examples of this type of coincidence of factors, which must have a major influence on the floristically derived site classification, are land-use and soil types. Both these factors tend to parallel the climatic trends, which is not surprising as they must be, to some extent, causally related. Land-use affects both the site boundaries, e.g. truncated sites on the east coast, or the vegetation directly, e.g. crofting in the west. Soil types follow a similar pattern, with shell-rich sands mostly on the west and north coasts and more siliceous sands in the east. Regional differences between the macro-topography of sites and the effects of isostasy also tend to be correlated with the climatic trends in Scotland.

One apparent coincidence that is barely credible, i.e. it is tempting to look for a genuine connection, can be observed in three sites in north Aberdeenshire. The most northerly of these sites, Fraserburgh, is the only east coast site that is allocated to the negative side, i.e. with the west and north coast types, in the first division in the site classification. Fraserburgh also contains 29% of quadrats allocated to base-rich dune grassland D1, normally a vegetation type with a distinctive western and northern distribution and which, as the name suggests, is thought to be associated with base-rich substrates. The other two sites, Strathbeg and St Fergus, are allocated along with the eastern types but are notable for also containing a significant proportion of D1 (Strathbeg 14%, St Fergus 14%). These observations give rise to the hypothesis that the environment of this particular part of north-east Scottish coast must have some similarities with the west coast. The most likely factor would seem to be sand type and, indeed, recent chemical analysis of sand samples collected during the survey (two samples per site taken from as near to the shoreline as possible) have given mean values for free calcium carbonate of Fraserburgh 24.5%, Strathbeg 16.6% and St Fergus 17.9%. These figures are in sharp contrast to nearby sites, Spey Bay (Central) 0.1%, Cruden Bay 3.1% and Forvie 0.2%. So locally high levels of calcium carbonate appears to be the explanation, that is until one examines the climatic maps and finds that the area around Fraserburgh is included in Birse's Hyperoceanic sub-sector (O1) and Strathbeg and St Fergus are only just outside this boundary. This is the only occurrence of the Hyperoceanic climatic regime on the east coast of Scotland, although it also just touches Morrich More on the Dornoch Firth. Curiously, this site that is also allocated to a western type - ST10. So once again there is confounding of factors and it is impossible to determine (on this evidence alone) whether the three sites in question have western affinities because of climatic regime or sand type. The coincidence also gives rise to speculation as to whether shell-sand and climate are causally linked, but, as there is no obvious mechanism by which this could happen, the idea must be abandoned.

Looking further south on the east coast, it will be noted that Arbroath, Dumbarnie and Yellowcraig also contain some base-rich dune grassland D1 (17%, 10% and 11% respectively). These sites are not located in one of the more oceanic climatic regimes but they do have some free calcium carbonate in the coastal sand - Arbroath 10.0%, Dumbarnie 10.1% and Yellowcraig 20.8%. The sand at other nearby sites also contains some calcium carbonate - Tentsmuir 1.1%, Aberlady 6.1%, Gullane 8.4% and Tyninghame 3.7%, i.e. somewhat lower values, but not as low as most other sites on this coast, so the effect is not absolutely clear-cut. The combined effect of these observations constitutes reasonable evidence that sand type is at least as important as climate in determining this particular vegetation type

(D1). Base-rich dune grassland D1 is so common (29% of all quadrats) that this conclusion must also have considerable bearing on the site classification itself. It is, however, difficult to come up with more definitive answers or to apportion the effect of various factors with greater certainty. The result of the chemical analyses of sand samples will be communicated in a supplementary report at some later date, along with some size fraction analyses and mineralogical assessments.

8.3 General Interpretation of Site Classification

Before proceeding to a detailed description of the 14 site types, it is useful to examine the overall characteristics of the site classification.

8.3.1 Geographical Distribution of the Site Types

As already noted, a number of the site types defined by the site classification show a marked geographical distribution. This characteristic is evident from the first split in the classification (see step 1 of key and associated maps - Section 8.6) in which there is a sharp division between the western and northern sites (-ve) and the eastern sites (+ve). On the negative side, just one site, Fraserburgh in north Aberdeenshire, is on the east coast. Freswick and Sinclairs Bay in eastern Caithness are, in fact, just round the north-eastern tip of Scotland (Duncansby Head) on the east coast but have been counted as being northern. The probable explanation for the status of Fraserburgh has been discussed above (Section 8.2) in relation to climatic regime and sand type. On the positive side, the division is not quite so clear-cut. Tong on Lewis is almost pure saltmarsh and, as such, has little to do with east/west trends. Torrs Warren (Wigtonshire), in the extreme south-west, is directed to the positive side but it does, in fact, closely conform to the basically eastern type to which it is eventually allocated (Site Type 9 - East Coast, Main type). There are good reasons, in terms of climate and sand type, why this should be so. The other exceptions (starting in the south-west and working round clockwise) are Laggan Bay (Mull), Oronsay, Garvard and Kiloran Bay (all these sites on Colonsay), Redpoint (Wester Ross) and Sandwood (north-west Sutherland) which, along with Morrich More (on the Moray Firth), make up Site Type 10 (West Coast, acid, dwarf shrub type). This type is characterized by containing a significant proportion of peaty habitats, i.e. up to 50% of quadrats. In the case of the six western members of the ST10, much of the peat is relatively unaffected by blown sand, often overlying rock and other substrates. Inclusion of these non-sandy habitats within the sites is the result of the way in which the site boundaries were drawn. Most of the Peatland vegetation types that characterize ST10 occur either near the inland boundary of the site or on rocky ridges or headlands that run through or fringe the sandier parts of the sites. Morrich More, the one eastern example of the type, is a borderline member of the ST10. Here the peat formation is due to high water table round the several small lochs on the site and the balance between Peatland and Grassland vegetation types is rather different from the other members of ST10.

Descending now to the level of the classification where the types are derived, it can be seen that the geographical distribution of sites within a site type conforms to two fairly distinctive patterns (dealing only with those types with five or more sites per type).

(a) Discrete distribution

These are cases in which all (or the majority) of the sites allocated to the type have a fairly well circumscribed geographical distribution. The following site types are examples of discrete distribution.

ST1 - West Coast, Hebridean, Machair type, only on South or North Uist (apart from Achnahaird on the mainland).

ST2 - West Coast, Hebridean, dune type, on the Outer and Inner Hebrides (Coll and Tiree only) (with the exception of Brechin on Shetland).

ST4 - Northern Isles type, only on Orkney, Shetland and the north-eastern tip of Caithness.

ST9 - East Coast, Main type, only on the east coast of mainland Scotland (with the exception of Torrs Warren in the south-west), avoiding the more extreme estuarine situations on that coast.

ST13 - East Coast, Firth type, only in the inner part of the three main firths (Dornoch, Moray and Forth) on the east coast of Scotland.

(b) Widespread distribution

These are types with no distinctive geographical distribution but in each case there is a connecting theme, such as an environmental factor or habitat type, which causes the sites within a type to be grouped together. The following site types are examples of widespread distribution.

ST3 - North and West Coast, truncated type, which occurs mainly on the southern part of the west coast, the Inner Hebrides (Islay and Mull) and on the north coast (with the exception of Fraserburgh on the east coast). The common factor in this site type is, as the name suggests, truncation. Land-use has restricted these sites to a fairly narrow coastal strip and, as a result, the proportion of vegetation types associated with unstable substrates is increased (e.g. means for the type are - D3=25%, C=6% and B=3%, or a total of 34% for unstable types).

ST5 - North and West Coast, acid heath type, with sites well spread on the islands off the west coast (Mull, Coll and Pabbay) and in two sites on the north coast (Faraid Head and Dunnet). Despite the fact that sand near the shore on these sites is calcium-rich (mean 42.4% free calcium carbonate), there are some areas of more acid soil or shallow peat further inland, giving conditions under which some of the more acid vegetation types are able to develop (e.g. means for type are - G1=15%, G2=7%, P1=7%, or a total of 29%). The origin of these heathy areas is probably topographical.

ST10 - West Coast, acid, dwarf shrub type. This type has already been discussed above, the conclusion being that it is determined by the presence of peaty habitats which, in this case, is under fairly general climatic control, i.e. it is not a local phenomenon but can occur in sites anywhere throughout the highly oceanic climate of western and northern Scotland. Again, topography, and the way in which the site boundaries have been drawn, is thought to be the determining factor for the type.

8.3.2 Indicator and Preferential Species

Because the site classification is so relatively simple and because there are so few steps in the key produced by the ISA (a total of 13 steps and a maximum of 4 steps leading to each type), it is possible to use the indicator species that define each division as a means of (ecological) interpretation. An overall interpretation was not really feasible in the case of the vegetation classification because of the complexity of the multi-path key, i.e. with up to 10 steps being required to determine a vegetation type. Nevertheless, some crucial steps have been interpreted in relation to particular vegetation types. In attempting an interpretation of site types based on indicator species, three important points must be kept in mind.

i) The indicator species are, in reality, frequency classes and in all cases the quantitative element is, to a greater or lesser extent, important. It is the degree of importance of the quantity, and its ecological interpretation, that it is not always easy to define. Also, it is possible to get confused between the quantity of a species in a series of quadrats, e.g. mean cover, and the statistic that is really involved, i.e. the number of times a species occurs in the series of quadrats that represent a given site. Not a very familiar concept!

ii) It must not be forgotton that the indicators defining a given division are also conditioned by the indicators in all superior levels of division, i.e. indicators in the fourth level of division are affected by those at levels 3, 2 and 1. Thus it is quite possible for an indicator to appear on apparently contradicting sides at different levels in the classification, i.e. species A may be indicative of the positive side at level 1 but may re-appear at, say, level 3 on the negative side of the hierarchy. This phenomenon does not occur very often in the site key (it is quite common in the vegetation type key) but it can be observed, e.g. Bellis perennis (40%+) in step 1 (-ve side) and repeated in the (20%+) form in step 12 (+ve side).

iii) Note should also be taken of the threshold value for each division, i.e. just how many negative or positive indicators have to be present, and in what balance, in order to achieve a particular outcome in that step of the key. For example, in step 1 of the key at least 4 of the 8 negative indicators must be present, with no positive indicators, for the threshold of -4 to be achieved, i.e. if only 3 negative indicators are present the score will be -3 and the outcome will be to follow the positive pathway, despite having recorded a negative score.

As a secondary aid to the interpretation of the floristic difference between various site types, tables of preferential species have been prepared. These tables refer specifically to the comparison between a particular pair of site types, e.g. a comparison between ST1 and ST2, and therefore only appear with the discussion of those steps in the site key which actually define site types. For the purposes of this exercise, a preferential species is defined as being present in a ratio of at least 2 to 1 in favour of the side to which it is preferential, on which side it must occur with a minimum frequency of 5% (cf. preferential species for the vegetation types required a ratio of 2 to 1 and a minimum frequency of 20%).

With the above provisos in mind and with the aid of the tables of preferential species to differentiate between related site types, it is now possible to examine the steps of the key (see also Figure 7 and the Site Type Key in Section 8.6).

In the first division of the site classification (step 1 or division 1/1) the negative side is defined by eight species that are typical of fixed dune grassland, i.e. species that are most common in the Duneland family of vegetation types. All eight species, with the possible exception of Ranunculus acris, are low-growing plants rarely exceeding 10cm in height. On the positive side, Chamaenerion angustifolium is tall-growing herb, characteristic of disturbance or fire and may also indicate relatively low grazing pressure, whilst Rumex acetosella is a small species, indicative of acid, dry conditions. It will be noted that both positive indicators belong to the first pseudo-species (0%+) and therefore only have to be present in one quadrat in the site to count, as does Trifolium pratense on the negative side. All the other species on the negative side have a quantitative qualification, i.e. Trifolium repens and Plantago lanceolata must be in at least 60% of quadrats in a site to count. As already noted, the threshold for this division is well on the negative side (-4), meaning that the negative affinities, in terms of indicators, have to be quite strong for a site to be allocated to the negative side, i.e. to the eight site types with an almost exclusively western and northern geographical distribution. The positive side leads on to the six site types with a largely eastern distribution, i.e. with the exception of ST10 - West Coast, acid, dwarf shrub type.

In the next division (step 2 in the key or division 2/1 in the hierarchy), which further splits the negative side of division 1, i.e. the western and northern types, Trifolium repens (80%+) is the sole negative indicator. This may be interpreted as referring to sites with a high proportion of Duneland vegetation types and, therefore, comparatively small amounts of other vegetation types. On the positive side are nine species typical of acid grassland or damp heath. Six of these species are of the lowest pseudo-species (0%+) - Pteridium aquilinum, Achillea ptarmica, Hieraceum pilosella, Festuca ovina, Vicia sepium and Erica tetralix. The rest of the indicators are at one class higher (20%+) - Agrostis tenuis, Potentilla erecta and Sieglingia decumbens. Again the threshold for the division of +5 is quite a stringent test for defining the positive types, i.e. 5 out of 9 if Trifolium repens (80%+) does not occur or 6 out of 9 if it does. This division really sets the seal on Site Types 1-4 (negative) in which there are few acid vegetation types and Types 5-8 (positive) in which there is an increasing acidic influence (in the order ST6-ST5-ST7-ST8) along with the basic complement of more base-rich vegetation types (mostly the Duneland family and particularly D1).

Step 3 (division 2/2) is the first subdivision of mainly eastern site types. There is only one positive indicator, Cirsium arvense (20%+). It is not easy to produce a ready interpretation for this species but, as the positive side of this division leads to three site types (ST12, ST13, and ST14) that are characterized by being truncated, somewhat unstable and/or disturbed, it is assumed that it is these features are what is being referred to by a high frequency of Cirsium arvense. Only one of the negative indicators has a quantitative qualification, Calluna vulgaris (20%+). The rest are just presence with any frequency (0%+) - Potentilla erecta, Juncus effusus, Erica cinerea, Erica tetralix, Salix repens, Nardus stricta, Luzula multiflora and Succisa pratensis. These indicators are interpreted as being associated with increasing acidity and heathland development. The threshold value of -3 means that at least 3 of the negative indicators must be present in the absence of Cirsium arvense, or 4 if the positive indicator is present.

A further division of the west coast site types (step 4 or division 3/1) results in a separation of the Hebridean sites from a group of sites in the southern Inner Hebrides, another in northern Scotland and sites on the Northern Isles, i.e. Site Types 1 and 2 are being separated from 3 and 4. The negative indicators for this division show for the first time the importance of wetland habitats in the Outer Hebrides. Of the eight negative indicators, higher frequencies of Trifolium pratense (20%+) and Leontodon autumnalis (40%+) are required, both machair species, but Daucus carota, Carex panicea, Molinia caerulea, Anagallis tenella, Glaux maritima and Lychnis flos-cuculi are only required to be present (0%+). On the positive side, Cirsium vulgare and Cirsium arvense, both (20%+), are probably associated with an increased level of disturbance. The threshold is again -3 which, with 8 possible negative indicators, is not an unduly stringent test for allocation to the negative side.

Step 5 (division 3/1) is concerned with a further division of mainly north coast sites (also some on the Inner Hebrides). On the negative side, Cynosurus cristatus and Lolium perenne both require a frequency of 20%+, whilst Sagina procumbens, Poa annua, Anagallis tenella, Iris pseudacorus and Plantago major only need to be present. The three grasses are taken as being indicators of short-grazed turf with some disturbance - possibly ploughing where Lolium occurs. Both Sagina procumbens and Plantago major are interpreted as being disturbance species. On the positive side are three indicators - Gentianella amarella (20%+), Carex capillaris (0%+) and Succisa pratensis (40%+). Carex capillaris is a species of closely-grazed, flushed, base-rich hill sides and its distribution is closely linked with base-rich soils on the north coast, particularly those that are influenced by Durness limestone. Both sides of the division have their complement of species that grow in damp, boggy places, e.g. Iris pseudacorus (-ve) and Succisa pratensis (+ve), but the precise requirements of these two species are rather different, i.e. Succisa pratensis grows on more acidic, peaty soils. The threshold value of 0 for this step is not obviously biased to one side or the other of the division.

Step 6 of the key (division 3/3) is merely concerned with the removal of Site Type 11, represented by one site (Tong on Lewis), from the main body of east coast sites. There are only positive indicators for this step and, with the exception of Carex distans and Leontodon autumnalis, the species listed are associated with the saltmarsh habitat - Armeria maritima, Aster tripolium, Cochlearia officinalis, Glaux maritima, Juncus gerardii, Puccinellia maritima and Spergularia media, all at 20%+, and Plantago maritima (60%+). The strong saltmarsh element in Tong and the fact that saltmarshes tend to be more common in east coast sites probably explain why this western site is initially segregated with the eastern group. With a threshold value of +4, at least 5 out of the 8 positive indicators need to be present for a site to be allocated to ST11.

Step 7 (division 4/4) is similar in function to step 6, isolating Site Type 14 from the more general run of eastern sites. This type is represented by the probably unique site of Spey Bay (Central) on the south side of the Moray Firth. The indicator species, which are again all positive, are clearly related to the carr woodland flora that occupies much of the site. Again, with a threshold value of +4, at least 5 of the 10 positive indicators need to be present for a site to be allocated to ST14.

Providing the original method of selecting sites is retained, i.e. choosing fairly natural land units, the likelihood of finding further sites that would be allocated to ST11 or ST14 is thought to be extremely low.

The stage in the key has now been reached (level 4) where the main site types are isolated. Such is the simplicity of the classification that the site types can usefully be compared in their natural pairings, i.e. as they appear in the classification hierarchy, 1 with 2, 3 with 4, etc. An ordination of the site types confirms this view. As well as interpreting the indicators which define a division, it is now possible also to consider the preferential species.

Step 8 (division 4/1) is concerned with partitioning sites, mostly in the Outer Hebrides, into Site Types 1 and 2 (ST1 - West Coast, Hebridean, Machair type and ST2 - West Coast, Hebridean, dune type). Of the eight negative indicators four have a quantitative qualification - Potentilla anserina (20%+), Agrostis stolonifera (60%+), Ranunculus repens (20%+) and Viola tricolor (20%+). The other four have only to be present to count, Saxifraga tridactylites, Erodium cicutarium, Eleocharis uniglumis and Atriplex hastata. On the positive side, the two indicators are Thymus drucei (20%+) and Lotus corniculatus (60%+). Two influences can be detected in these lists of species. On both sides of the division are species of dry machair grazings, with perhaps a hint of less stable conditions on the negative side (ST1), e.g. Erodium cicutarium. Also on the negative side, Potentilla anserina, Ranunculus repens and Eleocharis uniglumis are indicative of a higher proportion of damp or wet habitats, i.e. probably where the more inland parts of the sites in ST1 extend into the "blackland" or include small lochs. Atriplex hastata (also negative) is mainly a strandline species but one which also occurs in blow-outs and disturbed areas near the shore. The threshold value of -3 is balanced more or less in accord with the proportion of negative and positive indicators, i.e. 8 to 2 so that 3-0, 4-1 and 5-2 are the possible marginal scores for allocation to ST1.

The division of sites into ST1 and ST2 can be further investigated through the lists of preferential species for the two types.

Preferential Species for Site Type 1

Species Names	ST1 %	ST2 %
Agropyron repens	10.6	3.8
Agrostis canina	10.6	3.8
Caltha palustris	12.4	4.3
Carex panicea	21.3	6.9
Cerastium atrovirens	27.7	13.3
Crepis capillaris	11.0	4.3

Epilobium palustre	7.2	1.9
Eriophorum angustifolium	8.2	1.7
Erodium cicutarium agg.	10.9	0.6
Galium palustre	5.7	1.4
Geranium molle	17.9	3.6
Honkenya peploides	5.6	2.0
Hydrocotyle vulgaris	13.9	5.8
Juncus bufonius	7.6	1.4
Lychnis flos-cuculi	12.7	6.3
Myosotis arvensis	19.8	3.0
Plantago major	7.0	1.8
Polygonum amphibium	6.2	1.3
Potentilla anserina	42.7	13.0
Potentilla palustris	5.2	0.9
Ranunculus repens	43.2	10.8
Sagina procumbens	16.6	4.6
Saxifraga tridactylites	6.0	0.0
Sedum acre	6.3	3.1
Senecio aquaticus	5.4	1.1
Sonchus arvensis	5.7	1.2
Sonchus asper	5.4	0.9
Triglochin maritima	8.4	4.1
Veronica arvensis	20.1	5.9
Vicia cracca	26.3	11.7
Viola tricolor	26.3	4.4

Preferential Species for Site Type 2

Species Names	ST1 %	ST2 %
Agropyron junceiforme	6.4	12.9
Anthyllis vulneraria	10.5	22.0
Armeria maritima	4.8	9.7
Campanula rotundifolia	1.9	10.6
Carex flacca	12.9	26.4
Centaurea nigra	8.2	17.7
Coeloglossum viride	3.6	12.5
Daucus carota	11.4	32.4
Gentianella campestris	0.6	6.8
Helictotrichon pubescens	1.5	10.5
Hieraceum pilosella	0.0	5.4
Koeleria cristata	2.0	25.1
Luzula multiflora	3.1	7.6
Plantago maritima	13.8	28.5
Polygala vulgaris	8.5	22.3
Primula vulgaris	1.0	9.1
Thymus drucei	2.9	29.3
Viola riviniana	5.6	15.0

It will be noted that most of the above preferential species do, in fact, occur in both site types. The exceptions are Saxifraga tridactylites occurring, in ST1 (6.0%) and not in ST2, and Hieraceum pilosella, which was recorded in ST2 (5.4%) but not in ST1. The preferential species for ST1 reflect the same types of habitat that were interpreted from the indicators, five out of eight of which are listed as being preferential. Typical of wet areas or loch edge are such species as Caltha palustris, 12.4% in ST1 and 4.3% in ST2, Epilobium palustre (7.2% and 1.9%), Eriophorum angustifolium (8.2% and 1.7%), Galium palustre (5.7% and 1.4%), Lychnis flos-cuculi (12.7% and 6.3%), Polygonum amphibium (6.2% and 1.4%), Potentilla palustris (5.2% and 0.9%) and Senecio aquaticus (5.4% and 1.1%). Other species are typical of strandline or disturbance, e.g. Agropyron repens (10.6% and 3.8%), Erodium cicutarium (10.9% and 0.6%), Myosotis arvensis (19.8% and 3.0%), Plantago major (7.0% and 1.8%), Sagina procumbens (16.6% and 4.6%), and Veronica arvensis (20.1% and 5.9%). The species preferential to ST2 are fewer in number and less easy to interpret. Mostly they are plants that are found in short-grazed turf, e.g. Coeloglossum viride, 12.5% in ST2 and 3.6% in ST2, Gentianella campestris (6.8% and 0.6%), Koeleria cristata (25.1% and 2.0%) and Thymus drucei (29.3% and 2.9%). Some of these species convey a suggestion of slightly increased acidity. There is also some reflection of the increased proportion of active dune in ST2 through the relative frequency of Agropyron junceiforme, 12.9% in ST2 and 6.4% in ST1. Ammophila arenaria shows the same trend but the difference in not quite enough to qualify this species as a preferential.

These figures may not seem very spectacular (cf. the preferential species for the vegetation type - see Section 7) but it must be emphasized that they represent a difference that occurs only in a minority of quadrats, i.e. the majority of quadrats are the same in both site types. There is also reasonable evidence that ST1 and ST2 are the pair of site types between which there is the least difference, i.e. all other site types show more distinctive differences.

Step 9 in the key (division 4/2) is concerned with the separation of ST4 - Northern Isles type (positive) from ST3 - North and West Coast, truncated type (negative). These are contrasting types, with discrete and widely spread geographical distributions respectively. There are two positive indicators (for ST4), Coeloglossum viride (0%+) and Cerastium holosteoides (60%+), and these are taken as being indicative of closely-grazed, damp, base-rich habitats. All but one of the negative indicators only have to be present in a single quadrat to score - Geranium molle, Hypochoeris radicata, Thalictrum minus, Veronica chamaedrys, Arenaria serpyllifolia, Campanula rotundifolia and Ranunculus bulbosus (all at 0%+). The exception is Taraxacum spp. (20%+). The negative indicators are mainly species of dry machair with a tendency towards acidity. The threshold value of -2 is not a particularly demanding qualification for the negative side but does mean that not many negative indicators can be present if an allocation to the positive side is to occur.

A comparison between the two types ST3 and ST4 may also be made in terms of the preferential species contained in the following tables.

Preferential Species for Site Type 3

Species Names	ST3 %	ST4 %
Agropyron junceiforme	6.0	2.5
Angelica sylvestris	9.5	4.5
Anthriscus sylvestris	7.2	0.0
Arrhenatherum elatius	15.6	1.9
Campanula rotundifolia	25.2	0.0

Centaurea nigra	24.3	0.6
Cerastium atrovirens	15.0	3.1
Dactylis glomerata	23.8	11.3
Filipendula ulmaria	9.9	1.9
Geranium molle	6.4	0.0
Helictotrichon pubescens	8.4	1.3
Hieraceum pilosella	12.9	0.6
Hypochoeris radicata	6.0	0.0
Koeleria cristata	18.2	1.3
Lathyrus pratensis	8.7	1.3
Leontodon autumnalis	25.4	12.6
Leontodon taraxacoides	12.7	0.0
Myosotis arvensis	6.2	1.9
Odontites verna	5.7	0.6
Plantago major	11.9	5.8
Polygonum aviculare agg.	5.0	1.3
Primula veris	5.1	0.0
Ranunculus bulbosus	22.4	0.0
Rumex crispus	14.1	5.7
Sonchus asper	8.8	3.1
Taraxacum spp.	46.0	16.6
Thalictrum minus	13.0	0.0
Trifolium pratense	13.2	3.9
Tussilago farfara	5.2	0.0
Urtica dioica	11.3	2.6
Veronica chamaedrys	25.8	0.0
Vicia sepium	11.2	0.6
Viola canina	8.1	0.0

Preferential Species for Site Type 4

Species Names	ST3 %	ST4 %
Agrostis stolonifera	30.1	63.4
Cardamine pratensis	4.7	16.0
Carex nigra	8.4	25.9
Coeloglossum viride	0.0	7.6
Deschampsia cespitosa	1.5	13.6
Elymus arenarius	0.4	6.5
Euphrasia officinalis agg.	24.5	58.7
Galium sterneri	0.0	12.9
Gentianella amarella	5.1	22.5
Gentianella amarella/campestris	0.0	5.1
Luzula multiflora	1.9	8.3
Myosotis discolor	0.0	6.9
Parnassia palustris	1.4	15.5
Plantago maritima	6.0	19.1
Poa trivialis	1.6	22.9
Ranunculus acris	34.7	70.1
Sagina nodosa	1.4	5.8
Scilla verna	0.0	9.8
Selaginella selaginoides	0.5	5.1
Senecio aquaticus	1.6	16.1
Sonchus arvensis	0.9	6.5
Stellaria media	9.7	30.0
Viola riviniana	16.2	42.4
Viola tricolor	4.7	22.5

Species that are particularly characteristic of ST3 are Arrhenatherum elatius, 15.6% in ST3 and 1.9% in ST4, Campanula rotundifolia (25.2% and 0.0%), Centaurea nigra (24.3% and 0.6%), Cerastium atrovirens (15.0% and 3.1%), Hieraceum pilosella (12.9% and 0.6%), Koeleria cristata (18.2% and 1.3%), Leontodon taraxacoides (12.7% and 0.0%), Ranunculus bulbosus (22.4% and 0.0%), Taraxacum spp. (46.0% and 16.6%), Thalictrum minus (13.0% and 0.0%) and Veronica chamaedrys (25.8% and 0.0%). These species may be interpreted as being associated with dry, slightly acid habitats. By contrast, species preferential to ST4 are mostly indicative of damper conditions, e.g. Agrostis stolonifera, 63.4% in ST4 and 30.1% in ST3, Carex nigra (25.9% and 8.4%), Deschampsia cespitosa (13.6% and 1.5%), Gentianella amarella (22.5% and 5.1%), Parnassia palustris (15.5% and 1.4%), Plantago maritima (19.1% and 6.0%), Poa trivialis (22.9% and 1.6%) and Senecio aquaticus (16.1% and 1.6%). Other species are disturbance related, e.g. Stellaria media (30.0% and 9.7%). One species that seems to be particularly characteristic of the Northern Isles type is Galium sterneri which was recorded in 12.9% of quadrats in the type.

Steps 10 and 11 in the key (divisions 4/3 and 4/4) are concerned with partitioning the various site types that occur mainly on the north coast (ST5, ST6, ST7 and ST8). ST5 - North and West Coast, acid heath type, is the exception, containing some west coast sites (on Mull, Coll and Pabbay). The trend here is one of increasing acidity in the order ST6, ST5, ST7 and ST8.

Step 10 separates ST5 - North and West Coast, acid heath type (negative) from ST6 - North Coast, bayhead, well drained type (positive). The indicators for the negative side (ST5) are Carex panicea, Carex pulicaris and Erica tetralix all at the lowest pseudo-species (0%+). These species are interpreted as indicating rather more acidic conditions and even peat formation. On the positive side, there is rather a mixed bag of species, ranging from the very common, e.g. Achillea millefolium (60%+) and Heracleum sphondylium (20%+), to the rare species Oxytropis halleri (0%+), which has its main area of distribution on the north coast of Scotland. Other indicators for the positive side are Anthyllis vulneraria (0%+), Euphorbia helioscopia (0%+), Primula veris (0%+) and Trollius europaeus (0%+). All of these species tend to occupy rather specialized habitats which apparently occur with a reasonable frequency in the two sites that make up ST6. Why this should be so is not clear but it is probably result of plant geography and the presence in the sites of the necessary habitats. The threshold value of +1 is not stringent but, in fact, with the existing sites the division is highly polarized, with all seven sites in ST5 scoring -3 and the two sites in ST6 scoring +7, i.e. the most extreme scores possible.

A further comparison between ST5 and ST6 can be made in terms of the preferential species.

Preferential Species for Site Type 5

Species Names	ST5 %	ST6 %
Anagallis tenella	9.3	0.0
Arenaria serpyllifolia agg.	7.9	0.0
Calluna vulgaris	15.9	5.3
Campanula rotundifolia	20.3	10.0

Cardamine pratensis	9.6	3.1
Carex echinata	9.2	0.0
Carex nigra	40.6	3.9
Carex panicea	18.8	0.0
Carex pulicaris	14.2	0.0
Cirsium vulgare	12.6	5.6
Cynosurus cristatus	45.2	11.7
Dactylorchis spp.	9.0	0.0
Erica tetralix	11.4	0.0
Eriophorum angustifolium	9.6	0.0
Festuca vivipara	10.1	0.0
Helictotrichon pubescens	14.3	0.0
Hydrocotyle vulgaris	9.3	2.1
Juncus articulatus	14.7	3.1
Koeleria cristata	45.6	17.8
Leontodon taraxacoides	11.9	0.0
Luzula campestris	45.5	14.9
Molinia caerulea	17.6	2.1
Odontites verna	7.6	1.1
Parnassia palustris	12.3	2.1
Polygala vulgaris	24.3	5.5
Prunella vulgaris	50.2	20.2
Ranunculus bulbosus	21.2	0.0
Ranunculus flammula	10.9	2.8
Sieglingia decumbens	26.8	11.6
Thymus drucei	42.4	16.3
Viola canina	7.0	0.0

Preferential Species for Site Type 6

Species Names	ST5 %	ST6 %
Achillea millefolium	28.8	64.9
Agropyron junceiforme	4.7	9.5
Anthriscus sylvestris	0.0	5.7
Anthyllis vulneraria	0.0	5.5
Bromus mollis agg.	1.4	9.2
Centaurea nigra	11.8	48.2
Centaurea scabiosa	0.0	6.4
Cirsium palustre	6.0	14.2
Crepis capillaris	0.5	8.0
Dactylis glomerata	9.8	25.8
Daucus carota	5.8	24.1
Deschampsia cespitosa	0.6	6.3
Draba incana	1.5	5.5
Galium saxatile	4.3	15.6
Heracleum sphondylium	7.5	32.3
Holcus mollis	0.0	6.3
Juncus effusus	7.5	16.4
Juncus squarrosus	0.7	6.9
Knautia arvensis	0.0	11.8
Ononis repens	0.0	15.5
Oxytropis halleri	0.0	8.2
Pimpinella saxifraga	0.0	16.3
Primula veris	0.0	21.8
Rumex acetosa	20.0	44.1
Rumex acetosella	0.9	7.1
Rumex crispus	2.3	8.5
Sedum anglicum	2.7	5.5

Sonchus asper	0.9	6.5
Thalictrum minus	15.6	32.9
Vicia sepium	6.2	15.3
Vicia lathyroides/sativa	1.7	11.5

It will be noted that both lists of preferential species contain quite a high proportion of species that occur in one site type but are not present in the other. The most interesting species exclusive to ST5 (apart from the three negative indicators) are Festuca vivipara in 10.1% of quadrats, Helictotrichon pubescens (14.3%), Leontodon taraxacoides (11.9%) and Ranunculus bulbosus (21.2%). A number of species preferential to ST5 are indicative of acid wet habitats (some on peaty sands, Carex echinata, 9.2% in ST5 and 0.0% in ST6), Carex nigra (40.6% and 3.9%), Cynosurus cristatus (45.2% and 11.7%), Erica tetralix (11.4% and 0.0%), Eriophorum angustifolium (9.7% and 0.0%), Molinia caerulea (17.6% and 2.1%) and Sieglingia decumbens (26.8% and 11.1%). In ST6, some of the more notable exclusives (other than five of the seven indicators, discussed above) are Anthriscus sylvestris (5.6%), Centaurea scabiosa (6.4%), Holcus mollis (6.3%), Knautia arvensis (11.8%), Ononis repens (15.5%) and Pimpinella saxifraga (16.3%). Perhaps more significant in terms of overall ecology are such commoner species as Achillea millefolium, 64.9% in ST6 and 28.8% in ST5, Centaurea nigra (48.2% and 11.8%), Daucus carota (24.1% and 5.8%), Heracleum sphondylium (32.3% and 7.5%), Rumex acetosa (44.1% and 20.0%) and Thalictrum minus (32.9% and 15.6%). Many of these species are tall-growing, giving rise to local areas of tall herb/grass communities in which grazing is light (e.g. Duneland D5). However, it would be a mistake to draw too many detailed conclusions about a site type like ST6, consisting of just two sites, which, when examined more closely, can be seen to have quite large between-site differences .

Step 11 in the key (division 4/4) is concerned with the segregation of five sites that are located on the north coast (in north-west Sutherland) into ST7 - North West Coast, bog type (negative) and ST8 - North West Coast, montane type (positive). Positive indicators are Ammophila arenaria (40%+) and Dryas octopetala (0%+). This is one of the rare occasions when a site classification indicator is selected from the mobile dune zone. It is significant that Ammophila arenaria has a fairly high numerical qualification (40%+), meaning that mobile dune is more common on the positive side (ST8) but not absent on the negative side. The negative indicators are mainly species associated with damp marshy places, e.g. Angelica sylvestris, Caltha palustris, Cardamine pratensis, Daucus carota, Eleocharis palustris, Epilobium palustre and Filipendula ulmaria, all at the lowest pseudo-species value (0%+). Centaurea nigra (40%+) is a rather different species the interpretation of which is not immediately obvious. The threshold value for this division is -4, so it does require a fair number of indicators to achieve a negative allocation, i.e. 4-0, 5-1, or 6-2. For the existing sites, the division is highly polarized (as with step 10), with the three sites in ST7 scoring -7 and the two sites in ST8 scoring +2 (again the most extreme scores possible).

A further investigation of the differences between ST7 and ST8 can be made by examining the preferential species for these two types.

Preferential Species for Site Type 7

Species names	ST7 %	ST8 %
Achillea ptarmica	16.3	1.5
Angelica sylvestris	29.6	0.0
Caltha palustris	11.9	0.0
Cardamine pratensis	9.0	0.0
Carex arenaria	13.1	4.9
Carex panicea	46.9	12.9
Carex serotina	15.7	0.0
Centaurea nigra	60.1	16.5
Dactylis glomerata	27.4	11.7
Dactylorchis spp.	19.8	9.5
Daucus carota	50.8	0.0
Epilobium palustre	7.2	0.0
Equisetum arvense	6.9	0.0
Erica tetralix	20.5	3.1
Eriophorum angustifolium	7.3	1.5
Filipendula ulmaria	16.6	0.0
Galium palustre	7.6	0.0
Heracleum sphondylium	29.9	1.5
Hydrocotyle vulgaris	6.9	0.0
Juncus articulatus	29.4	4.7
Juncus effusus	11.7	0.0
Leontodon taraxacoides	8.9	0.0
Lychnis flos-cuculi	5.3	0.0
Molinia caerulea	24.0	7.7
Nardus stricta	14.0	4.5
Narthecium ossifragum	14.0	1.5
Pedicularis sylvatica	9.1	1.5
Pedicularis spp.	7.2	0.0
Phragmites communis	11.7	0.0
Pinguicula vulgaris	10.3	4.7
Plantago coronopus	6.2	1.5
Potentilla anserina	17.0	1.5
Primula veris	16.9	0.0
Ranunculus flammula	10.5	1.5
Ranunculus repens	10.6	1.7
Rumex acetosa	22.7	8.2
Rumex acetosella	7.0	0.0
Sagina nodosa	7.7	1.7
Scilla verna	8.0	0.0
Senecio jacobaea	40.4	13.4
Stachys palustris	5.5	0.0
Vicia cracca	21.4	10.0
Vicia sepium	20.1	6.7

Preferential Species for Site Type 8

Species Names	ST7 %	ST8 %
Ammophila arenaria	17.8	45.9
Antennaria dioica	7.6	29.4
Arctostaphylos uva-ursi	0.0	6.0
Campanula rotundifolia	17.0	39.4
Carex capillaris	6.3	13.1
Carex nigra	26.6	58.3

Conopodium majus	0.0	5.0
Dryas octopetala	0.0	9.5
Empetrum nigrum	3.0	14.0
Erica cinerea	0.0	6.0
Gentianella campestris	5.7	16.4
Gymnadenia conopsea	1.1	23.3
Helictotrichon pubescens	1.1	20.0
Hypericum pulchrum	6.1	15.6
Juniperus communis	0.0	13.7
Pteridium aquilinum	1.2	9.4
Schoenus nigricans	0.3	6.2
Trifolium campestre	1.1	5.0
Veronica chamaedrys	5.7	21.7
Veronica officinalis	0.0	6.0

The list of species preferential to ST7 is long, with no less than 19 exclusive species, some of which have high frequencies, e.g. Angelica sylvestris (29.6%), Caltha palustris (11.9%), Carex serotina (15.7%), Daucus carota (50.8%), Filipendula ulmaria (16.6%), Juncus effusus (11.7%) and Primula veris (16.9%). Other species are not exclusive but, nevertheless, indicate considerable differences between the two site types, e.g. Carex panicea, 46.9% in ST7 and 12.9% in ST8, Centaurea nigra (60.1% and 11.5%), Erica tetralix (20.5% and 3.1%), Heracleum sphondylium (29.9% and 1.5%), Juncus articulatus (29.4% and 4.7%), Molinia caerulea (24.0% and 7.7%), Rumex acetosa (22.7% and 8.2%), Senecio jacobaea (40.4% and 13.4%), Vicia cracca (21.4% and 10.0%) and Vicia sepium (20.1% and 6.7%). A fair proportion of these preferentials are marsh or bog species but others are tall herbs, suggesting moderate to light grazing in some parts of the sites. Some of the smaller species, such as Primula veris (16.9%) and Scilla verna (8.0%) grow in the more closely cropped pastures on the higher ground near the site margins.

There are fewer preferential species for ST8. Of the exclusive species, only Juniperus communis (13.7%) has a frequency of over 10%. Also of interest is Ammophila arenaria, with 45.9% in ST8 and 17.8% in ST7 (also an indicator). Most of the preferential species reflect the flora of the more acidic, high level areas found in these sites, e.g. Antennaria dioica (29.4% and 7.6%), Arctostaphylos uva-ursi (6.0% and 0.0%), Dryas octopetala (9.5% and 0.0%), Empetrum nigrum (14.0% and 3.0%) and Schoenus nigricans (6.2% and 0.3%). Two interesting species that are preferential to ST8, are Gentianella campestris (16.4% and 5.7%) and Gymnadenia conopsea (23.3% and 1.1%).

The next step in the key (step 12, division 4/5) marks the transition to the positive side of the hierarchy, i.e. positive at step 1, division 1/1, so the remaining divisions at this level are concerned with segregating the mainly east coast sites. As two stems of the hierarchy have already terminated at level 3, with one site each (ST11 and ST14), there are only two more divisions on this side of the classification.

Step 12 is concerned with separating the main group of sites on the east coast, ST9 - East Coast, Main type (with 14 sites), from ST10 - West Coast, acid, dwarf shrub type (7 sites). The negative indicators for this division are Chamaenerion angustifolium (0%+) and Agrostis tenuis (40%+). Chamaenerion is thought to be related to fire and disturbance, whereas Agrostis is a reflection of general dry, acid conditions. Agrostis tenuis is an important species in Grassland G3, which vegetation type constitutes over 50% of the quadrats in ST9. The positive indicators are mainly bog species - Carex panicea (20%+), Erica tetralix (20%+), Carex pulicaris (0%+), Drosera rotundifolia (0%+), Molinia caerulea (20%+), Trichophorum cespitosum (0%+), Narthecium ossifragum (0%+) and Bellis perennis (20%+). It will be noted that the last of these species, Bellis, is not a bog plant but it is one of the general indicators of western sites (see step 1 of key). The threshold for this step is -4 which is in close accord with the balance of indicators (8 to 2).

The following table of preferential species further defines the floristic differences between ST9 and ST10.

Preferential Species for Site Type 9

Species Names	ST9 %	ST10 %
Agrostis tenuis	62.2	19.6
Arrhenatherum elatius	5.8	1.3
Carex arenaria	50.0	21.1
Chamaenerion angustifolium	8.8	0.0
Cirsium arvense	9.1	2.7
Deschampsia flexuosa	9.9	4.2
Galium saxatile	32.3	13.6
Holcus mollis	5.1	0.2
Hypochoeris radicata	21.3	9.4
Pinus contorta	6.4	0.0
Pinus sylvestris	8.5	0.0
Rosa pimpinellifolia	6.1	0.5
Rumex acetosella	18.4	4.6
Senecio jacobaea	27.7	3.9
Ulex europaeus	23.9	1.6
Veronica officinalis	19.6	5.0
Viola tricolor	5.3	1.7
Vicia lathyroides/sativa	6.4	0.0

Preferential Species for Site Type 10

Species Names	ST9 %	ST10 %
Agrostis canina	6.8	26.1
Anagallis tenella	0.1	6.0
Bellis perennis	4.4	24.3
Carex binervis	0.0	7.3
Carex echinata	0.8	14.3
Carex flacca	4.6	13.3
Carex nigra	10.0	24.4
Carex panicea	1.8	33.8
Carex pilulifera	1.9	5.6
Carex pulicaris	0.1	7.6
Cynosurus cristatus	1.8	9.2
Dactylorchis spp.	1.0	10.0
Drosera rotundifolia	0.0	9.8
Erica tetralix	8.2	36.4
Eriophorum angustifolium	0.5	17.0

Eriophorum vaginatum	0.1	5.1
Erodium cicutarium agg.	0.3	5.0
Euphrasia officinalis agg.	5.6	23.9
Festuca vivipara	0.0	6.8
Juncus squarrosus	5.4	16.0
Leontodon autumnalis	4.6	10.7
Linum catharticum	5.0	18.7
Molinia caerulea	1.0	35.9
Myrica gale	0.6	12.6
Nardus stricta	8.2	22.3
Narthecium ossifragum	0.1	11.7
Pedicularis sylvatica	0.5	8.9
Plantago coronopus	0.6	5.0
Plantago lanceolata	17.0	35.8
Plantago maritima	2.8	15.3
Poa annua	2.6	6.8
Polygala serpyllifolia	3.7	7.4
Polygala vulgaris	3.1	12.1
Potentilla erecta	22.6	50.6
Prunella vulgaris	4.4	20.7
Pteridium aquilinum	4.2	10.1
Ranunculus acris	3.9	11.1
Selaginella selaginoides	0.0	5.1
Sieglingia decumbens	4.9	23.2
Succisa pratensis	2.9	26.1
Thymus drucei	11.9	34.9
Trichophorum cespitosum	0.0	15.7

Species that are exclusive to one type or the other are all relatively unimportant as, with the exception of Trichophorum cespitosum (15.7% in ST10), they all have frequencies of under 10%. Some of the low frequency exclusives are, however, quite interesting, e.g. Pinus contorta (6.4%) and Pinus sylvestris (8.5%) both in ST9. The more common species preferential to ST9 are mostly indicative of drier, acid conditions or disturbance - Agrostis tenuis, 62.2% in ST9 and 19.6% in ST10, Carex arenaria (50.0% and 21.1%), Galium saxatile (32.3% and 13.6%), Hypochoeris radicata (21.3% and 9.4%), Rumex acetosella (18.4% and 4.6%), Senecio jacobaea (27.7% and 3.9%) and Ulex europaeus (23.9% and 1.6%). In the opposite direction, preferential to ST10, are a series of species that are indicative of wet, peaty conditions. The most frequent (20% or over) of these are Agrostis canina, 26.1% in ST10 and 6.8% in ST9, Carex nigra (24.4% and 10.0%), Carex panicea (33.8% and 1.8%), Erica tetralix (36.4% and 8.2%), Euphrasia officinalis agg. (23.9% and 5.6%), Molinia caerulea (35.9% and 1.0%), Nardus stricta (22.3% and 4.9%) and Succisa pratensis (26.1% and 2.9%). Other bog species have lower frequencies but further reinforce this interpretation. Indeed, very high frequencies are not to be expected, as bog is only a minority habitat in otherwise sandy sites with quite high levels of free calcium carbonate in the sand. Several other species preferential to ST10 indicate the more general oceanic conditions or shell-rich sand in the western sites, e.g. Bellis perennis (24.3% and 4.4%), Linum catharticum. (18.7% and 5.0%), Plantago lanceolata (35.8% and 17.0%), Prunella vulgaris (20.7% and 4.4%) and Thymus drucei (34.9% and 11.9%).

The final division in the site key (step 13, division 4/7) is concerned with the separation of sites in which there is a maritime influence. In ST12 - East Coast, truncated type (6 sites), the maritime influence takes the form of instability near to the sea, leading to a preponderance of the less stable vegetation types D3, C and B. The maritime influence, in the case of ST13 - East Coast, Firth type (6 sites), takes the form of saltmarsh included within the site boundary (vegetation types S1, S2, S3, S4, S5 and F1). The negative indicators for this division are Achillea millefolium (20%+), Campanula rotundifolia (20%+), Rumex obtusifolius (0%+) and Thalictrum minus (0%+). The interpretation of these four species is not easy. Thalictrum and Campanula usually imply the presence of rather acid habitats but four out of six sites have beach sand with 10% or more free calcium carbonate in it. The same four out of the six sites also include some base-rich dune grassland D1. However, this does not preclude there being acid parts to the sites. Rumex obtusifolius is interpreted as being a sign of disturbance. Finally, Achillea millefolium is something of a mystery plant. It certainly favours base-rich as opposed to base-poor substrates, e.g. it has a frequency of 66.0% in D1 as compared with 16.9% in D2, but it is also thought to be related to freely drained habitats where its drought resistance (it is a very deep rooted species) may be important. It is a species that may also be favoured by heavy grazing and trampling. Nevertheless, the curious behaviour of Achillea millefolium, present in some quadrats and absent from other apparently similar ones, and common in some sites but rare in others, was noted throughout the survey. Even within the six sites in ST12, its frequency varies from 23% at Cruden Bay to 93% at Arbroath. This is a species that clearly merits further investigation in the coastal habitat. Indicators on the positive side of the division (defining ST13) are all saltmarsh species - Armeria maritima, Glaux maritima, Puccinellia maritima, Salicornia maritima and Suaeda maritima, all at the lowest pseudo-species (0%+), and Plantago maritima (20%+). The threshold value of +1 is not very critical, i.e. it only needs 2 saltmarsh species to give the necessary score of +2 to allocate a site to ST13.

The following table of preferential species further illustrates the differences between ST12 and ST13.

Preferential Species for Site Type 12

Species Names	ST 12 %	ST 13 %
Achillea millefolium	44.3	4.4
Agropyron repens	24.3	10.5
Arrhenatherum elatius	34.6	13.1
Briza media	8.4	0.0
Campanula rotundifolia	39.4	2.1
Centaurea nigra	21.9	1.1
Cirsium vulgare	25.6	10.0
Crepis capillaris	6.4	0.3
Cynosurus cristatus	6.1	0.0
Dactylis glomerata	44.9	7.9
Echium vulgare	11.2	4.6
Equisetum arvense	11.2	2.0
Euphrasia officinalis agg.	13.3	3.9
Filipendula ulmaria	7.6	3.2
Galium verum	66.9	32.3
Helictotrichon pratense	5.1	0.0
Heracleum sphondylium	25.2	5.3
Koeleria cristata	24.4	4.8
Lathyrus pratensis	9.7	3.6
Linum catharticum	10.8	4.9

Lolium perenne agg.	5.6	2.4
Luzula campestris/multiflora	5.4	0.0
Ononis repens	19.9	5.7
Phleum bertolonii/pratense	7.8	0.0
Plantago lanceolata	54.6	20.1
Primula veris	7.1	0.0
Ranunculus repens	11.0	3.8
Rumex acetosa	8.9	1.4
Rumex obtusifolius	5.5	0.0
Scabiosa columbaria	5.2	0.0
Thalictrum minus	13.7	0.0
Torilis japonica	13.9	1.6
Tragopogon pratensis	6.2	0.4
Trifolium repens	38.1	14.3

Preferential Species for Site Type 13

Species Names	ST12 %	ST 13 %
Aira caryophyllea	1.7	5.6
Armeria maritima	0.0	26.3
Aster tripolium	0.0	9.2
Calluna vulgaris	0.0	5.5
Carex extensa	0.0	5.7
Cerastium atrovirens	6.8	22.7
Cochlearia officinalis	0.6	5.2
Fragaria vesca	0.0	6.5
Geranium molle	0.4	5.5
Glaux maritima	0.0	21.0
Juncus gerardii	0.6	9.6
Myosotis ramosissima	1.5	11.2
Plantago maritima	2.9	29.7
Puccinellia maritima	0.0	18.1
Salicornia spp.	0.0	12.4
Sedum acre	0.0	5.2
Spergularia media	0.0	10.3
Suaeda maritima	0.0	18.8
Teucrium scorodonia	1.9	6.0
Triglochin maritima	0.0	6.8
Valerianella locusta	0.0	5.4
Veronica arvensis	4.3	9.3
Veronica officinalis	3.4	8.8

In addition to the negative indicator species that have already been discussed above, there is a long list of preferentials for ST12. Some of these are tall grasses, e.g. Agropyron repens, 24.3% in ST12 and 10.5% in ST13, and Arrhenatherum elatius (34.6% and 13.1%). Many other preferentials are, at least in part, a by-product of the different balance between non-maritime and maritime habitats, i.e. 34% of quadrats in ST13 belong to the Saltmarsh family as compared with none in ST12. Preferential species with a frequency of 20% or more in ST12 are Centaurea nigra (21.9% and 1.1%), Cirsium vulgare (25.6% and 10.0%), Dactylis glomerata (44.9% and 7.9%), Galium verum (66.9% and 32.3%), Heracleum sphondylium (25.2% and 5.3%), Koeleria cristata (24.9% and 4.8%), Plantago lanceolata (54.6% and 20.1%) and Trifolium repens (38.1% and 14.3%). Species preferential to ST13 are fewer in number and include many saltmarsh species. Those not already discussed in relation to the indicators are Aster tripolium, 9.2% in ST13 and 0.0% in ST12, Carex extensa (5.7% and 0.0%), Juncus gerardii (9.6% and 0.6%) and Spergularia media (10.3% and 0.0%). The only other preferential for ST13 worthy of note is Cerastium atrovirens (32.7% and 6.8%).

8.3.3 Vegetation Types

The relative merits of deriving the site classification from a data summarization using species frequency, as compared with one using frequency of vegetation types, have been discussed at some length in Sections 6.3 and 8.1. Because the final decision was to use species frequency, this enables the proportion of vegetation within site types to be used as a ready means of interpretation. Whilst both classifications are based on the same raw data, the classifications themselves are independent and this gives added validity to this means of interpretation.

As the two "test" classifications referred to above were so similar, it comes as no surprise that there are characteristic differences in the proportion of vegetation types in the various site types. The proportions of vegetation types are summarized in Table 4. Across the top of the table, the ordering of vegetation types is the same as for Tables 2 and 3 (see Section 7.7). On the lefthand side of the table, the site types have been arranged in approximate order of the diagonal of the first and second axis of a reciprocal average ordination of the site types (ST11 and ST14 have been placed at the end because they do not really fit anywhere). Within a site type, the sites are listed in order of their survey code number. The first page of the table is devoted to the negative side of the classification hierarchy (ST1-8) and the second page to the positive side (ST9-14). The "blocking" of vegetation types in particular site types will be noted. The means for a site type are given at the bottom of each type. The entry of a dot (.) in the table means a vegetation type was absent and a plus sign (+) means it was present but with a frequency of less than 0.5%, i.e. it could not be rounded up to 1.

Dealing now with the general distribution of various vegetation types in the table, those types that are associated with the extreme coastal zone are present throughout, e.g. Colonist C, Duneland D3 (and Bare Ground B, if this can be deemed a vegetation type). Semi-stable dune grassland D3 does, however, show a series of peaks in some of the site types - ST1=4%, ST2=6%, ST4=5%, ST3=25% ST6=15%, ST5=6%, ST7=10%, ST8=9%, ST12=51%, ST13=22%, ST10=7% and ST9=10%. Along with similar figures for colonizing communities C, these two vegetation types give a good idea of the proportion of active sand dune and instability in the site types. Other less common vegetation types that depend on the presence of specialized habitats, which are themselves largely independent of the main trends in the site classifications, are also widely spread in Table 4, e.g. Foredune F1, and Marshland M1 and M2.

By contrast, the really common vegetation types in the Duneland and Grassland families have quite distinctive distributions. For example, base-rich dune grassland D1 is mostly in the first half of the table, with frequencies of ST1=52%, ST2=58%, ST4=52%, ST3=33%, ST6=45%, ST5=40%, ST7=23% and ST8=16%. In the second half of the table the frequency of D1 is much diminished - ST12=9%, ST13=2%, ST10=11% (a western type) and ST9=1%. Damp, base-rich dune grassland D4, a vegetation type that is closely linked with D1, shows a remarkably similar distribution (lower absolute values because it is less

TABLE 4. - TWO-WAY TABLE OF VEGETATION TYPES (%) IN SITES AND SITE CLASSES

SITE CLASSES
SITE NAMES

VEGETATION TYPES (% in site)

SITE CLASS NO.- 1	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	H3	H4	H2	H1	F1	F2	S5	S4	S3	S2	S1	B
21 Daliburgh	.	.	.	.	.	.	13	.	8	.	.	.	.	68	.	.	6	.	.	6	.	.	.	.	.	.	.	.	.
22 Ornaiclate	.	.	.	.	.	.	7	.	9	.	.	.	4	63	.	2	.	.	.	11	.	.	.	.	.	.	.	.	4
23 Howbeg	.	.	.	.	.	.	14	.	24	.	.	.	.	48	.	5	.	.	.	5	.	5	.	.	.	.	.	.	.
24 Stilligarry (North)	.	.	.	.	.	.	17	.	17	.	.	3	21	41	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
25 Loch Bee	.	.	1	.	.	.	13	1	27	.	.	.	19	23	.	5	.	.	.	4	.	.	.	.	2	.	.	5	.
26 Borve	.	.	.	.	.	.	.	.	4	.	.	.	4	81	.	.	.	.	.	.	.	4	.	.	.	.	.	.	7
27 Stilligarry (South)	.	4	4	.	.	.	4	4	4	.	.	1	8	60	.	1	1	.	2	8	+	1	.	.	.	+	.	.	.
28 Baleshare	.	.	.	.	.	.	.	.	16	.	.	.	27	45	2	4	2	.	.	.	.	.	.	2	4	.	.	.	.
31 Paible	.	.	.	.	.	6	.	.	6	.	.	.	6	44	.	19	6	.	.	.	.	.	.	.	13	.	.	.	.
32 Hosta	.	.	3	.	.	.	.	.	10	.	.	.	7	66	.	7	.	.	.	.	.	3	.	.	.	.	.	.	3
34 Leathann	.	.	.	.	.	.	6	.	3	.	.	.	3	74	.	6	6	.	.	.	.	3	.	.	.	.	.	.	.
35 Balranald	.	.	.	.	.	.	11	.	16	.	.	.	4	52	.	2	+	.	.	11	.	1	.	.	2	.	+	.	+
52 Achnahaird	.	.	11	.	.	.	7	4	22	.	.	.	.	15	.	7	7	.	.	.	.	.	.	.	15	.	.	7	4
MEANS	0	+	1	0	0	+	7	1	13	0	0	+	8	52	+	4	2	0	+	3	+	1	0	+	3	+	+	1	1

SITE CLASS NO.- 2	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	H3	H4	H2	H1	F1	F2	S5	S4	S3	S2	S1	B
12 West Tiree	.	.	.	.	.	.	6	5	3	.	.	.	8	65	.	3	1	.	.	3	.	.	.	.	.	1	.	1	3
13 Ballevullin	.	.	.	.	.	.	3	.	.	.	.	.	3	81	.	8	.	.	.	3	.	3	.	.	.	.	.	.	.
14 Hynish Bay	.	.	.	.	.	.	.	.	21	.	.	.	9	62	3	3	.	.	.	.	.	.	.	.	.	.	.	.	3
16 Totamore Dunes	.	.	.	.	.	.	8	.	3	.	.	.	8	64	.	11	.	.	.	3	.	.	.	.	.	.	.	.	3
18 Vatersay	.	.	.	.	.	.	.	.	.	.	.	.	.	60	.	20	3	.	.	3	.	.	.	.	.	.	.	7	7
19 West Barra	.	.	.	.	.	.	.	.	3	.	.	.	3	61	.	11	3	.	.	.	.	3	.	8	.	.	.	.	11
20 North Barra	.	.	2	.	.	.	.	2	2	.	.	.	2	80	.	2	9	.	.	.	.	.	.	.	.	.	.	.	.
29 Kirkibost	.	.	.	.	.	.	11	.	7	.	.	.	7	43	.	7	.	.	.	.	.	.	.	7	11	.	.	4	4
30 Monach Isles	.	.	.	.	.	.	5	2	5	.	.	.	2	85	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
33 Vallay	.	.	3	.	.	.	.	.	6	.	.	3	3	69	.	3	6	.	.	3	.	3	.	.	.	.	.	.	.
36 Robach	.	.	.	.	.	.	3	.	8	.	.	.	8	74	.	3	.	.	.	.	.	.	.	.	3	.	.	3	.
37 Bernerau	.	.	.	.	.	.	3	.	13	.	.	.	27	33	.	13	8	.	.	.	.	.	.	.	.	.	.	2	.
39 Northton	.	.	5	.	.	.	.	8	11	.	.	.	5	37	.	.	5	.	.	.	.	.	.	5	8	.	.	.	16
40 Luskintyre	.	.	.	.	.	.	.	3	.	.	.	.	.	42	.	13	6	.	.	.	.	.	.	.	26	.	6	.	3
41 Uig	3	.	3	.	.	.	.	3	.	.	.	.	20	53	.	7	.	.	.	.	.	.	.	.	3	.	.	.	7
42 Valtos	.	.	4	.	.	.	4	4	12	.	.	.	8	54	.	8	.	.	.	.	.	.	4	.	.	.	.	.	4
43 Barvas	.	.	10	.	.	.	.	.	13	.	.	.	7	57	.	3	3	.	.	.	3	.	.	.	.	.	.	.	3
44 Europie	.	.	.	.	.	.	.	3	10	.	.	.	13	43	.	3	7	.	.	10	3	.	.	.	.	.	.	.	7
45 Tolsta	.	.	3	.	.	.	.	3	.	.	.	.	7	57	.	3	3	.	.	.	13	.	.	.	3	.	.	.	7
49 Breckin	.	.	.	.	.	.	.	19	22	.	.	4	.	37	.	7	.	.	.	.	.	.	.	4	4	.	.	.	.
MEANS	+	0	2	0	0	0	2	3	7	0	0	+	7	58	+	6	3	0	0	1	1	+	+	1	3	+	+	1	4

SITE CLASS NO.- 4	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	H3	H4	H2	H1	F1	F2	S5	S4	S3	S2	S1	B
47 Quendale	..	.	.	.	.	3	.	.	43	.	.	9	3	31	9	3	.	.	.	.	.	.	.	.	.	.	.	.	.
48 Scousburgh	.	.	.	.	.	.	3	.	7	.	.	3	13	60	.	.	3	.	.	7	.	.	3	.	.	.	.	.	.
51 Holland	.	.	.	.	.	.	.	.	3	.	.	.	10	74	.	.	3	.	.	6	3	.	.	.	.	.	.	.	.
65 Sinclairs Bay	.	.	.	.	.	.	3	3	16	.	.	3	19	19	3	7	19	.	.	3	.	.	.	.	.	.	.	.	4
73 Overbister	.	.	.	.	.	.	.	.	.	.	.	.	13	74	.	13	.	.	.	.	.	.	.	.	.	.	.	.	.
MEANS	0	0	0	0	0	1	1	1	14	0	0	3	12	52	2	5	5	0	0	3	1	0	1	0	0	0	0	0	1

SITE CLASS NO.- 3	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	H3	H4	H2	H1	F1	F2	S5	S4	S3	S2	S1	B
2 Machrihanish Dunes	.	.	.	.	.	.	.	.	.	.	.	+	12	62		16	3	.	.	+	4	.	.	.	.	.	.	.	2
4 Kilchoman Dunes	.	.	.	.	.	.	.	.	20	.	.	10	3	53	3	10	.	.	.	.	.	.	.	.	.	.	.	.	.
10 Calgary Dunes	.	.	.	.	.	4	.	.	8	.	.	28	4	36	4	4	.	.	.	.	.	4	.	.	.	.	.	.	8
11 Sanna	.	.	.	.	.	.	.	.	7	.	.	3	7	53	.	3	17	.	.	.	.	.	.	.	3	.	.	.	7
61 Reay	.	.	.	.	.	.	.	.	.	.	.	4	1	21	.	57	8	.	.	.	5	.	.	.	.	.	.	.	4
63 Freswick	.	.	.	.	.	.	3	.	12	.	.	6	11	28	.	37	.	.	.	3	.	.	.	.	.	.	.	.	.
79 Fraserburgh	.	.	.	.	.	.	.	.	.	.	.	3	.	29	3	51	11	.	.	.	.	.	.	.	.	.	.	.	3
MEANS	0	0	0	0	0	1	+	0	7	0	0	8	4	33	10	25	6	0	0	+	1	1	0	0	+	0	0	0	3

SITE CLASS NO.- 6	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	H3	H4	H2	H1	F1	F2	S5	S4	S3	S2	S1	B
58 Farr Bay	.	.	.	.	+	.	.	.	1	.	.	8	4	68	.	14	2	.	.	1	.	.	.	.	.	.	.	.	2
60 Melvich	.	.	.	.	5	8	.	14	18	.	.	9	.	21	.	15	4	.	.	.	.	.	.	.	.	.	2	.	4
MEANS	0	0	0	0	3	4	0	7	10	0	0	9	2	45	0	15	3	0	0	1	0	0	0	0	0	0	1	0	3

SITE CLASS NO.- 5	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	H3	H4	H2	H1	F1	F2	S5	S4	S3	S2	S1	B
5 Saligo Bay	.	.	.	.	.	13	7	3	10	.	.	7	.	33	10	10	.	.	.	.	.	.	.	.	.	.	.	.	7
6 Gruinart	.	.	4	.	.	3	10	3	9	.	1	3	1	24	6	10	12	.	.	1	3	.	.	.	4	.	.	3	.
15 Crossapol and Gunna	.	.	11	.	.	1	1	2	12	.	.	3	.	52	5	4	1	.	.	1	.	.	.	.	1	.	.	.	5
17 Ballanach	.	.	7	.	.	.	2	7	13	.	.	.	2	63	.	2	.	.	.	2	.	.	.	.	.	.	.	.	2
38 Pabbay	2	.	23	.	.	.	5	13	23	.	.	.	6	24	.	2	2	.	.	2	.	.	.	.	.	.	.	.	.
56 Faraid Head	.	.	7	.	.	.	.	13	10	.	.	.	3	50	.	7	3	.	3	.	.	3	.	.	.	.	.	.	+
62 Dunnet	.	.	.	.	.	.	4	8	28	.	.	+	4	32	4	9	1	.	.	5	4	.	.	.	.	.	.	.	+
MEANS	+	0	7	0	0	2	4	7	15	0	+	2	2	40	4	6	3	0	+	2	1	+	0	0	1	0	0	+	2

SITE CLASS NO.- 7	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	H3	H4	H2	H1	F1	F2	S5	S4	S3	S2	S1	B
53 Oldshore More	.	.	16	.	.	.	.	11	14	.	.	+	8	46	.	1	2	.	.	.	.	+	.	.	.	.	.	+	1
54 Sheigra	.	.	4	.	.	.	4	28	19	.	.	5	8	8	.	8	.	.	.	11	.	1	.	.	.	+	.	.	4
59 Strathy	.	.	10	.	.	.	3	7	24	.	.	14	.	14	3	21	.	.	.	.	.	.	.	.	.	.	.	.	3
MEANS	0	0	10	0	0	0	2	15	19	0	0	6	5	23	1	10	1	0	0	4	0	+	0	0	0	+	0	+	3

SITE CLASS NO.- 8	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	H3	H4	H2	H1	F1	F2	S5	S4	S3	S2	S1	B
55 Durness	.	.	3	.	.	.	.	10	53	.	.	3	3	23	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
57 Bettyhill	.	.	6	.	.	9	.	21	3	.	.	.	.	9	6	18	21	.	.	.	.	.	.	.	.	.	3	.	3
MEANS	0	0	5	0	0	5	0	16	28	0	0	2	2	16	5	9	11	0	0	0	0	0	0	0	0	0	2	0	2

(Table 4. cont.)

SITE CLASS NO.- 12	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1	B
81 St. Fergus	.	.	.	.	.	.	2	.	.	.	.	.	2	14	9	42	23	.	.	.	.	.	.	.	.	.	.	.	7
82 Cruden Bay	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	47	10	.	.	.	3	3	.	.	.	.	.	.	37
87 Lunan Bay	.	.	.	.	.	.	.	.	.	.	.	.	.	.	16	79	.	.	.	.	5	.	.	.	.	.	.	.	.
88 Arbroath	.	.	.	.	.	.	.	.	.	.	.	3	.	17	.	72	.	.	.	.	7	.	.	.	.	.	.	.	.
91 Dumbarnie	.	.	.	.	.	3	.	.	7	.	.	3	3	10	31	24	7	.	.	.	10	.	.	.	.	.	.	.	.
94 Yellowcraig	.	.	.	.	.	.	.	.	.	.	.	.	.	11	44	39	6	.	.	.	.	.	.	.	.	.	.	.	.
MEANS	0	0	0	0	0	1	+	0	1	0	0	1	1	9	17	51	8	0	0	0	4	1	0	0	0	0	0	0	7

SITE CLASS NO.- 13	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1	B
68 Dornoch	.	.	.	.	.	.	.	.	.	.	.	.	.	9	6	23	7	.	.	.	.	6	.	.	44	2	.	3	.
71 Whiteness	.	.	.	.	.	21	.	.	.	2	.	.	.	.	10	12	.	.	.	.	4	.	.	.	.	8	16	19	10
72 Culbin Bar	.	.	.	.	.	14	.	.	.	.	.	.	.	.	14	16	5	.	.	.	.	5	.	2	.	.	2	30	12
92 Aberlady	.	.	.	.	.	.	.	.	.	.	.	.	3	.	29	10	6	.	.	16	10	.	.	3	6	3	.	10	3
93 Gullane	.	.	.	.	.	.	.	.	.	.	.	.	.	.	62	27	9	.	.	1	.	.	.	.	.	.	.	.	1
95 Tyninghame	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	43	13	.	.	.	10	.	.	.	1	11	.	17	1
MEANS	0	0	0	0	0	6	0	0	0	+	0	0	1	2	20	22	7	0	0	3	4	2	0	1	9	4	3	13	5

SITE CLASS NO.- 10	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1	B
3 Lossan Bay	40	.	7	.	.	12	2	2	2	.	.	2	.	14	2	2	10	.	.	.	.	.	.	.	.	.	.	.	2
7 Oronsay	5	.	26	.	2	19	.	7	7	2	.	2	.	7	7	9	2	.	.	2	.	.	.	.	.	2	.	.	.
8 Garvard	29	.	16	.	.	3	3	6	6	.	.	.	.	19	3	10	3	.	.	.	.	.	.	.	.	.	.	.	.
9 Kiloran Bay	.	.	21	.	.	3	.	9	.	.	.	.	.	18	18	6	18	.	.	3	.	.	.	.	.	.	.	.	3
50 Redpoint	22	4	27	.	4	16	.	5	+	.	.	7	.	.	4	2	6	.	.	.	.	1	.	.	+	.	.	.	2
64 Sandwood	4	.	20	.	.	.	.	8	.	.	.	.	.	19	4	15	16	.	.	4	.	.	.	.	.	.	.	.	12
70 Morrich More	.	.	9	.	.	28	9	6	16	.	.	.	.	.	2	4	.	.	.	.	.	.	.	1	11	.	5	6	3
MEANS	14	1	18	0	1	12	2	6	4	+	0	2	0	11	6	7	8	0	0	1	0	+	0	+	2	+	1	1	3

SITE CLASS NO.- 9	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1	B
1 Torrs Warren	2	3	.	1	5	52	.	.	1	.	1	.	.	.	12	6	13	1	.	1	.	.	1	.	.	.	.	1	1
66 Ferry Links	.	.	.	.	.	57	.	.	.	.	4	.	.	.	24	13	1	.	.	.	.	+	.	.	.	.	.	.	1
67 Coul Links	.	.	.	3	.	43	3	10	+	.	.	+	3	3	15	10	7	.	.	.	.	1	.	.	1	.	1	.	.
69 Clashmore	.	.	.	.	.	77	.	3	.	.	.	.	.	.	6	11	3	.	.	.	.	.	.	.	.	.	.	.	.
74 Findhorn	.	.	.	.	.	76	.	.	.	.	.	.	.	.	9	6	5	.	.	.	.	+	.	2	.	+	.	.	1
75 Lossiemouth	.	.	.	.	4	62	.	.	.	.	.	.	.	.	8	5	9	4	.	+	.	.	.	.	.	.	.	.	9
76 Sgrew Bay (West)	.	.	.	.	18	18	.	4	.	.	.	.	.	.	.	18	.	4	.	26	4	.	.	.	.	.	.	.	8
78 Sgrew Bay (East)	.	.	.	.	.	83	.	.	.	.	4	.	.	.	4	4	.	.	.	.	4	.	.	.	.	.	.	.	.
80 Strathbeg	.	.	.	.	3	5	.	.	3	.	.	.	3	14	13	14	22	.	.	19	.	.	.	.	2	.	.	2	2
83 Forvie	.	2	.	7	.	64	.	.	.	.	.	.	.	.	5	6	15	.	.	.	.	.	.	.	.	.	.	.	1
84 Don to Ythan	.	2	.	.	2	40	.	.	.	.	.	.	.	.	11	11	32	.	.	.	2	.	.	.	.	.	.	.	2
86 St. Cyrus and Montrose	.	.	.	3	.	62	.	.	.	.	.	.	.	.	8	22	.	.	.	.	.	.	.	3	.	.	.	3	.
89 Barry Links	.	.	.	9	1	56	.	.	3	.	.	1	.	.	17	4	4	.	.	3	2	.	.	.	.	.	.	.	1
90 Tentsmuir	.	.	1	13	5	40	.	.	.	.	.	.	.	.	21	8	4	1	.	4	.	3	.	.	.	.	.	.	.
MEANS	+	1	+	3	3	53	+	1	1	0	1	+	+	1	11	10	8	1	0	4	1	+	+	+	+	+	+	+	2

SITE CLASS NO.- 14	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1	B
77 Sgrew Bay (Central)	.	.	.	.	.	3	.	.	.	.	8	3	.	.	.	60	.	.	.	1	5	.	5	1	2	.	.	.	9
MEANS	0	0	0	0	0	3	0	0	0	0	8	3	0	0	0	60	0	0	0	1	5	0	5	1	2	0	0	0	9

SITE CLASS NO.- 11	P2	P3	P1	G4	G7	G3	G6	G2	G1	G5	D6	D5	D4	D1	D2	D3	C	M3	M4	M2	M1	F1	F2	S5	S4	S3	S2	S1	B
46 Tong	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	.	.	27	10
MEANS	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	27	10

common). Slightly acid dune grassland D2 is the converse of D1, with ST1=+, ST2=+, ST4=2%, ST3=10%, ST6=0%, ST5=4%, ST7=1%, ST8=5%, ST12=17%, ST13=20%, ST10=6%, and ST9=11%. These distributions clearly reflect the initial west and north versus east split in the site classification and this type of geographical distribution has already been noted for a number of vegetation types (see Section 7).

Some of the Grassland family of vegetation types show similar types of distribution. For example, slightly acid, damp grassland G1 also has a western and northern distribution but reaches its peak in the lower half of the first part of the table - ST1=13%, ST2=7%, ST4=14%, ST3=7%, ST6=10%, ST5=15%, ST7=19%, ST8=28%, ST12=1%, ST13=0%, ST10=4%, (western again) and ST9=1%. Wet, slightly acid dune grassland D5 behaves in a similar manner to G1. Acid, dry grassland G3 is the converse of G1, being most frequent in the second part of the table - ST1=+, ST2=0%, ST4=1%, ST3=1%, ST6=4%, ST5=2%, ST7=0%, ST8=5%, ST12=1%, ST13=6%, ST10=12% and ST9=53%.

Most of the other vegetation types are either too rare to draw any firm conclusion or they are limited to just a few site types where they occur with high frequencies. A good example of this type is transitional peat bog P1, which is common in ST5 (7%), ST7 (10%) and ST8 (5%), on the negative side of the hierarchy, and again in ST10 (18%) on the positive side. Wet peat bog P2 is even more extreme, being virtually limited to ST10 (14%). The Saltmarsh family tends to be fairly well scattered over the table (particularly the common upper saltmarsh S4) but ST13 - East Coast, Firth type, contains a marked concentration (S1=13%, S2=3%, S3=4%, S4=9% and S5=1%). Slightly acid, wet grassland G6 is mainly associated with one site type, ST1, with 7% (and to a lesser extent with ST5=4%). This vegetation type is strongly linked with the presence of water bodies (loch, marsh, stream or drainage channel) in the site. Finally, very acid, damp grassland G4 is limited to just one site type, ST9, with 3% of quadrats.

The relative proportions of the different vegetation types within a site constitutes quite a good, simple summary for that site - a sort of "vegetative profile". In this context, it is revealing to compare the individual site profile with the type profile, i.e. the means for the site type. From this it is possible to assess the typicality of a site within the site type to which it has been allocated. For example, Achnahaird can be immediately identified as the "odd man out" in ST1 through the observation that it only has 15% of D1 (compared with a mean for the type of 52%). The nature of the deviation can also be judged from the type and proportion of the vegetation types that make up the difference. In the case of Achnahaird, there is 11% of P1 (mean 1%), 22% of G1 (mean 13%), 15% of S4 (mean 3%) and 7% of S1 (mean 1%). Stilligarry (North) is another anomolous site in ST1 and its character can also be judged from its vegetation type profile. Similarly in ST9, Strathbeg may be picked out as being a rather odd site by having only 5% of G3 (mean 53%), the difference being made up over a number of vegetation types but particularly D1 with 14% (mean 1%), C with 22% (mean 8%) and M2 with 19% (mean 4%). Spey Bay (West) is another site that differs somewhat from the profile for ST9, with an above average amount of M2, whereas Spey Bay (East) can be seen as a rather monotonous member of ST9, with 83% of G3 and little else. The relationship between site and vegetation types will be discussed in more detail in the Site Type Descriptions (Section 8.4).

8.3.4 Site Boundaries

Some of the problems arising from the definition of the site boundaries have been discussed in Section 5.2. The question remains as to how far the boundaries affect the classification of the sites. As a broad generalization, the early stages of the site classification seem to be determined by climate and other geographically linked factors, e.g. sand type and land-use, but it is suspected that some of the lower divisions might have been slightly different if the site boundaries could have included the whole area of blown sand. Similarly, the boundaries of other sites have strayed beyond the limits of the blown sand and this has undoubtedly had some effect on the lower levels of division in the site classification. It is possible to investigate the effects of site boundary by:

i) excluding selected quadrats from the analysis, i.e. those samples that show no evidence of being on blown sand; and
ii) re-surveying sites to include the full extent of blown sand.

It would then be necessary to re-classify on the basis of the revised data. The first of the data modifications, exclusion of quadrats not on blown sand, is quite feasible (the soil data can supply that information - see Handbook of Field Methods) but the second, surveying the full extent of the sand, would be not only time consuming but, in many cases, would be near impossible. In a high proportion of sites where the full extent of blown sand has not been sampled there are good reasons. Often parts of the site are under a golf course or forestry plantation, in which case some relics of the original semi-natural vegetation may remain, but in other cases it has been totally destroyed by intensive agriculture or industrial development. In the light of these arguments, there is little alternative but to accept the boundaries of the sites as they have been defined. In most cases the site is the practical unit with which conservation is concerned and some "artificial", i.e. non-ecological, effects on the site classification must be accepted. It is, however, useful to consider which sites and site types have been most affected and in what way.

The site types with truncated dune systems are obvious candidates for investigation. ST3 - North and West Coast, truncated type, is a collection of sites from west and north facing coasts, with a wide geographical spread. In most cases, part of the dune system was not surveyed: Machrihanish contains an airfield and golf course; at Sanna the landward boundary is the road and not the limit of blown sand; at Calgary 17% of quadrats were lost through being on cultivated ground and most of the landward part was disturbed by agriculture; at Reay there is a golf course on most of the site; and at Fraserburgh the landward parts are cut off by the railway and have been converted into a golf course or are intensively used for agriculture. However, in the case of Kilchoman Dunes on Islay and Freswick in Caithness, as far as can be judged from the maps, the sites contain all the blown sand. These two sites seem to have been included in an otherwise truncated site type because they have remained rather immature, i.e. unstable, with 80% or more of the vegetation in the Duneland family (see Table 4).

A similar picture emerges on examining ST12 - East Coast, truncated type. Several of these sites have lost their hinterland but a few are complete in terms of the blown sand complement and, again, this has remained immature, e.g. St Fergus and Arbroath. The others have had their blown sand areas used for agriculture or converted to golf courses.

The East Coast, Firth type (ST13) is interesting because of the nature of the truncation. In the northern Moray Firth group, sites tend to be limited in depth by spit development, although a large proportion of the area of blown sand at Culbin is now under forest. Golf courses have taken parts of the sites located on the Firth of Forth, leaving only a narrow dune area or making this habitat a higher proportion of the site.

One can speculate that had the area of blown sand to the north of the site at Sandwood been included in the area surveyed, the site might have been classified with Bettyhill in ST8 rather than ST10. The area to the north of the existing site has sand blown up on to the hill and this area contains populations of Dryas octopetala and other montane species growing close to sea level, thus making it topographically similar to Bettyhill.

The sites and site types that could have been modified by the choice of site boundary are in the minority in relation to the total of 94 sites. In general, the boundaries have been satisfactory for the majority of sites and only very few sites are suspected of having been biased in their allocation to a site type, i.e. they would be a better fit in an alternative type. Should the need arise, additional areas could be surveyed and the site re-classified using the existing site key. In the majority of cases, the boundary is the most practical and realistic one from a nature conservation view-point and information on industrial sites, airfields and golf courses is not relevant.

8.3.5 Landforms

The influence of landform on the vegetation is most clearly demonstrated in the case of ST11 and ST14. Each of these site types comprises a single site. In the case of ST11, Tong is situated exclusively on inter-tidal flats which support little more than saltmarsh vegetation types. ST14, Spey Bay (Central), has developed on river deposited shingles and is frequently disturbed by spate conditions. Neither site is like any other in the sample of 94. Saltmarsh, which always occupies a characteristic landform, also plays an important part in the determination of ST13 - East Coast, Firth type. Curiously, the active saltmarsh development at Morrich More (ST10) has not been important in the classification of this site and the acidic hinterland, which is atypical of the rather truncated or immature ST13, has proved to be dominant in the analysis, presumably because the species associated with this habitat are numerically dominant in the site data.

Elsewhere the picture is not so clear. In ST1 - West Coast, Hebridean, Machair type, the junction between the blown sand and the "blackland" is usually marked by lochs and marshes which are not present in ST2. Nevertheless, it is believed that other factors, such as land-use, may be at least as important in separating the two site types. There is no information in the data collected that can be used to investigate the subtleties of the effects of raised beach deposits, or how adjacent cliffed coast affects a site. The sites on the raised shingle beaches around the Moray Firth have been allocated to ST9 - East Coast, Main type, but so have many other sites further south on the east coast. Raised beaches and "fossil" cliffs are found further south but not shingle beaches. The lack of active dune formation in ST1 and the presence of spits in ST13 seem to have influenced the types of vegetation found there, and, hence, have played a role in determining the site classification. It is not evident in the rest of the site classification that landform has had any special effect that can be singled out for attention. There remains, however, the general effects of landform on such factors as the distribution of blown sand, pedogenesis, drainage, local modification of climate, e.g. shelter, and land-use.

8.3.6 Climate

Many data concerned with climatic factors were extracted and examined in an investigation of the relationships between climate and the site classification. Most of these were simple averages for the various sites and, as such, were not easily interpreted. More sophisticated analysis of these data has not been attempted to date. The three volumes of "The Assessment of Climatic Conditions in Scotland " (Birse and Dry, 1970; Birse and Robertson, 1970; Birse, 1971) have proved most useful, as they bring together various measures of climate as composite variables. The climatic factors that have been used in these publications have been deliberately chosen to relate to plant growth but are obviously important in virtually all biological activity. They are also relevant to soil development. The maps published with the books have been used to locate the 94 sites in relation to climatic regimes displayed on them.

The first map depicts the distribution of accumulated temperature and potential water deficit. The threshold for the integrated temperature is 5.6 degrees C, which is approximately the temperature at which plant growth commences. The map thus plots two essential factors for plant growth, warmth and moisture combined. Certain general features are noteworthy in relation to the coastal survey. The south-western coast is shown as warm and moist, whilst the north-western coast is wet and cooler. Shetland is moist and cool and Orkney is fairly warm and somewhat drier. Most of the east coast is fairly warm and dry, with the shores of the Moray Firth and Firth of Forth being the warmest and driest.

The map in the second volume is concerned with exposure and accumulated frost. Exposure is based on five categories of wind speed and accumulated frost is derived in a similar way to accumulated temperature, except that the degrees of frost are accumulated below a threshold of 0 degrees C. The very exposed coasts of the Hebridean Islands, the west and north mainland and the Northern Isles contrast with more sheltered east coast sites. This division corresponds well with the first division of the site classification. All the coasts of Scotland, as opposed to further inland, are subject to mild winters with less than 20 day degrees C of frost.

The third map in the series is an attempt to draw up a scheme of bio-climatic sub-regions for Scotland. If the climatic factors on the first two maps are combined, they give quite a useful assessment of climate on a local basis. However, the third map has been prepared to give a broader view and eliminate the local effects. This map has been constructed in terms of: 1. thermal zonation from north to south and from low to high altitude; 2. oceanicity, taking into account the influence of large areas of sea; and 3. a measure of moisture status based on Penman's formula for evapotranspiration.

The first division of the site classification separates most of the sites on the west and north coasts from those on the east coast, from the Moray Firth southwards. There is a remarkable coincidence between this division and the Oceanicity sub-sectors of Birse (1971). The west and north coasts and the Northern Isles are in sub-sector 01 - Hyperoceanic. Fraserburgh on the east coast also falls in this sector, as does part of Morrich More. The east coast sites, on the positive side of the first division of the site classification, fall into sub-sector 02 - Euoceanic. Although these sub-sectors are derived from a combination of climatic factors, one of the more important ones seems to be temperature. The Oceanicity sub-sectors have been established on "thermal criteria alone" (Birse, 1971). The Hyperoceanic sub-sector has less than 50 day degrees C of accumulated frost and Euoceanic between 50 and 110.

Dealing now with the eight sites that apparently conflict with the above climatic trends, Tong on Lewis is such a peculiar site that no real conclusion can be drawn. As the dominant environmental factor in saltmarsh is periodic inundation by saltwater, it is likely that this type of site responds less to general climate than do other more "terrestrial" sites. It has already been argued that ST11 initially cohabits with the eastern types because of the predominant saltmarsh influence. Six of the remaining sites are allocated to ST10 - West Coast, acid, dwarf shrub type, along with Morrich More on the east coast. This is considered to be a fundamentally western site type, in which the inclusion or development of peaty habitats within what is otherwise a fairly typical western site, i.e. if the peaty vegetation types were ignored the site would move to the negative side of the classification, is the crucial factor. In this context, it is interesting to note that Morrich More is just within the Hyperoceanic (01) sub-sector, i.e. the same as the western members of ST10. The remaining western site that has been allocated to the eastern group is Torrs Warren. This site is a member of ST9 - East Coast, Main type, in which it is quite comformable. This is probably an example in which the effect of sand type (there is virtually no free calcium carbonate in the sand at Torrs Warren = 0.1%) has overridden that of climate.

As was discussed earlier (Section 8.2), Fraserburgh on the coast of the Buchan district is included in the Hyperoceanic sub-sector (01). The boundary between the two sub-sectors just clips the coast in this region. It includes Fraserburgh but not the coast to the south where Strathbeg and St Fergus are located. However, the effect of climate is confounded by that of sand type because there are raised levels of free calcium carbonate in the sites in this area. The overall conclusion is that sand type is probably more important in determining the affinities of the sites in this instance.

Subsequent divisions of the site classification do not show any clear-cut relationships with the climate data available. It is tempting to suggest that the 14 sites on the positive side of division 2/1 are possibly linked to a more boreal climate associated with the proximity of the mountains in Sutherland. However, all these sites contain areas of peat which can be explained in terms of more local factors, e.g. the position of the site boundary and landform.

8.3.7 Land-use

The first division of the site classification, besides reflecting the climatic trends around the Scottish coast, also approximates to a major difference in land-use. This is the difference between the traditional crofting system to be found in the Hebrides and on north and west coasts, and more conventional agriculture and recreational uses on the east coast.

On the Outer Hebrides, the differentiation of the two main site types, ST1 - West Coast, Hebridean, Machair type (with 13 sites) and ST2 - West Coast, Hebridean, dune type (with 20 sites), is thought to be due, at least in part, to differences in the crofting system as practised on North and South Uist (with ST1) as compared with that on the rest of the islands (with ST2). In ST1, signs of recent or old cultivation was recorded from 25.2% of quadrats and this may be compared with 5.1% in ST2. Similarly, the number of quadrats that had to be abandoned in the course of the survey because they were located in a standing crop of some type, i.e. that might be damaged by survey, was 245 quadrats in the 14 sites in ST1 or a mean of 17.5 quadrats per site. Equivalent figures for ST2 (20 sites) are 37 quadrats or 1.9 quadrats per site. There are also less marked differences in sheep grazing between the two types, 22.7% in ST1 and 48.5% in ST2, i.e. more than twice as much. Records for cattle (66.9% and 54.2%) and rabbit (56.5% and 54.2%) are more closely similar but the estimates of grazing intensity show that there is greater pressure from this factor in ST2 (45.7% moderately or heavily grazed as compared with 35.1% in ST1).

The land within the Hebridean sites is held in common by the crofters in a given township. Similar arrangements apply to sites on the west and north coasts of the mainland, where there is common grazing and a rotation of areas that are brought into periodic cultivation, but not in quite the same way or to the same extent as on the Outer Hebrides. The traditional system has declined even further on Orkney and Shetland, where areas of common have been divided between the crofters and fenced to control stock. The result is an agricultural system that is more akin to modern farming than to crofting.

By contrast, on the east coast the farmers take what land can profitably be used into the farming system fencing out the delicate mobile dunes, which are left untended, but may be used for casual grazing or recreation.

This division into farming on east coast and crofting in the north and west of Scotland closely follows the major divisions of the site classification and the climate matches both. It seems reasonable to assume that climate has the more dominant role in determining the vegetation and that the type of agricultural practice has also developed in response to the climate. However, sand type is certainly an important additional factor, with the base-rich, shell sand in the west and north and the mainly siliceous sands in the east, i.e. the same distribution as climate and farming. The fact that shell sands are inherently more fertile may have an important bearing on the traditional land-uses. Subsequently, this pattern has been modified by social and economic factors, particularly in recent times.

Other uses to which dune systems are put do not seem to have had much effect on the site classification. Car parks, caravan and camping sites and other intensive recreational uses have a detrimental effect on the vegetation generally. Where the dunes have been taken over for ball games, e.g. football pitches, the semi-natural vegetation has often been replaced with an even more artificial, seeded turf. Golf courses were excluded from the survey, but large areas of semi-natural vegetation are left in the rough and fairways. If it had been possible to sample golf courses, one would expect them to fit into the classification reasonably well. In some cases, e.g. Cruden Bay, the exclusion of the golf course reduced the site to the seaward dunes only. In this respect, the presence of a golf course may have modified the site classification, giving rise, for example, to ST12 which is largely composed of truncated sites.

In general, forestry plantations were excluded from the survey. However, some small areas under this land-use were included (mainly sites surveyed in the first year). The ground flora of these samples seems to have retained its essential features, despite the imposition of a canopy of mainly coniferous trees, so the site classification is not apparently deflected.

It has not been possible to determine any influence on the site classification due to a site, or part thereof, being used by the Ministry of Defence as a range or training area. Torrs Warren has been a range since the late 1930's and had apparently not been burnt during that period (part has been burnt since the survey). As a result, the heather on this site was up to a metre high. If a different use had been made of the site, e.g. troop training, it might have been burnt more frequently. A rifle range on the Don to Ytham coast had been burnt by a flare used on an exercise shortly before it was surveyed. However, it was such a small burnt area in relation to the rest of the site that the effect was not detectable.

A few sites, both on the west and east coasts, contain an aircraft landing strip but there are no obvious differences in the vegetation due to this use and their presence is not thought to have had any effect on the site classification.

In conclusion, the major effect of land-use on the site classification would seem to be a negative one, i.e. it is not the effect of land-use on the samples that were recorded that matters but the fact that land-use affected what was actually sampled. As already noted, certain land-uses disbarred areas from inclusion within the site, e.g. golf courses, forestry plantations, most enclosed agricultural land and industrial developments. The most serious effects of these exclusions are felt on the east coast where there is a tendency for all the "useful" land to be taken up for other purposes, leaving only the less stable dune areas. In fact, many sites were not even included in the survey because of this effect, i.e. there was too little semi-natural habitat left to make it worth surveying. The most notable area, where there is soft coast but there are no sites in the survey, is south-west Scotland. In Ayrshire, all the soft coast seems to be occupied by golf courses that extend right up to the coast, so that there is not even a fringe of semi-natural vegetation left.

In cases where part of a site had to be excluded due to land-use, the effect is usually selective, reducing the proportion of certain habitats and increasing the apparent frequency of others, i.e. a bias is introduced. On the west and north coasts, where the sites are more or less intact and cover the full extent of blown sand, the bias is minimal. However, the abandonment of quadrats due to the presence of a standing crop may have had an effect in some cases (see ST1 above). By contrast, on the east coast, land-use may introduce a serious bias. Tentsmuir, with a total area of blown sand about twice as large as that surveyed, is a good example of what can happen. Half the site has been excluded because it is under forestry plantation and it is impossible to know if this is a more or less random loss or whether it is selective. Fortunately, at Tentsmuir, there were strips of land running into the hinterland that were under agriculture but could be surveyed (large paddocks of rough grazing). Had these areas not been included within the site, Tentsmuir would probably have been allocated to ST12 - East Coast, truncated type, whereas it was actually allocated to ST9 - East Coast, Main type, where it conforms quite well.

8.3.8 Soil Types

The interpretation of the site classification in terms of the soil types, follows the same lines as that for the vegetation classification. Details of the soil classification, with 33 types and series akin to the vegetation type families, e.g. Deep Sandy Soils, Peaty Soils, etc., are given in Section 9. Table 5 (analogous to Table 4) shows the proportion of soil types by site and site types. Ordering of the soil types across the top of the table is again approximately according to the diagonal between the first and second axes of an ordination of soil types (NS means not sampled). Sites and sites types are in the same order as for Table 4. The first page of the table is devoted to ST1-8 and the second page to ST9-14.

The overall distribution of soil types shows many of the general features which were discussed in relation to the vegetation types. For example, the very common Deep Sandy Soil, DS6 (with 1109 quadrats, 29.6%), has a fairly well marked west and north versus east distribution: ST1=42%, ST2=45%, ST4=53%, ST3=28%, ST6=14%, ST5=31%, ST7=14%, ST8=21% (end of negative side of site classification), ST12=7%, ST13=22%, ST10=15% and ST9=17%. The other common Deep Sandy Soil, DS5 (with 811 quadrats or 21.6%), is more generally distributed but with slightly increased levels in the positive side of the site classification: ST1=15%, ST2=14%, ST4 =22%, ST3=33%, ST6=21%, ST5=17%, ST7=13%, ST8=10%, ST12=56%, ST13=21%, ST10=20% and ST9=30%. Some site types are characterized by Peaty Soils, e.g. ST7 (PS1=1%, PS2=10%, PS3=3%, PS4=7% and PS5=10%, or a total of 31%) and ST10 (PS1=2%, PS2=4%, PS3=1%, PS4=9% and PS5=5%, or a total of 21%).

TABLE 5. - TWO-WAY TABLE OF SOIL TYPES (%) IN SITES AND SITE CLASSES

SITE CLASSES SITE NAMES — SOIL TYPES (% in site)

SITE CLASS NO.- 1	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
21 Daliburgh	.	.	.	.	.	.	2	.	.	.	.	6	.	.	42	30	.	6	.	.	.	.	.	.	.	4	8	.	.	.	.	4	.	.
22 Ormiclate	.	4	.	.	.	.	.	.	2	.	.	2	.	.	48	24	.	9	.	4	.	.	.	.	.	.	4	.	.	.	2	.	.	.
23 Howbeg	.	.	.	5	.	.	.	.	.	.	.	10	.	.	38	10	.	10	.	.	.	.	.	.	.	.	5	5	.	.	.	19	.	.
24 Stilligarry (North)	.	3	.	.	.	3	.	.	.	.	.	3	.	.	17	21	.	10	.	.	.	.	.	21	.	.	14	.	.	.	.	7	.	.
25 Loch Bee	.	.	.	.	.	.	.	.	1	.	.	.	.	.	8	20	.	13	.	1	.	.	.	6	2	4	12	2	.	6	1	21	1	.
26 Borve	.	.	.	.	.	4	.	.	.	.	.	.	4	.	.	63	.	26	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.
27 Stilligarry (South)	.	+	+	1	.	.	.	1	.	.	.	1	+	.	.	48	.	8	.	.	+	.	11	.	.	4	11	1	.	4	8	.	4	.
28 Baleshare	.	2	.	.	.	2	.	.	.	.	.	.	.	.	37	34	.	9	.	.	.	.	.	2	.	2	.	.	.	.	.	12	.	.
31 Paible	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.	75	.	.	.	.	.	.	.	6	6	.	.	.	.	6	.	.	.	.
32 Hosta	.	.	.	.	.	.	.	.	7	.	.	.	17	3	.	41	.	3	3	.	.	.	.	.	.	.	7	.	.	10	7	.	.	.
34 Leathann	.	.	.	.	.	.	.	.	.	.	.	.	14	.	.	80	.	.	.	.	.	.	.	.	.	.	6	.	.	.	.	.	.	.
35 Balranald	.	1	.	.	.	.	.	.	7	.	.	5	7	.	.	57	.	.	+	2	.	2	.	.	.	1	8	.	4	.	4	.	4	.
52 Achnahaird	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	41	.	11	.	.	.	.	.	4	.	.	.	.	.	.	4	22	7	.
MEANS	0	1	+	+	0	1	+	+	1	0	0	3	3	+	15	42	0	8	+	1	+	+	1	3	1	1	6	1	+	2	2	7	1	0

SITE CLASS NO.- 2	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
12 West Tiree	.	.	.	.	.	.	.	2	3	.	.	.	.	.	4	63	1	10	.	.	.	.	.	1	.	.	1	4	2	5	1	2	.	.
13 Ballevullin	.	.	.	.	.	.	.	.	.	.	.	.	3	.	3	70	.	11	.	.	.	.	.	.	.	.	3	8	.	.	.	.	3	.
14 Hynish Bay	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	74	.	15	.	.	.	.	.	.	.	.	.	6	.	.	.	.	.	.
16 Totamore Dunes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	67	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.
18 Vatersay	.	.	.	.	3	.	.	.	.	.	.	13	3	.	27	30	.	10	.	.	.	.	.	.	.	.	3	7	.	.	.	3	.	.
19 West Barra	.	.	.	3	.	.	.	3	3	.	.	3	5	.	11	47	.	5	.	.	.	.	3	.	.	3	.	16	.	.	.	.	.	.
20 North Barra	.	.	.	.	.	.	.	.	.	.	.	2	2	.	44	18	.	24	.	.	.	.	2	.	.	.	.	4	.	.	2	.	.	.
29 Kirkibost	.	.	.	.	.	.	.	.	.	.	.	.	.	.	36	39	.	11	.	.	.	.	.	4	.	.	.	.	.	.	.	7	4	.
30 Monach Isles	.	2	.	.	.	.	.	.	.	.	.	5	.	.	7	70	.	.	.	.	.	5	7	.	.	.	.	2	.	.	.	.	.	.
33 Valley	.	.	6	.	.	.	.	.	.	.	.	3	.	.	34	25	.	19	.	.	.	.	.	.	.	.	3	.	3	3	3	.	.	.
36 Robach	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8	59	.	18	.	.	.	.	3	3	.	3	5	.	.	.	.	.	3	.
37 Berneray	.	.	.	.	.	.	.	.	.	.	.	.	.	.	27	43	.	10	.	.	.	.	2	8	.	.	3	.	.	2	.	5	.	.
39 Northton	.	.	.	.	.	.	.	3	.	.	.	.	18	.	8	29	.	.	.	.	.	.	3	11	3	3	8	.	.	13	.	3	.	.
40 Luskintyre	.	.	.	.	.	.	.	.	.	.	.	6	16	.	6	35	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	19	10	.
41 Uig	.	.	.	.	.	.	.	.	.	3	.	.	7	.	3	33	.	23	3	.	.	.	3	.	.	.	.	.	.	10	3	.	10	.
42 Valtos	.	.	.	.	.	.	.	.	.	.	.	.	8	.	4	54	.	19	.	.	.	.	.	.	.	.	.	.	.	4	.	8	4	.
43 Barvas	.	.	.	.	.	.	.	.	7	.	.	.	7	.	3	40	.	27	3	.	.	.	.	.	.	3	.	.	.	.	.	3	7	.
44 Europie	.	.	.	.	.	.	.	.	.	.	.	.	7	.	3	47	.	10	.	.	.	.	.	.	.	3	7	3	.	7	10	.	3	.
45 Tolsta	.	.	.	.	.	.	.	.	3	.	.	.	10	.	7	17	.	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.
49 Breckin	.	.	.	.	.	.	.	4	.	.	.	.	.	4	7	44	.	4	.	.	.	.	7	.	.	4	4	.	4	15	4	.	.	.
MEANS	0	+	+	+	+	0	0	1	1	+	0	2	4	+	14	45	+	14	+	0	0	+	2	1	+	1	2	3	+	3	1	3	3	0

SITE CLASS NO.- 4	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
47 Quendale	.	.	.	.	.	.	.	.	3	.	.	.	.	.	3	83	.	9	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.
48 Scousburgh	.	.	.	.	3	.	.	3	.	.	.	.	.	.	17	60	3	10	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.
51 Holland	.	.	.	.	.	.	.	.	.	.	.	6	.	.	32	42	.	10	.	3	.	.	.	.	.	.	.	.	.	3	.	.	3	.
65 Sinclairs Bay	.	.	.	.	7	.	.	.	.	.	.	1	13	3	6	32	.	35	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.
73 Overbister	.	.	.	.	.	.	.	.	.	.	.	.	.	.	52	48	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MEANS	0	0	0	0	2	0	0	1	1	0	0	1	3	1	22	53	1	13	0	1	0	0	1	0	0	0	1	0	0	1	0	1	1	0

SITE CLASS NO.- 3	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
2 Machrihanish Dunes	.	+	.	.	1	.	.	4	.	.	.	5	.	10	36	36	.	8	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
4 Kilchoman Dunes	.	.	.	.	.	3	.	.	3	.	.	.	.	.	33	23	3	30	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.
10 Calgary Dunes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	44	.	20	.	.	.	4	.	.	.	.	.	.	.	32	.	.	.	.
11 Banne	.	.	.	.	.	.	.	.	.	.	10	10	7	3	30	30	.	3	.	.	.	.	.	.	.	.	.	7	.	.	.	.	.	.
61 Reay	.	.	.	.	.	3	.	.	.	.	11	.	.	4	48	17	.	4	.	.	1	.	3	.	1	.	4	.	.	3	.	.	.	.
63 Freswick	.	.	1	.	.	.	.	.	3	.	.	2	.	.	7	42	.	23	.	.	.	.	.	.	.	.	6	3	.	10	.	3	.	.
79 Fraserburgh	.	.	.	.	.	3	.	.	.	.	3	.	3	6	74	3	.	6	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.
MEANS	0	+	+	0	+	1	0	1	1	0	3	2	1	3	33	28	+	13	0	0	+	1	+	0	+	0	1	1	0	7	0	+	0	0

SITE CLASS NO.- 6	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
58 Farr Bay	.	.	.	.	.	.	.	.	.	.	.	.	.	14	26	26	4	12	.	.	.	.	4	.	.	.	2	1	.	7	.	4	.	.
60 Melvich	.	.	.	.	5	5	2	.	6	.	2	.	18	6	15	2	.	7	.	4	.	5	.	.	.	.	.	.	.	8	8	.	4	.
MEANS	0	0	0	0	3	3	1	0	3	0	1	0	9	10	21	14	2	10	0	2	0	3	2	0	0	0	1	1	0	8	4	2	2	0

SITE CLASS NO.- 5	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
5 Saligo Bay	.	.	.	.	.	.	.	.	.	.	.	.	3	3	57	3	3	20	.	.	.	.	.	.	.	.	3	3	.	.	.	3	.	.
6 Gruinart	.	.	.	.	.	.	.	.	1	.	.	1	1	7	30	21	6	15	.	1	.	.	.	.	.	.	.	.	1	4	1	6	1	.
15 Crossapol and Gunna	.	.	.	.	.	.	2	.	.	.	.	.	.	.	15	43	.	17	.	.	.	.	4	.	.	.	.	3	1	3	11	.	.	.
17 Gallanach	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	54	.	20	.	.	.	.	7	.	2	.	.	4	4	2	2	.	2	.
38 Pabbay	.	.	.	.	.	.	.	.	.	2	.	.	.	.	8	19	.	19	.	.	.	.	8	.	.	5	13	.	.	21	.	3	2	.
56 Faraid Head	.	.	.	.	.	.	.	.	.	.	.	.	.	13	.	40	.	13	.	.	.	.	.	.	.	3	.	+	.	17	10	.	3	.
62 Dunnet	.	.	.	.	.	+	.	.	.	.	.	.	1	1	4	36	.	48	.	.	.	.	.	.	.	.	6	.	.	4	.	.	.	.
MEANS	0	0	0	0	0	+	+	0	+	+	0	+	1	3	17	31	1	22	0	+	0	0	3	0	+	1	3	1	1	7	3	2	1	0

SITE CLASS NO.- 7	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
53 Oldshore More	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	23	.	15	1	.	.	.	7	.	.	.	9	2	4	16	7	5	5	.
54 Sheigra	.	.	+	.	.	.	.	.	.	.	.	.	4	9	.	2	.	30	.	.	.	.	.	.	1	8	5	.	.	7	8	.	26	.
59 Strathy	.	.	.	.	.	.	.	.	.	.	7	.	.	10	38	17	.	10	.	.	.	.	.	.	.	.	.	.	.	7	7	3	.	.
MEANS	0	0	+	0	0	0	0	0	0	0	2	0	1	8	13	14	0	18	+	0	0	0	2	0	+	3	5	1	1	10	7	3	10	0

SITE CLASS NO.- 8	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
55 Durness	.	.	.	.	.	.	.	3	3	.	.	.	.	.	7	23	3	43	.	3	.	3	.	.	.	.	.	.	3	3	3	.	.	.
57 Bettyhill	.	.	.	.	.	.	.	.	3	.	9	.	.	24	12	18	6	12	.	3	.	6	.	.	.	.	.	.	3	3	.	.	.	.
MEANS	0	0	0	0	0	0	0	2	3	0	5	0	0	12	10	21	5	28	0	3	0	5	0	0	0	0	0	0	3	3	2	0	0	0

(Table 5. cont.)

SITE CLASS NO.- 12	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
81 St. Fergus	.	.	.	.	.	.	.	.	.	.	12	.	2	16	65	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.
82 Cruden Bay	.	.	.	.	.	.	.	.	.	.	7	23	20	37	10	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.
87 Lunan Bay	.	.	.	.	.	.	.	.	.	.	.	.	.	.	79	21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
88 Arbroath	.	3	.	.	.	14	.	.	3	.	.	.	.	.	55	3	.	10	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.
91 Dumbarnie	.	.	.	.	.	.	3	.	3	.	.	.	.	.	59	14	.	17	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.
94 Yellowcraig	.	.	.	.	.	6	.	.	.	.	.	.	.	.	67	6	.	22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MEANS	0	1	0	0	0	3	1	0	1	0	3	4	4	9	56	7	0	9	0	2	0	0	0	0	0	1	0	0	0	1	0	0	0	0

SITE CLASS NO.- 13	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
68 Dornoch	.	.	.	.	.	.	.	.	.	.	3	.	1	43	13	25	.	16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
71 Whiteness	.	22	.	.	4	29	.	2	.	2	2	.	.	5	6	.	.	11	.	9	.	.	.	5	.	.	5	.	.	.	.	.	.	.
72 Culbin Bar	.	11	.	3	.	12	.	.	2	6	.	2	.	2	23	10	.	4	.	2	.	.	.	2	.	.	10	.	.	.	.	12	.	.
92 Aberlady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19	35	.	16	.	.	.	.	3	.	.	.	3	.	.	3	.	19	.	.
93 Gullane	.	.	.	.	.	.	.	.	.	.	.	.	.	5	46	30	.	10	1	.	1	1	.	.	.	.	.	.	.	7	.	.	.	.
95 Tyninghame	.	.	8	.	.	.	.	.	.	.	8	.	.	.	20	31	.	20	.	.	.	.	.	.	.	1	3	.	.	7	.	.	.	.
MEANS	0	6	1	1	1	7	0	+	+	1	2	+	+	9	21	22	0	13	+	2	+	+	1	1	0	+	4	0	0	3	0	5	0	0

SITE CLASS NO.- 10	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
3 Lassan Bay	.	.	.	.	.	.	.	2	2	.	.	.	.	5	17	21	.	10	.	.	.	.	.	.	.	.	.	.	.	.	29	.	14	.
7 Oronsay	.	.	.	.	.	.	.	.	.	.	.	2	.	.	35	14	2	5	2	.	.	2	16	.	.	.	.	7	.	5	2	2	5	.
8 Garvard	.	.	.	.	.	.	.	.	3	.	.	6	.	.	26	6	3	.	.	.	.	.	23	.	.	.	.	3	10	10	3	.	6	.
9 Kiloran Bay	.	.	.	.	.	3	.	.	.	.	.	.	6	9	42	9	.	.	3	.	.	3	3	.	.	.	.	3	3	6	9	.	.	.
50 Redpoint	.	.	+	+	.	.	.	.	.	.	.	.	.	.	20	26	.	7	.	2	.	.	.	.	4	.	6	1	.	4	18	7	5	.
64 Sandwood	.	.	.	.	.	.	.	.	.	.	.	.	1	17	+	29	.	11	.	.	.	.	7	4	.	.	11	.	4	4	4	1	7	.
70 Morrich More	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	100
MEANS	0	0	+	+	0	+	0	+	1	0	0	1	1	4	20	15	1	5	1	+	0	1	7	1	1	0	2	2	2	4	9	1	5	14

SITE CLASS NO.- 9	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
1 Torrs Warren	.	.	.	.	.	.	.	1	1	.	.	.	.	2	.	49	.	31	.	.	.	.	.	2	.	5	5	.	.	2	1	1	.	1
66 Ferry Links	.	.	1	.	+	4	.	.	.	.	2	.	.	8	20	47	.	18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
67 Coul Links	.	.	.	.	1	7	.	1	3	.	3	.	1	9	38	19	.	11	.	3	.	.	.	.	.	.	+	.	.	+	.	3	.	.
69 Clashmore	.	.	.	.	1	13	.	.	1	.	3	.	7	.	36	6	7	20	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.
74 Findhorn	.	2	+	4	4	.	.	5	4	.	4	.	25	16	16	.	9	4	.	.	.	.	4	.	.	.	.	.	4	.	.	.	.	.
75 Lossiemouth	.	7	.	.	.	43	+	.	.	.	2	5	.	.	38	.	4	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
76 Spey Bay (West)	5	3	.	4	4	11	.	22	.	.	.	.	.	.	.	4	7	.	.	.	.	.	.	.	.	15	4	.	11	4	.	.	7	.
78 Spey Bay (East)	.	.	.	.	.	42	.	4	8	.	.	.	.	.	13	.	17	4	.	8	.	4	.	.	.	.	.	.	.	.	.	.	.	.
80 Strathbeg	.	.	.	.	.	3	.	.	.	.	14	.	3	13	36	2	.	9	.	.	.	.	.	.	.	.	2	.	.	.	6	2	11	.
83 Forvie	.	.	.	.	.	1	.	.	.	.	5	1	.	10	45	29	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.
84 Don to Ythan	.	.	.	.	.	.	.	.	.	.	4	2	.	18	49	19	.	5	.	.	.	.	.	2	.	.	2	.	.	.	.	.	.	.
86 St. Cyrus and Montrose	.	.	.	.	.	11	.	.	3	.	.	3	.	.	70	.	.	.	.	3	.	.	.	.	.	.	.	3	.	5	.	3	.	.
89 Barry Links	.	.	.	.	.	1	.	.	.	.	.	.	.	.	35	15	.	4	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	44
90 Tentsmuir	.	.	.	.	.	.	.	.	.	.	1	.	.	.	27	42	.	25	.	.	.	.	.	.	.	.	.	1	.	.	.	4	.	.
MEANS	+	1	+	1	1	10	+	2	1	0	3	1	3	5	30	17	3	10	0	2	0	+	+	+	0	2	1	+	1	1	1	1	1	3

SITE CLASS NO.- 14	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
77 Spey Bay (Centre)	.	14	.	.	.	37	.	.	.	.	.	.	.	.	13	9	3	5	.	7	.	.	.	.	.	2	3	.	.	.	5	.	1	.
MEANS	0	14	0	0	0	37	0	0	0	0	0	0	0	0	13	9	3	5	0	7	0	0	0	0	0	2	3	0	0	0	5	0	1	0

SITE CLASS NO.- 11	BD1	BD2	BD3	CS1	CS2	CS4	CS3	CS5	CS6	CS7	DS1	DS4	DS3	DS2	DS5	DS6	DS8	DS7	TS6	TS3	TS4	TS5	TS7	TS1	TS2	TS8	TS9	TS10	PS1	PS2	PS4	PS3	PS5	NS
46 Tong	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	17	.	.	.	.	.	.	.	.	.	3	7	.	.	3	.	10	57	.
MEANS	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	3	7	0	0	3	0	10	57	0

8.4 Site Type Descriptions

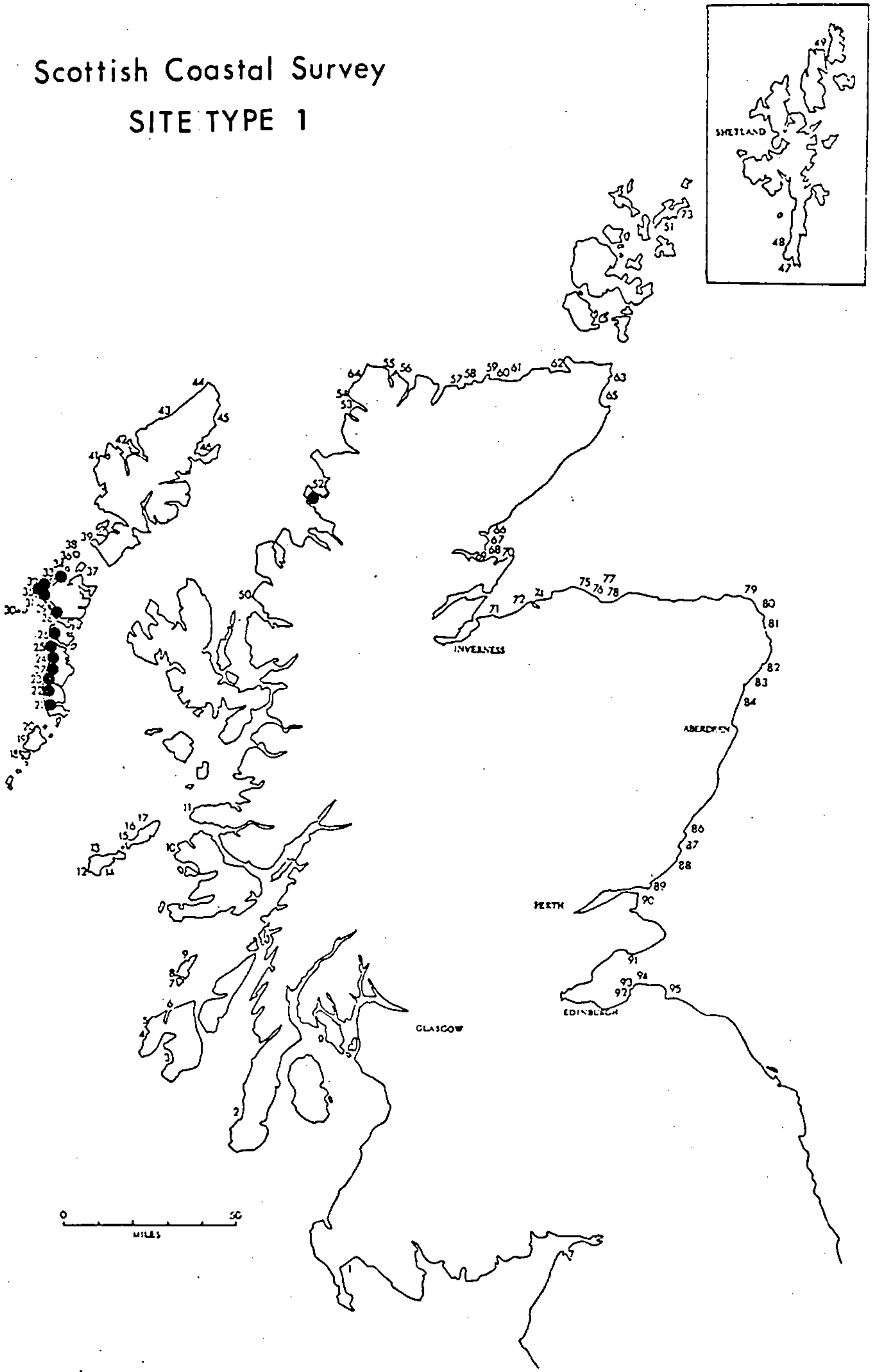
The following section contains site type descriptions for each of the fourteen site types. Each description starts on a new righthand page with a map of site distribution on the opposite (lefthand) page. The first part of the description takes the form of a table listing the site names (and survey numbers) along with the geographical region in which they occur and their area (ha). This table also serves as a key to the map where only the site numbers are shown.

The table is followed by a series of standard headings covering such matters as a general type description, relationship with other site types, vegetation types, vascular plants, cover, landforms, soil types, site boundaries and land-use. The first of these sub-sections - General Description and Relationship with other Site Types - attempts to characterize the site type being described according to its most salient features as well as comparing and contrasting it with other site types. The probable underlying causes of the differences between site types are also discussed under this heading. Some of the information in this opening sub-section is given in more detail under the specific headings. Wherever possible, comparisons between site types are retrospective, i.e. a given site type is compared and contrasted with ones that have already been described, but this has not been possible in all cases. Some attempt has also been made to draw attention to and illustrate by example the range of variation within a site type. Sites which are extreme in some feature, e.g. the relative proportion of vegetation or soil types which they contain, have usually been mentioned in context.

Finally, for further information on vegetation types within site types reference should be made to Table 4 (Section 8.3.3) and for soil types to Table 5 (Section 8.3.8). Tables listing preferential species for most of the inter-type comparisons are given in Section 8.3.2 and the indicator species which define the types can be found in the site type key (Section 8.6).

Scottish Coastal Survey

SITE TYPE 1



8.4.1 Site Type 1

Name - West Coast, Hebridean, Machair type

List of Sites in ST1

Site no. & name	Geographical region	Size (ha)
21 Daliburgh	Barra & Uists	512
22 Ormiclate	Barra & Uists	448
23 Howbeg	Barra & Uists	60
24 Stilligarry (North)	Barra & Uists	288
25 Loch Bee	Barra & Uists	752
26 Borve	Barra & Uists	160
27 Stilligary (South)	Barra & Uists	547
28 Baleshare	Barra & Uists	512
31 Paible	Barra & Uists	256
32 Hosta	Barra & Uists	192
34 Leathann	Barra & Uists	432
35 Balranald	Barra & Uists	524
52 Achnahaird	Wester Ross	80

General Description and Relationship with other Site Types

This type has 13 sites (13.8%) allocated it, with a mean area of 366ha and a range of 60-752ha. The type is characterized by having a narrow strip of Ammophila dune at the seaward edge. This is backed by a broad zone of short, herbaceous communities (the machair), eventually grading into wetter land at or near the inland boundary. The type is strongly associated with the crofting system as practiced on the Uists, on which islands all but one of the sites (Achnahaird on the north-western mainland) are located. ST1 is one of the best examples of a site type with a discrete geographical distribution. Periodic cultivation is an important influence (see below) and this factor is evidenced by an unusually high proportion of "weed" species in the flora, e.g. Avena spp., Erodium cicutarium, Geranium molle, Myosotis arvensis, Plantago major, Sagina procumbens, Stellaria media and Veronica arvensis (see also 8.3.2, step 8). As the name for the type suggests, ST1 is most similar to ST2 and the difference between the two types are discussed in the description of the latter. Other closely related site types are ST4 - Northern Isles type, and ST3 - North and West coast, truncated type, and these relationships will also be discussed in context.

Vegetation Types

The most important vegetation types in ST1 are base-rich dune grassland D1, with a mean frequency in the type of 52% of quadrats, and slightly acid, damp grassland G1 (13%). These two types form the main vegetation on the machair plain. Other quite common vegetation types are damp, base-rich dune grassland D4 (8%), slightly acid, wet grassland G6 (7%) and semi-stable dune grassland D3 (4%). The proportion of a given vegetation type varies a good deal from site to site (see Table 4). In the case of D1, the range is from 81% in Borve to 15% at Achnahaird. For ST1, there seems to be a varying balance in terms of quantity between D1, G1 and D4 and this is entirely consistent with the supposed successional relationships of these vegetation types (see Sections 7.4.3 and 7.4.4 and Figure 3). D4 is found in the wetter parts of the machair plain and the area occupied by this habitat is somewhat variable, e.g. 27% at Baleshare and 0% at Daliburgh, Howbeg and Achnahaird. Slightly acid, wet grassland G6 is found fringing wet areas further inland on the sites. It usually occurs in association with some definite features such as a marsh, stream or loch. The proportion of semi-stable dune grassland D3 (mean 4%) in the different sites is also rather variable, occupying 19% of the site at Paible but not being recorded at all at Daliburgh, Stilligarry (North) and Borve. All other vegetation types occur with a frequency of less than 4% but even these can be important in particular sites, e.g. P1 (mean 1%) but with 11% at Achnahaird, M2 (mean 3%) but with 11% at Ormiclate and Balranald and S4 (mean 3%) but with 13% at Paible and 15% at Achnahaird. It is evident from the above discussion, that Achnahaird, the only mainland site, is rather atypical of ST1, with only 15% of D1 but with compensating amounts of P1 (11%), S4 (15%) and S1 (7%). It does, however, contain the "core" vegetation types that define ST1. Ordination diagrams confirm that Achnahaird is an extreme example of its type.

Vascular Plants

ST1 is relatively species-rich, with a mean of 23.2 species per quadrat. A total of 35 species have a frequency of 20% or more, Festuca rubra (82.2%), Trifolium repens (81.9%), Plantago lanceolata (76.7%) and Bellis perennis (75.4%) being most common. Ammophila arenaria has a frequency of only 28.4%, reflecting the low proportion of active dune in these sites but, at Leathann, it does occur in 74% of quadrats. This rather more active site can be contrasted with Balranald with only 9% of Ammophila. The frequency of the commoner species is fairly uniform within the type but that for the disturbance species, associated with the agricultural activity, is quite variable, e.g. Veronica arvensis (0-51%, mean 20.1%), Myosotis arvensis (0-44%, mean 19.8%), Geranium molle (3-43%, mean 17.9%) and Sagina procumbens (0-40%, mean 16.6%). The only site that can be picked out as being rather different in terms of species frequency, is, again, Achnahaird. A number of relics from cultivation, such as cereals and Brassica species, were also quite commonly recorded in ST1.

Cover Types

Vascular plants were recorded in a mean of 98.5% of quadrats with a mean cover of 87.8%. The most important species contributing to this cover are Festuca rubra (17.3%), Trifolium repens (6.4%), Agrostis stolonifera (4.6%), Bellis perennis (3.6%), Potentilla anserina (3.6%), Ammophila arenaria (3.5%, despite occurring in only 28.4% of quadrats) and Carex nigra (3.2%). Ammophila achieves its highest cover at Paible (11%) and Leathann (9%) but can be as low as 0.5% at Balranald. Bryophytes occur in 83.1% of quadrats with mean cover of 8.8% and equivalent figures for lichens are 13.8% and 0.1%. The most important non-living cover category is bare sand, in 49.3% of quadrats and with mean cover of 9.5%. Freshwater was recorded in 7.2% of quadrats with a mean cover of 1.1%, this reflecting the wetter inland area that is included in most sites.

Landforms

The general form of the sites that comprise ST1 is a gently undulating coastal sandy plain extending inland to the peatland beyond. There may be a coastal dune, but it is not always present, and there is often a marsh or small loch at the junction between the sand and peat.

The general aspect of the sites, i.e. as measured from the map, shows that 75.3% of quadrats face west. However, in terms of local aspect, i.e. that measured on the ground, it appears that 63.8% of quadrats face either east or west. This is interpreted as meaning that the sites consist of low ridges running mainly north-south on a generally west facing slope. General aspect is determined by measurements of contours on the 6 inch map but the sites in ST1 have such low relief in relation to the contour interval as shown on the map that most samples are interpreted as facing the sea which nearly always lies to the west. Local aspect is that measured on the ground at the sample point using a compass and therefore reflects the topography at a smaller scale (not quite micro-topography but more like "meso-topography"). Most of the ground surface is plane (59.6%) or simple undulating (26.5%) and slopes are similar, with 50.2% under 1 degree and 42.0% in the 1-5 degree category. These figures reflect the relatively flat machair plain that occupies a high proportion of the area in most sites. As might be expected, the sites in ST1 are extremely low-lying, with 93.7% of their area under the 50ft contour and no quadrats over 150ft. Only Hosta (34.4%), Leathann (14.3%) and Achnahaird (33.3%) contain land over 50ft OD. The sites mostly extend a long way inland, with an average of 1.2% of quadrats being 1500m+ from the sea and with 4.0% in the 1000-1500m zone. Howbeg and Borve are the "shallowest" sites, with no quadrats further than 600m from HWMST. Most quadrats are located within 600m of the shore (83.5%) and the modal distance is 200-400m (22.2%).

Soil Types

The majority of soils in ST1 belong to the Deep Sandy Soil series. DS6 was recorded in 42% of quadrats and the similar, but drier, DS5 in 15%. Other Deep Sandy Soils, DS3 (3%), DS4 (3%) and DS7 (8%), are also present, giving total of 71% in this series. There is another quite important contribution from the Peaty Soils, PS1 (+) PS2 (2%), PS3 (7%), PS4 (2%) and PS5 (1%), giving a total of 12%. The peaty soils occur mostly near the inland boundary of sites, near to or beyond the limits of blown sand. The only other soil type contributing over 5% is TS9 (6%). This "soil" type is characterized by having the water table at or near to the surface at the time of sampling. Most of the soils in this type are, in fact, peaty and this is particularly true in the case of ST1 in which most examples occur in the more landward part of the sites. Other soil types which are present in just a few sites include the Beach Deposits, the Sandy Cobble Soils and most of the Thin Soil series, although only TS1 (3%) has a mean for the type of over 1%. Stilligarry (North), with 21% of TS1 (a highly organic or peat soil with high water table, 20-40cm), is worthy of note.

The balance of soil types in ST1 is quite varied, the biggest contrast being between sites that have predominantly sandy soils and those that contain quite a high proportion of peaty types. The most sandy sites are Borve, with 93% of soils in the Deep Sandy series and no peaty soils, and Leathann, with 94% of DS types and only 6% peaty (all TS9). At the other extreme, Loch Bee has only 41% of soils in the DS series, nearly all the remainder being peaty to some degree. Achnahaird is also quite peaty, with 62% of soils in the DS series and 33% in the PS series.

Boundaries

In general, the boundaries of the sites in ST1 are formed by natural rather than man-made features. Thus in South Uist, the sites extend inland to the "blackland". Laterally, however, they are subdivided rather arbitrarily by roads and other artificial features. Further north, and particularly in North Uist, the sites tend to be defined by other features. For example, Borve is bounded on the landward side by a tarmac road, which separates the site from the damp pastures around Loch Borve. Other sites are confined on the landward side by enclosed croftland, which usually occurs somewhere near the junction between the sand and the peaty "blackland". Achnahaird, on the mainland, follows a similar pattern of coastal sand backing on to peat covered land away from the sea, except that the site is bounded to the east by a shallow river estuary, hence the contribution from the Saltmarsh family of vegetation types.

Land-use

The sites in ST1 are heavily influenced by the crofting system of agriculture as practiced in the Outer Hebrides. An average of 27.1% of quadrats showed some signs of cultivation (4.9% recent and 22.2% old). In addition, a mean of 17.5 quadrats per site had to be abandoned because they were under active cultivation at the time of survey, i.e. there was a standing crop that would have been damaged by survey activities. Other features that give an insight into the agricultural regime are the grazing records - horse (1.6%), cattle (65.8%) and sheep (24.4%). The level of cattle grazing is very uniform across the type, with only Paible (38%) under 50%, the rest lie in the range 52-77%. The frequency of sheep is much more variable, with only 6% at Paible (a conspicuously lightly grazed site) to 57% at Daliburgh and 89% at Achnahaird. Rabbits were recorded in 60% of quadrats. Grazing intensity is recorded as being quite low in ST1, with 12.6% ungrazed, 52.3% lightly grazed, 13.2% moderately grazed and only 1.3% heavily grazed. It is interesting to note that no mole hills were recorded in any site in ST1. The most common man-made features were fence (3.6%), tarmac road (1.0%), dirt road (1.0%), vehicle track (12.5%, access by tractors and other agricultural equipment), unsurfaced path (1.2%), spent cartridge (2.8%) and rubbish (28.5%). Traces of birds (mean 20.1%) were recorded from all sites except Achnahaird. Some of the machair areas are important breeding grounds for coastal birds and 1.9% of quadrats were recorded as having nests in them. Aquatic habitats are quite variable within the type but are important in a few sites. Howbeg, Stilligarry (North) and Loch Bee are sites that are notable for containing water bodies of various types (about 20% of quadrats are affected). Paible has 13% of quadrats with saltmarsh pan or creek, which exactly ties up with the 13% of upper saltmarsh S4 found in this site.

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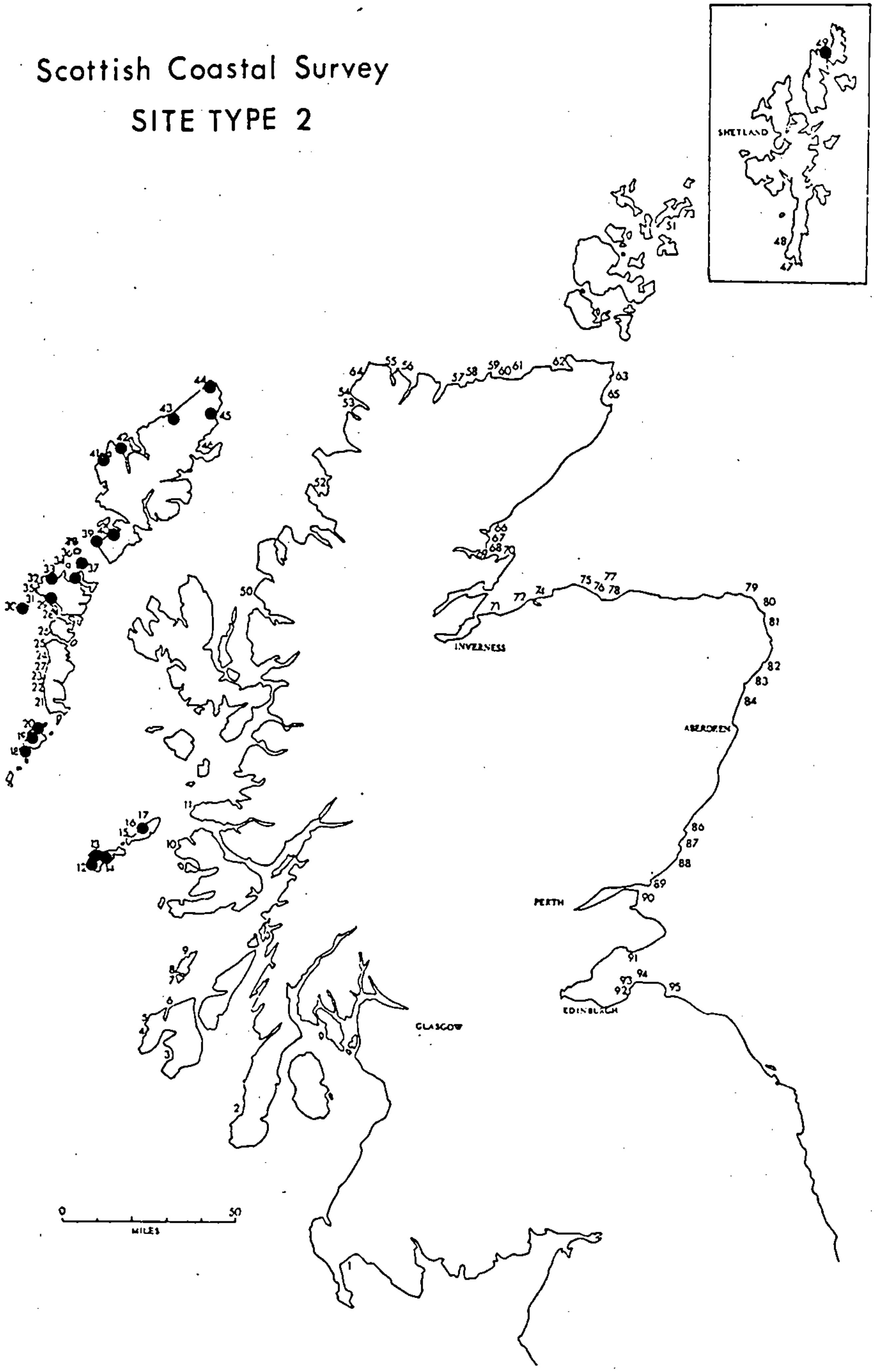
SITE TYPE 2



8.4.2 Site Type 2

Name - West Coast, Hebridean, dune type

List of Sites in ST2

Site no. and name	Geographical region	Size (ha)
12 West Tiree	*Tiree, etc.	816
13 Ballevullin	*Tiree, etc.	320
14 Hynish Bay	*Tiree, etc.	288
16 Totamore Dunes	*Tiree, etc.	144
18 Vatersay	Barra & Uists	80
19 West Barra	Barra & Uists	208
20 North Barra	Barra & Uists	240
29 Kirkibost	Barra & Uists	224
30 Monach Isles	Barra & Uists	336
33 Vallay	Barra & Uists	256
36 Robach	Barra & Uists	368
37 Berneray	Barra & Uists	544
39 Northton	Harris & Lewis	304
40 Luskentyre	Harris & Lewis	128
41 Uig	Harris & Lewis	96
42 Valtos	Harris & Lewis	128
43 Barvas	Harris & Lewis	240
44 Europie	Harris & Lewis	240
45 Tolsta	Harris & Lewis	96
49 Breckin	Shetland	62

*Tiree, Coll, Mull and Ardnamurchan

General Description and Relationship with other Site Types

This site type has 20 sites (21.3%) allocated to it with a mean area of 256ha (range 62-816ha). This is the most common site type in the survey. As the names suggest, ST2 is most similar to ST1, one of the most obvious differences being an increase in semi-stable habitats in ST2, i.e. there is more sand movement. This is reflected in the changed proportion of three vegetation types - bare ground B, with 1% in ST1 and 4% in ST2, colonizing communities C (2% and 3%) and semi-stable dune grassland D3 (4% and 6%). This is not a spectacular difference, but significant nevertheless, with totals of 7% for ST1 as compared with 13% for ST2. The different proportion of unstable vegetation types must be seen in the perspective that most of this habitat occurs within 200m of the sea (there may be a few blow-outs further inland). Because the sites in ST2 extend such a long way inland (see Landforms below), it is inevitable that the potentially unstable areas account for quite a small proportion of the whole site. Conversely, large areas are occupied by stable substrates that would require very drastic disturbance to become de-stabilized. The difference in stability between the two site types is also reflected in the frequency of Ammophila arenaria, 28.4% in ST1 as compared with 43.2% in ST2. However, it should be noted, that this difference does not qualify the species as being preferential (see Section 8.3.2, step 8) but the 2 to 1 ratio required for this status is just an arbitrary value. The cover of Ammophila arenaria, 3.5% in ST1 and 6.5% in ST2, confirms the nature of the difference.

There are also fewer wet habitats in ST2 as compared with ST1 and, in terms of vegetation types, this is reflected in frequency differences for slightly, acid, wet grassland G6 (2% in ST2 and 7% in ST1) and wet marsh M2 (1% and 3%). This difference is confirmed by a number of species and that preferential to ST2 and which are typical of wet areas or the marginal habitats associated with water bodies, e.g. Caltha palustris, Cardamine pratensis, Epilobium palustre, Eriophorum angustifolium, Galium palustre, Lychnis flos-cuculi and Polygonum amphibium (see list of preferential species in 8.3.2, step 8).

The disturbance of ST1 by agriculture has already been noted in the description of that type and many of the associated "weeds" are absent or have a lower frequency in ST2. Finally, the higher intensity of grazing in ST2 as compared with ST1 (the main cause probably being the higher proportion of sheep grazing) is reflected by an increase in a number of preferential species that are typical of closely grazed turf, e.g. Gentianella campestris, Helictotrichon pubescens and Koeleria cristata. This difference is, however, not particularly evident in the vegetation types which are not thought to descend to this level of detail, i.e. there are no lightly and heavily grazed facies of such common vegetation types as D1 and G1, although there is some evidence that they exist in practice. Small differences such as this may account for the observation (see Section 6.3) that a site classification based on 53 vegetation types (as opposed to the 29 that have been interpreted for this report) gave a result that was more closely comparable with that obtained using species frequency.

West Coast, Hebridean, dune type (ST2) is also closely related to site types ST4 and, to a lesser extent, ST3. These relationships will be discussed in context.

Vegetation Types

The profile of vegetation types for ST2 (see Table 4) is very similar to that for ST1. As already noted, one of the main differences is in the proportion of the less stable types B, C and D3, together totalling 13% in ST2 (cf. 7% in ST1). There is also a small but probably significant, increase in the most common vegetation type, base-rich dune grassland D1, up from 52% in ST1 to 58% in ST2 (and present in all sites in the type). In terms of individual sites, there is quite a range in the proportion of D1, from 33% at Berneray to 85% on the Monach Isles. The increase in D1 in ST2 seems to be balanced by a proportionate decrease in the frequency of the closely related slightly acid, damp grassland G1, 13% in ST1 but down to 7% in ST2. Whereas G1 is present in all sites in ST1, it is absent from five sites (25%) of ST2. The only other vegetation type that shows a quantitative difference between the two types is slightly acid, wet grassland G6, 7% in ST1 as compared with 2% in ST2. G6 is a borderline marsh vegetation type (see Section 7.4.4) which is known to be associated with water bodies of various types, e.g. stream, drainage channel, loch, etc., and the decreased proportion in ST2 probably reflects a reduction of this type of habitat in the site type.

A number of other vegetation types are present in ST2 but none achieve a mean frequency of more than 3% or occur in more than 50% of the sites in the type. Some do, however, form a significant proportion of individual sites, e.g. P1 with 10% at Barvas, G6 with 11% at Kirkibost, G2 with 19% at Breckin, M2 with 10% at Europie, M1 with 13% at Tolsta and S4 with 11% at Kirkibost and 26% at Luskentyre.

Comparing individual sites with the type profile, there are no deviations of the magnitude of Achnahaird in ST1. Hynish Bay is notable for having a higher proportion of G1 (21% compared with a mean of 7%), Vatersay is seen as a comparatively unstable site, with a total of 30% for B, C and D3 (cf. mean of 13%), and nearby West Barra is similar, with 25% of unstable vegetation types. As already noted, the Monach Isles are dominated by 85% of D1 (cf. mean 58%) with only four other vegetation types present in small amounts (the least diverse site in ST2), whereas Berneray has only 33% of D1 but this is made up by unusually high proportions of D4 (27% cf. mean 7%), G1 (13% cf. mean 7%), D3 (13%, cf. mean 6%) and C (8% cf. mean 3%). Kirkibost and Luskentyre are notable for having an important saltmarsh component, 22% and 32% respectively. Finally, Breckin on Shetland, the only site not on either the Inner or Outer Hebrides, is rather different from the rest of the sites in ST2 by having a low proportion of D1 (37% cf. mean 58%), which is made up mainly by G1 (22% cf. mean 7%) and G2 (19% cf. mean 3%). The latter vegetation type, acid, damp grassland G2, is much more typical of the north-west coast site types ST7 and ST8.

Vascular Plants

ST2 is relatively species-rich, having an average of 22.5 species per quadrat (cf. ST1 with 23.2) and 36 species with a mean frequency of 20% or more (cf. ST1 with 35). The most common species are Festuca rubra (85.4%), Plantago lanceolata (81.5%), Trifolium repens (80.9%), Ranunculus acris (73.2%) and Poa pratensis (70.8%), i.e. very similar to the most common species in ST1. As already noted, Ammophila arenaria occurs in 43.2% of quadrats compared with 28.4% in ST1.

The frequency of the commoner species is fairly consistent within the site type. Ammophila arenaria is most common at Uig (67%) and least at Europie (10%). Breckin on Shetland stands out as being the most divergent site in terms of species frequency with the total absence of a number of species that are otherwise common in ST2, e.g. Senecio jacobaea (mean 60.6%), Galium verum (60.6%), Carex arenaria (mean 32.6%), Daucus carota (mean 32.4%), Thalictrum minus (mean 30.4%) and Cynosurus cristatus (mean 28.0%). Other species have markedly lower species at Breckin than elsewhere within the type, e.g. Trifolium pratense (15% cf. mean 51.2%), but, at the other extreme, some species are more common, e.g. Plantago coronopus (41% cf. mean 13.4%) or Agrostis tenuis (52% cf. mean 10.0%).

Cover Types

Vascular plants were recorded in 96.2% of quadrats in ST2 (cf. 98.5% in ST1) with a mean cover of 94.3% (cf. 87.8% in ST1). The most important species contributing to this cover are Festuca rubra (20.5% cf. 17.3% in ST1), Ammophila arenaria (6.5%), Plantago lanceolata (5.5%), Trifolium repens (4.3%), Holcus lanatus (3.2%), Galium verum (3.2%), and Poa pratensis (3.1%). Bryophytes are present in 81.7% of quadrats with a mean cover of 7.6% (cf. ST1 with 83.1% and 8.8%). Equivalent figures for lichens are 22.2% and 0.3% in ST2 (cf. 13.8% and 0.1% in ST1). Again, the most important non-living cover category is bare sand, in 40.8% of quadrats and with mean cover of 12.5% (cf. ST1 with 49.3% and 9.5%, i.e. more frequent but less cover). Freshwater was only recorded from 2.0% of quadrats with mean cover of 0.4% (cf. 7.2% and 1.1% for ST1).

Landforms

Many of the sites in this type are bayhead systems. Offshore the sea bed shelves fairly steeply so that is quite deep close to the shore. This in is contrast to the much more gently shelving sea bed off the Uists, where all but one of the members of ST1 are located. Many sites in ST2 contain an extensive bare, eroded area at the top of the beach, i.e. the strandline, with dune formations at the head of the bay, hence the increase in vegetation types B, C and D3 as compared with ST1. The machair plain is relatively small and there is usually some sand blown up on to the country rock to landwards so that most sites contain rocky outcrops surrounded by sand. Only rarely is there a loch on the landward side of the system but there are some streams and rivers draining across the sites.

General aspect is slightly biased towards west (37.3%) but local aspect is neutral, with roughly equal proportions of all aspects. Slopes tend to be steeper than in ST1, with 23.4% of less than 1 degree (cf. 50.2% in ST1), 50.7% in the 1-5 degree category (cf. 42.0% in the ST1), 23.2% in the 5-15 degree category (cf. 7.5% in ST1) and 2.6% over 15 degrees (cf. 0.3% in ST1). Surface type show similar trends, with 32.4% plane and 45.0% simple undulating in ST2 (cf. 59.6% and 26.5% in ST1). Most quadrats (75.0%) are under the 50ft contour (cf. 93.7 in ST1), with 14.5% in the 50-100ft zone (cf. 6.1% in ST1). Maximum altitude in ST2 is 300-350ft (0.1%) compared with ST1 100-150ft (0.3%). The lowest sites, with no quadrats over 50ft OD, are Hynish Bay, Kirkibost and the Monach Isles, whilst the most generally elevated site is Tolsta, with 73.3% of its quadrats over the 50ft contour. As with ST1, the sites in ST2 are mostly deep, extending, in some cases, to 1500m+ from the sea (0.3% for ST2 compared with 1.2% for ST1). The deepest sites (1500m+) are West Tiree and Europie and the shallowest, with the most inland quadrats only 400m from the sea, are Vatersay, West Barra, Kirkibost, Monach Isles, Vallay, Luskentyre and Breckin. Most of the area is located 100-600m from the sea (49.4% cf. 42.5% for ST1) with only 11.3% beyond this distance (cf. 16.6% for ST1, i.e. the sites in ST2 are slightly shallower).

Soil Types

The most common soil in ST2 is semi-mature Deep Sandy Soil DS6, with 45% of quadrats (cf. 42% in ST1), and this is followed by the similar, but somewhat drier, DS5 with 14% (cf. 15% in ST1) and the mature DS7 also with 14% (cf. 8% in ST1). Together these comprise 73% of the soils in ST2. Other less common soil types are DS3 (4%), DS4 (2%), both rather less mature in terms of profile development, TS7 (2%), TS9 (2%) and TS10 (3%). Peaty soils are also present (PS1=+, PS2=3%, PS3=3%, PS4=1% and PS5=3%) with a total of 10% of quadrats (cf. 12% in ST1). There is a good deal of between-site variation but this mostly consists of an interchange between the most common types DS5, DS6 and DS7 which are all closely related in terms of pedogenesis. The sites on Harris and Lewis, i.e. sites 39-45, and the more northerly Breckin tend to be systematically different from those further south by having a greater proportion of peaty soils - PS1=1%, PS2=7%, PS3=4%, PS4=2% and PS5=5%), or a total of 19% in this series. This increase in peaty soils is probably the result of underlying rock and climate rather raised water table, i.e. blanket rather than basin peat.

Boundaries

The landward boundaries of ST2 are usually formed by the enclosed croftland. This may, to some extent, have truncated the sites and reduced the proportion of the more mature sand/humus soils. In some cases there was no obvious inland boundary on the map and an arbitrary line has been drawn. This may have resulted in the omission of blown sand in some cases and the inclusion of blanket peat in others. The lateral boundaries of the sites are often formed by the relatively steep sides that are an integral part of the bayhead situation.

Land-use

Like its closely related type ST1, West Coast, Hebridean, dune type ST2 is linked to the crofting system of agriculture but the balance of activity is rather different. Whereas in ST1 27.1% of quadrats showed signs of cultivation, this is reduced to 4.7% in ST2. Similarly, the mean number of quadrats per site that had to be abandoned because they were occupied by a standing crop at the time of survey was 17.5 in ST1 and only 1.9 in ST2. On the basis of these mean data it might be assumed that the difference between the two site types was the direct result of agricultural practice. However, when the record for individual sites is examined in detail it is seen that there are sites in ST1 with low levels of cultivation, e.g. Hosta (3%) and Achnahaird (0%), and also the converse, sites in ST2 with high levels of cultivation, e.g. Vallay (16%), Robach (31%) and Luskentyre (16%). It must, therefore, be concluded that cultivation is not the sole factor underlying the distinction between ST1 and ST2 but there must be more fundamental differences in terms of climate and landform. As far as other agricultural activities are concerned, the intensity of grazing in ST2, with none in 13.5%, light in 40.8%, moderate in 31.4% and heavy in 14.3%, is seen as being somewhat heavier than that in ST1 (none in 12.6%, light in 52.3%, moderate in 21.9% and heavy in 13.2%). There are also differences in the proportion of sheep, the signs of which were recorded in 48.5% of quadrats in ST2 as compared with 24.4% in ST1. Cattle are slightly more common in ST1 (65.8%) than in ST2 (54.2%) and rabbits are similar (60.0% and 54.2% respectively). Once again, there are quite wide within-site type differences in sheep grazing for ST2 (more so than for ST1), e.g. no sheep at all were recorded in Kirkibost, whereas at Breckin they were recorded in 96% of quadrats. Similarly, no cattle were recorded on the Monach Isles, but West Tiree and Ballevullin had 95%. Other human activities recorded in ST2 include fence in 4.0% of quadrats (cf. 3.6% in ST1), tarmac road in 1.9% (cf. 1.0% in ST1), vehicle track in 7.4% (cf. 12.5% in ST1) and unsurfaced path in 7.0% (cf. 1.2% in ST1). Rubbish was recorded in 22.3% of quadrats in ST2 (cf. 28.5% in ST1). Finally, the proportion of various aquatic habitats recorded in ST2 is somewhat reduced as compared with ST1 - puddle (1.1%), saltmarsh pan (2.3%) and stream (1.0%). Luskentyre is notable for containing a high level of saltmarsh habitats (saltmarsh pan 32.0% and saltmarsh creek 6.0%) and this is related to the high proportion of Saltmarsh vegetation types in this site (35.0% of quadrats).

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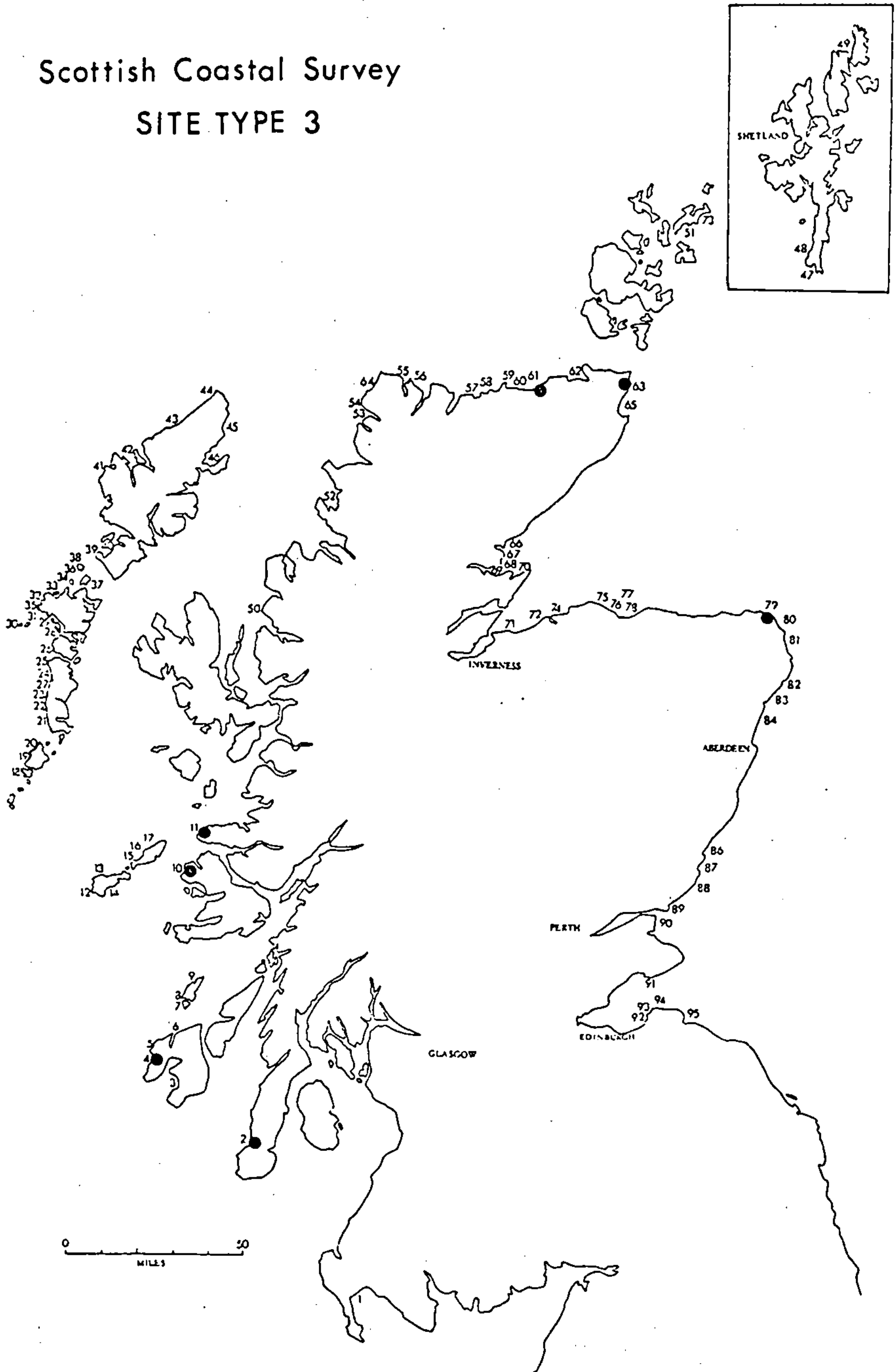
SITE TYPE 3



8.4.3 Site Type 3

Name - North and West Coast, truncated type

List of Sites in ST3

Site no. & name	Geographical region	Size (ha)
2 Macrihanish Dunes	*Colonsay, etc.	353
4 Kilchoman Dunes	*Colonsay, etc.	160
10 Calgary Dunes	**Tiree, etc.	17
11 Sanna	**Tiree, etc.	38
61 Reay	Caithness	77
63 Freswick	Caithness	22
79 Fraserburgh	Aberdeenshire	112

*Colonsay, Islay and Kintyre
**Tiree, Coll, Mull and Ardnamurchan

General Description and Relationship with other Site Types

As the name, North and West Coast, truncated type, suggests this site type is characterized by the high proportion of active dune within the site boundary. The mean area of the seven sites (7.4%) that are allocated to the type is 111ha but the variation in size is considerable - from Macrihanish Dunes, with 353ha, down to Calgary Dunes, with a mere 17ha (a size ratio of about 21 to 1). Some of the sites are long, thin, coastal strips, e.g. Macrihanish Dunes (beach length of 5km) and Fraserburgh (beach length of 2.9km) and others are relatively short, but with very active, bayhead systems, e.g. Calgary Dunes (beach length of 0.5km) and Reay (beach length of 1.06km). The activity of the sites, in terms of sand movement, is evidenced by the increase in the unstable vegetation types - B=3%, C=6% and D3=25%, giving a total of 34%, as compared with ST1 and ST2 with totals of 7% and 13% respectively. The frequency of <u>Ammophila arenaria</u> (53.2%) also confirms this interpretation (ST1=28.4% and ST2=43.2%). However, it should be noted that a high level of this species is not invariably the case in the ST3. For example, no <u>Ammophila</u> at all was recorded at Calgary Dunes, a site that has fairly intensive agricultural use, whereas at Macrihanish Dunes the species occurred in 94.0% of quadrats. Calgary is, however, a rather extreme site within ST3 in a number of respects. All six sites in ST3 are influenced by the presence of streams or rivers and several have a stream as a lateral boundary. In terms of vegetation types, the stream influence is exemplified by the presence of wet, slightly acid dune grassland D5 (8%), which has its greatest abundance in this site type (and ST6 with 9%) but is comparatively rare elsewhere, e.g. ST1=+ and ST2 =+. There are small amounts of other marshy vegetation types, e.g. G6=+, M1=1% and M2=+.

From its derivation in the site key, the most obvious site type for comparison with ST3 is ST4 - Northern Isles type. This comparison is discussed in Section 8.3.2 (step 9), the conclusion being that the former is distinguished by the presence of dry, slightly acid habitats. This difference is indicated by preferential species such as Campanula rotundifolia, Centaurea nigra, Cerastium atrovirens, etc. By contrast, ST4 contains a higher proportion of damp habitats, as evidenced by species such as Agrostis stolonifera, Deschampsia cespitosa, Gentianella amarella, Parnassia palustris, etc. There are also a number of preferential "weed" species in ST3, e.g. Geranium molle, Myosotis arvensis, Plantago major and Polygonum aviculare. Other comparisons between ST3 and ST4 are given in the context of the latter type.

An examination of an ordination of site types also reveals evidence of a relationship with ST12 - East Coast, truncated type. A more detailed ordination of the individual sites shows that there is, in fact, continuous variation between the two site types, with Macrihanish, Reay and Fraserburgh (north-eastern members of ST3) being closely related to St Fergus, Cruden Bay and Dumbarnie in ST12. A comparison between these two types in terms of preferential species shows that the high frequency preferentials for ST3 are typical of the western machairs, i.e. vegetation types D1 and G1, involving such species as Bellis perennis, 59.8% in ST3 and 17.8% in ST12, Leontodon autumnalis (25.4% and 4.1%), Linum catharticum (25.3% and 10.8%), Prunella vulgaris (34.2% and 4.0%), Ranunculus acris (34.7% and 6.3%), Ranunculus bulbosus (22.4% and 1.0%), Ranunculus repens (30.7% and 11.0%). Trifolium pratense (13.2% and 2.6%) and Trifolium repens (76.7% and 38.1%). Conversely, species preferential to ST12 are mainly those that are much commoner in, or even limited to, eastern Scotland, e.g. Agropyron repens, 24.3% in ST12 and 8.5% in ST3, Arrhenatherum elatius (34.6% and 15.6%), Astragalus danicus (16.4% and 0.0%), Briza media (8.4% and 0.0%), Echium vulgare (11.2% and 0.0%), Ononis repens (19.9% and 0.0%), Torilis japonica (13.9% and 2.4%) and Viola hirta (8.8% and 0.0%). It will be noted that most of the preferential species that distinguish ST3 from ST12 are not in any way associated with the unstable habitats because this is the common factor between the two types. The only interesting difference that emerges is the observation that both Agropyron junceiforme (12.0% in ST12 and 6.0% in ST3) and Elymus arenarius (12.2% and 0.4%) are preferential to ST12. The different proportions of these two species is about the only evidence that unstable vegetation types such as C and D3 have western and eastern facies.

The geographical distribution of ST3 consists of a group of four sites in the south-west, a totally separate group of two sites on the north-east coast and one site on the east coast. There is also some evidence to suggest that the three out of the four south-western sites are systematically different from the rest, being more closely similar to ST4, the exception being Macrihanish. By contrast, the three sites in the north and east and Macrihanish are in some respects more similar to ST12, which type, it should be noted, has a totally separate geographical distribution, all sites being located to the south of Fraserburgh on the east coast. ST3 is therefore seen as a prime example of a site type with a widespread geographical distribution, the common factor for the type being truncation which results in a high proportion of unstable habitats. The effects of truncation appear at least partially to override the more general influence of climate but sand type still seems to be a potent factor in differentiating ST3 from its eastern equivalent, ST12.

Vegetation Types

The most common vegetation type in ST3 is still base-rich dune grassland D1, with 33% of quadrats, but this represents a considerable reduction from ST1 (52%) and ST2 (58%) and also from the site type to be described next, ST4 with 52%. The second most common vegetation type is semi-stable dune grassland D3, with 25% (cf. ST1=4%, ST2=6% and ST4=5%). This is followed by slightly acid dune grassland D2, with a mean of 10%, but this figure is boosted by a contribution of 62% from Macrihanish and the type is not present at all at Sanna, Reay and Freswick. D2 is really an eastern vegetation type but its presence at Macrihanish can probably be explained by the moderate calcium carbonate content of the beach sand at that site (16.7%), as compared with the other sites in the type - Kilchoman (33.0%), Calgary (62.2%), Sanna (62.1%), Reay (34.9%), Freswick (54.7%) and Fraserburgh (24.5%). It is also suspected that Macrihanish is a "fairly old" land surface, so that the sand further inland may be well leached, but it would take further analysis of the soil samples to prove the point. Damp, base-rich dune grassland D4 (4%) is also somewhat depleted compared with the previously described sites types (ST1=8%, and ST2=7%) but the closely related wet, slightly acid dune grassland D5, with 8%, is much increased (cf. ST1=+, ST2=+ but ST4=3%). As already noted, D5 is associated with streams and rivers and may be regarded as a rather less acidic version of slightly acid, wet grassland G6 (usually associated with peaty soils) that is so characteristic of ST1 (7%). Slightly acid, damp grassland G1 occurs in 7% of quadrats in ST3 (cf. ST1=13%, ST2=7% and ST4=14%) and colonizing communities C occurs in 6% of quadrats (cf. ST1=2%, ST2=3% and ST4=5%). Bare ground B has a frequency of 3%, giving a total of 34% for unstable types (B, C and D3), as already noted. No other vegetation types make a really significant contribution to ST3, i.e. they have a frequency of 1% or less for the type, but individual sites have up to 5%, e.g. Calgary with 4% of G3 and 4% of F1, Macrihanish with 4% of M1 and Reay with 5% of M1.

One site which conspicuously deviates from the vegetation type profile for the site type is Macrihanish, with 62% of D2 (mean 10%), but the status of this site has already been discussed at some length above. Reay and Fraserburgh, the two sites that are most like ST12, are characterized by having an abnormally high proportion of D3 (57% and 51% respectively as compared with a mean of 25%). The total for unstable vegetation types in Reay and Fraserburgh (B, C and D3) is 69% and 65% respectively. Finally, Calgary Dunes is notable for the high proportion of D5 (28% cf. mean 8%) present.

Vascular plants

ST3 is slightly less species-rich than the previous site types with a mean of 20.1 species per quadrat (cf. 23.2 for ST1 and 22.5 for ST2) and with 33 species having a frequency of 20% or more (cf. 35 for ST1 and 36 for ST2). Again, the most common species are associated with the machair grasslands (D1, G1 and to some extent D3), with Festuca rubra (82.2%), Poa pratensis (80.2%), Plantago lanceolata (77.7%) and Trifolium repens (76.7%). After this there is a big drop to Bellis perennis (59.8%) and Galium verum (59.2%). As already noted, Ammophila arenaria occurs in 53.2% of quadrats and this may be compared with 28.4% in ST1, 43.2% in ST2, 44.4% in ST4 and 69.7% in ST12 (the eastern truncated site type).

Whereas most of the commoner species in ST3 have a fairly uniform frequency within the site type, there are some interesting exceptions. The absence of Ammophila arenaria from Calgary Dunes (mean for ST3 is 53.2%) has already been noted. Holcus lanatus is a curiously variable species, with only 11% at Sanna as compared with 92% at Freswick (mean 51.7%), and Senecio jacobaea is similar, with 13% at Kilchoman Dunes and 83% at Macrihanish (mean 45.8%). Galium verum, with 7% at Freswick and 89% at Macrihanish, is another example of a species with widely divergent frequency within ST3. Several other species show similar levels of variation but there is nothing obviously systematic about these differences except that they commonly involve Freswick and Macrihanish as the sites with the most extreme values. Other differences are more obviously systematic, being related to geographical distribution, e.g. Thymus drucei with 67% at Macrihanish, 57% at Kilchoman, 28% at Calgary and 53% at Sanna (the south-western members of ST3), as compared with Reay 6%, Freswick 0% and Fraserburgh 3% (the northern members). A number of other species also show this type of distribution, e.g. Prunella vulgaris, Luzula campestris, Linum catharticum and Ranunculus bulbosus. A few species show the converse distribution, being more common in the three northern sites, e.g. Heracleum sphondylium and Cirsium arvense.

Cover Types

Vascular plants were recorded in 96.7% of quadrats in ST3 (very similar proportions to ST1 and ST2), with a mean cover of 86.0% which is similar to ST1 with 87.8% but less than that for ST2 with 94.3%. Species contributing most to this cover are Festuca rubra (20.9%), Ammophila arenaria (16.8%, cf. ST1 with 3.5% and ST2 with 6.5%), Poa pratensis (5.3%), Trifolium repens (3.6%), Lolium perenne (3.1%) and Agrostis stolonifera (3.0%). Bryophytes are present in 81.7% of quadrats with a mean cover of 7.0% (cf. ST1 with 83.2% and 8.8%, ST2 with 81.7% and 7.6% and ST4 with 80.6% and 5.0%, i.e. all very similar). Equivalent figures for lichens are 11.5% and 0.1%. The most important non-living cover category is bare sand, present in 54.9% of quadrats with a mean cover of 14.0%. This represents a small increase compared with ST1 (49.3% and 9.5%), ST2 (40.8% and 12.5%) and ST4 (48.2% and 9.1%) but is less than ST12 (51.8% and 17.2%). Freshwater was recorded in 4.5% of quadrats with a mean cover of 1.2%.

Landforms

As already noted, the sites in ST3 range from long, thin systems, such as Macrihanish or Fraserburgh, to narrow bayhead systems, such as Calgary or Reay. Kilchoman Dunes is somewhere intermediate in the range. As with the other site type that has the word "truncated" included in its name, ST12, it would appear that this is only a partial truth. The sites are characterized by instability but not all this activity is due to there only being a narrow strip of dune at the seaward edge. Some of the sites, or parts thereof, have remained in a state of relative immaturity for other reasons about which it is only possible to speculate.

The landward extent of the sites is usually limited by some man-made constraint, e.g. agriculture, golf course, airfield, or naturally by the limited spread of sand in an inland direction. In several of the sites, i.e. the bayhead type, the land rises fairly steeply to the side, thus limiting the spread of the sand. In most sites there is a river or stream crossing or bordering the site on its way to the sea.

General aspect of the sites in ST3 is north or west (together 74.0%) but local aspect favours south and west (61.7%). The explanation for this is not clear and the only definite conclusion is that east is not a common aspect (11.0% general and 14.2% local). Attention has now moved from the basically flat sites in ST1 and ST2 (slightly less so) to a site type in which only 8.8% of quadrats have a slope of less than 1 degree (cf. 50.2% for ST1 and 23.4% for ST2). In ST3, the majority (52.3%) of the quadrats have a slope in the 1-5 degree range, with 32.4% in the 5-15 degree range and 6.6% over 15 degrees. Surface types show similar trends, with 33.2% plane, 36.8% simple undulating 19.3% complex undulating and 10.7% broken. Despite the steep slopes in ST3, 85.5% of quadrats are still under the 50ft contour and none are above the 100-150ft zone. This feature, which is more similar to ST1 with 93.7% under the 50ft contour and no quadrats over 150ft, emphasizes the limited extent to which sand has been blown up the slopes that surround the sites. Kilchoman Dunes is the most elevated site, with 53.3% of its quadrats over the 50ft contour, and Calgary and Sanna are the most low-lying, with no quadrats over 50ft OD. In general, the sites in ST3 extend less distance inland than those in ST1 or ST2. There are no quadrats further than 1000m from the sea and most of the area lies in the 100-400m zone (46.6%). Macrihanish and Kilchoman are the deepest sites (up to 1000m from the sea) and Sanna and Fraserburgh are the shallowest (nothing further than 400m). At the seaward edge, 16.7% of quadrats are within 50m of HWMST. This figure is closely comparable with that for ST1 (12.4%) and ST2 (14.7%) but is in sharp contrast to the other truncated type ST12, with 41.0% of quadrats within 50m of the sea.

Soil Types

The most common soil type in ST3 is Deep Sandy Soil DS5 (a semi-mature type), with 33% of quadrats (cf. ST1=15% and ST2=14%). The next most frequent type is DS6 (a mature type), with 28% of quadrats (cf. ST1=42%, and ST2=45%). It can now be seen that ST3 is characterized by a change of balance from a fairly mature, i.e. a well-developed profile with humus deeply incorporated, sand based soil, such as DS6, to a less mature type, such as DS5, i.e. with only a relatively shallow zone of humus incorporation in the profile. Also quite common in ST3 is the mature DS7 (13%), which is roughly the same proportion as in ST1 (8%), ST2 (14%) and ST4 (13%). Other immature soil types DS1 (3%), DS2 (3%), DS3 (1%) and DS4 (2%) are present, with a combined total of 9%. The only other soil type with a mean frequency of greater than 1% is Peaty Soil PS2 (7%). Curiously the only other peaty type present is PS3 (+). There is fairly wide within-type variation in the proportion of different soil types. Calgary Dunes is unusual by virtue of having no DS5 (when the mean is 33%), and this is made up by 44% of DS6 (mean 28%), 20% of DS7 (mean 13%) and 32% of PS2 (mean 7%). This preponderance of mature profile types at Calgary is atypical of ST3 but is in close accord with the equally unusual proportion of vegetation types in this site (see above) and the absence of Ammophila. Freswick is similar to Calgary through having a higher proportion of more mature soil types than would be expected in ST3 - DS6 (42%), DS7 (23%) and PS2 (10%). Finally, Fraserburgh is notable for being at the other extreme, with 74% of semi-mature DS5, plus a contribution from the even less mature types DS1, DS2 and DS3, which total 12%, i.e. 86% of immature soil types. Mature soils DS6 (3%) and DS7 (6%) occur in only 9% of quadrats at Fraserburgh.

Boundaries

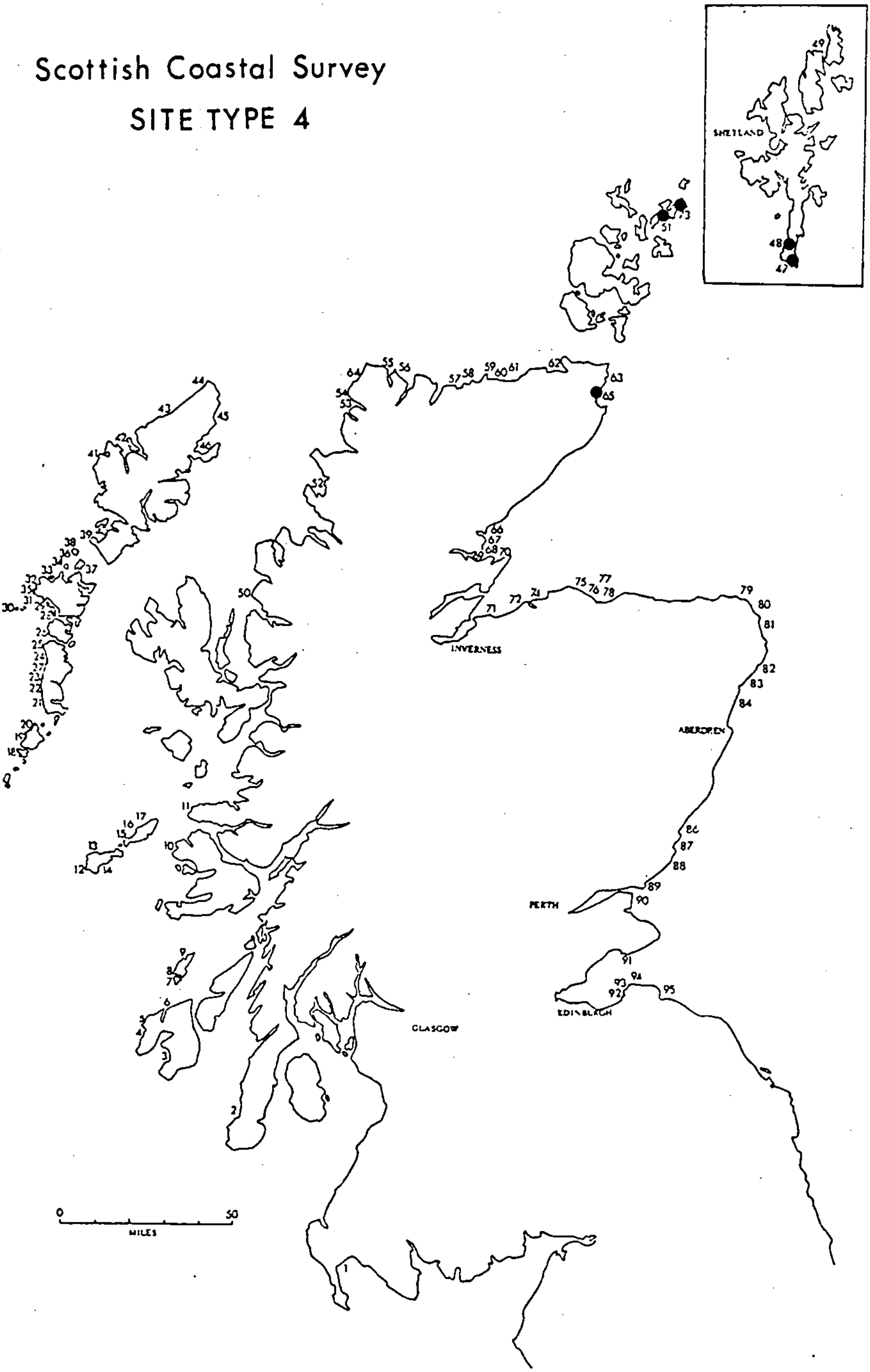
The lateral boundaries of the sites in ST3 usually follow some natural feature such as rising ground or a stream or a combination of both. Landwards the sites are limited in extent either naturally, because the blown sand has not spread far inland, or artificially, by agriculture, golf courses or other developments, e.g. use by MOD.

Land-use

Except at Calgary, the agricultural activities are mainly pastoral in nature. Grazing intensity in ST3 is quite heavy compared with ST1 and ST2 with only 9.1% of quadrats being ungrazed, 32.3% lightly grazed, 24.9% moderately grazed and 33.7% heavily grazed (cf. ST2 with 13.5%, 40.8%, 31.4% and 14.3% respectively). The most important grazing animals are cattle (55.6%), sheep (43.4%) and rabbit (76.2%) and this can be compared with 54.2%, 48.5% and 54.2% respectively in ST2. Horses were recorded in 1.7% of quadrats but this is entirely due to a figure of 12% at Calgary. Reay is unusual by virtue of having no cattle and only 12% of quadrats grazed by sheep (but 94% by rabbits), the explanation being that most of the site is occupied by a golf course. Both Reay and Fraserburgh are characterized by being lightly grazed (73% and 77% of quadrats respectively with no or light grazing). The most heavily grazed site is Kilchoman Dunes, with cattle (97%), sheep (80%), rabbit (90%) and, not surprisingly, 67% of quadrats being recorded as heavily grazed. Freswick is also subject to greater than average grazing intensity, with cattle and rabbits being the most important agencies. The site most subject to arable agriculture, Calgary Dunes, had 8% of quadrats in which recent cultivation was recorded and 8% with a standing crop at the time survey (but not the type of crop that prevented sampling). In addition, five quadrats of the original sample had to be abandoned because there was a crop that could have been damaged, and this happened despite all the more obvious agricultural land having been excluded when drawing the site boundary. Other common signs of human activity on the sites is evidenced by the presence of embankment (1.5%), wall (1.6%), fence (8.7%), tarmac road (1.0%), vehicle track (10.8%), unsurfaced path (21.0%), sand quarrying (2.6%, mostly at Reay), spent cartridge (3.2%), fire evidence (1.2%) and rubbish (37.7%). Aquatic habitats worthy of note are stream (2.9%), river (1.2%) and dried-up ditch (2.0%).

Scottish Coastal Survey

SITE TYPE 4



8.4.4 Site Type 4

Name - Northern Isles type

List of Sites in ST4

Site no. & name	Geographical region	Size (ha)
47 Quendale	Shetland	208
48 Scousburgh	Shetland	36
51 Holland	Orkney	256
65 Sinclairs Bay	Caithness	146
73 Overbister	Orkney	256

General Description and Relationship with other Site Types

The five sites in ST4 (5.3%) are quite variable in size, ranging from 256ha for Holland and Overbister to 36ha at Scousburgh, the mean for the type being 180ha. As the name suggests, geographical distribution is the most obvious characteristic of ST4. There are two sites in Shetland, two on Orkney and one (Sinclairs Bay) just round the corner on the north-east coast of Caithness. The discrete distribution of the type is only violated by Breckin on Shetland which belongs to ST2, which, as will be shown below, is a closely related type anyway. The sites in this type are characterized by having a high proportion of damp pasture, grading into wet areas near loch margins and the edges of streams or drainage channels. There is evidence of cultivation in some sites and there are a few quite common "weed" species in the flora.

The sites in this type are geographically at the transition between the west and north coast site types and those on the east coast (the first division of the site classification) and this is, to some extent, reflected in the flora, e.g. Daucus carota absent in ST4 but common in the other western and northern site types, or, Cirsium arvense, common in ST4 and the eastern types but relatively uncommon in the western and northern types. Trifolium pratense is very much a western species that has fallen to a very low level (3.9%) in ST4. Within ST4, some species show quite distinctive distributions, e.g. Viola tricolor, Galium sterneri and Plantago major, not being recorded on the three Shetland sites but which are quite common elsewhere (Galium sterneri on Orkney only). Or, conversely, Scilla verna was recorded from Shetland only, and Anthoxanthum odoratum was not recorded in the Orkney sites. Despite this and other fairly marked discontinuities in terms of individual species, the vegetation types in ST4 seem to be little affected. This is because the majority of species are behaving in a more consistent manner, i.e. they are responding to the environment rather than to the effects of geographical distribution. Geographical distribution tends to be influenced by independent factors, such as rate of spread and geographical barriers, e.g. isolation by water.

A comparison between ST4 and ST3, on the basis of indicator and preferential species, has already been made in Section 8.3.2 (step 9), the conclusion being that ST3 has a higher proportion of dry, slightly acid habitats. This is evidenced by such preferentials as Campanula rotundifolia, Centaurea nigra, Cerastium atrovirens, etc. Conversely, ST4 is interpreted as being damper and this is reflected by the increased frequency of such species as Agrostis stolonifera, Carex nigra, Deschampsia cespitosa, Gentianella amarella, Parnassia palustris, Plantago maritima, Poa trivialis and Senecio aquaticus. A similar comparison can be made between ST4 and ST2. Preferential to ST2, and indicative of dry habitats, are such species as Anthyllis vulneraria (22.0% in ST2 and 0.7% in ST4), Koeleria cristata (25.1% and 1.3%) and Thalictrum minus (30.4% and 0.0%). Other species that are preferential to ST2 clearly result from the presence of peaty conditions which are less common in ST4 (despite the dampness), e.g. Molinia caerulea (6.2% and 0.6%) and Potentilla erecta (5.4% and 0.0%). Other species are more difficult to interpret, e.g. Senecio jacobaea (60.0% and 23.8%). In the other direction, species preferential to ST4 are either indicative of dry, acid conditions, e.g. Agrostis tenuis (30.6% in ST4 and 10.0% in ST2), Cirsium arvense (25.7% and 6.8%) and Cirsium vulgare (46.0% and 7.1%), or they are marsh species, e.g. Cardamine pratensis (16.0% and 6.0%), Deschampsia cespitosa (13.6% and 0.2%) and Parnassia palustris (15.5% and 0.4%). Finally, the are a number of preferential "weed" species, e.g. Plantago major (5.8% and 1.8%), Poa annua (11.2% and 4.5%) and Stellaria media (30.0% and 4.8%). Again, with all these species, it is difficult to differentiate between those that indicate genuine differences between the sites and those that are geographically limited on the islands.

In summary, it is considered that ST4 is really a rather damper and perhaps more intensively managed (as agricultural grazings) version of ST2 and that its relationship with ST3 is rather more tenuous. Only Sinclairs Bay on the mainland has the degree of instability that is typical of ST3. Further comparisons of ST4 with the related types ST5 and ST6 appear, in context, below.

Vegetation Types

The profile of vegetation types in ST4 is remarkably similar to that for ST1 and ST2. For example, the most common vegetation type in ST4 is base-rich dune grassland D1, in 52% of quadrats (cf. ST1 with 52% and ST2 with 58%). The next most common type is slightly acid, damp grassland G1, with 14% (cf. ST1 with 13% and ST2 with 7%, i.e. a slight increase), closely followed by damp, base-rich dune grassland D4, with 12% (cf. ST1 with 8% and ST2 with 7%, i.e. again a slight increase). The so called unstable vegetation types are present but are not an important feature of this site type - D3 (5%), C (5%) and B (1%) giving a total of 11% of quadrats (cf. 7% in ST1, 13% in ST2 and 34% in ST3). The damper nature of ST4 is evident through the presence, albeit in small amounts, of a number of vegetation types that reflect this trend, e.g. wet, slightly acid dune grassland D5, with 3% (cf. ST1=+ and ST2=+ but ST3=8%), slightly acid, wet grassland G6, with 1% (cf. ST1=7%, ST2=2% and ST3=+, this is more peaty type), damp disturbed marsh M1 with 1%, wet marsh M2 with 3% and wet foredune F2 1%. Another feature of ST4 that it is totally devoid of saltmarsh vegetation, at least none were sampled in the survey, so it would have to be present in very small quantities. This must be compared with 4% in ST1 and 5% in ST2 for combined members of the Saltmarsh family. In this respect, ST4 is more like ST3, with only a trace of saltmarsh. A slight eastern influence is evident in ST4 through the presence of small proportions of slightly acid dune grassland D2 (2%) and acid, dry grassland G3 (1%).

Looking now at the profile of vegetation types for individual sites in ST4, Quendale is notable for having a rather low proportion of D1 (31%, compared with a mean of 52%) and this is made up by an increase in the closely related G1 (43%, compared with a mean of 14%). At the other extreme, Overbister has 74% of D1 (mean 52%) and no G1, the remainder of the site being composed of D4 (13%) and D3 (13%), i.e. only three vegetation types in the site. The most extreme example of ST4 is probably the mainland site of Sinclairs Bay, with 19% of D1 (mean 52%), 19% of D4 (mean 12%) and 16% of G1 (mean 14%). The difference is made up by an unusually high proportion of unstable vegetation types - D3 (7%), C (19%) and B (4%), giving a total of 30%. In this respect Sinclairs Bay shows similarities with ST3 - North and West Coast, truncated type, and an examination of the site ordination confirms this interpretation, that Sinclairs Bay is, indeed, on borderline with ST3. Presumably the high proportion of the damp, base-rich dune grassland D4 at Sinclairs Bay (19%) makes a difference, because this vegetation type has a mean of only 4% in ST3.

Vascular Plants

Like most of the western site types, ST4 is reasonably species-rich with a mean of 20.3 species per quadrat and 32 species with a frequency of 20% or more (cf. ST1 with 23.2 and 35 and ST2 with 22.5 and 36). Once again, the most common species in ST4 are those associated with the machair grasslands (D1, D4 and G1), with <u>Festuca rubra</u> in 89.4% of quadrats, <u>Poa pratensis</u> (86.4%), <u>Trifolium repens</u> (86.2%), <u>Cerastium holosteoides</u> (79.1%), <u>Lotus corniculatus</u> (76.1%), <u>Plantago lanceolata</u> (75.6%) and <u>Ranunculus acris</u> (70.1%). <u>Ammophila arenaria</u> was recorded in 44.4% of quadrats (cf. ST1=28.4%, ST2=43.2% and ST3=53.2%).

As already noted, a number of relatively common species show discontinuous distributions within ST4, e.g. <u>Viola tricolor</u> and <u>Galium sterneri</u> (see General Description above). Other curiosities are the absence of <u>Carex arenaria</u> from Scousburgh in Shetland (only 17% at Quendale, compared with the mean of 32.4%), <u>Senecio jacobaea</u> absent from Holland on Orkney (but also only 3% at Quendale, compared with the mean of 23.8%) and <u>Poa trivialis</u> absent from Sinclairs Bay but present in all sites on Shetland and Orkney.

Cover Types

Vascular plants were recorded in 99.3% of quadrats in ST4 with a mean cover of 102.6% (cf. ST1=87.8%, ST2=94.3% and ST3=86.0%). The most important species contributing to the high cover are <u>Festuca rubra</u> with 26.9% (cf. ST1=17.3%, ST2=20.5% and ST3=20.9%), <u>Ammophila arenaria</u> (12.6%), <u>Trifolium repens</u> (8.3%), <u>Agrostis stolonifera</u> (7.0%), <u>Poa pratensis</u> (4.3%), <u>Plantago lanceolata</u> (3.7%) and <u>Lotus corniculatus</u> (3.2%). Bryophytes were recorded in 80.6% of quadrats with a mean cover of 5.0% (cf. ST1 with 83.1% and 8.8%, ST2 with 81.7% and 12.5% and ST3 with 81.7% and 7.0%). Equivalent figure for lichens are 14.0% and 0.1%. The most important non-living cover category is bare sand, present in 48.2% of quadrats with a mean cover of 9.1%, but it should be noted that most of this cover is contributed by Sinclairs Bay with no less than 28.0%, the other sites in ST4 having relatively low values for this cover type.

Landforms

The basic features of ST4 are very similar to ST2, with a coastal zone of Ammophila dune backed by a fairly extensive, level plain. There may also be a water body or marsh somewhere near the landward boundary of the site. Although the sites are mostly of a bayhead type, they are not constricted laterally by steeply rising ground. The inland part of the site may rise gradually from the plain, Holland reaches up to 200ft, Quendale 170ft, Scousburgh 130ft but Sinclairs Bay and Overbister are almost completely flat. Overbister on Orkney contains spits that link islands to the main island of Sanday. These enclose inlets that dry out at low water but, despite this, no saltmarsh was recorded in the site with boundaries as drawn. Only Sinclairs Bay contains a river of any size, the Water of Wester. All the other sites include or are adjacent to lochs.

General aspect of the sites shows a bias towards either east (36.1%) or west (38.7%) facing slopes but local aspect favours south (42.5%). The explanation for this observation is not immediately obvious. The slope characteristics of ST4 lie somewhere between the very flat ST1 and the more sloping ST2, with 34.4% under 1 degree, 48.3% in the 1-5 degree category, 16.7% in the 5-15 degree category and 0.6% over 15 degrees (cf. ST1 with 50.2%, 42.0%, 7.5% and 0.3% respectively and ST2 with 23.4%, 50.7%, 23.2% and 2.6%). Surface type shows similar trends, with 40.5% plane, 35.1% undulating simple, 20.7% undulating complex and 3.8% broken. The overall distribution of height categories is very similar to that for ST2, with 75.1% under 50ft, 11.4% 50-100ft, 6.4% 100-150ft and 7.1% 150-200ft (cf. 75.0%, 14.5%, 6.9% and 2.7% for ST2 which also has 0.9% over 200ft). As already noted, Sinclairs Bay and Overbister are low-lying sites, with all their quadrats under 50ft OD. Although some of the sites extend quite a long way inland, e.g. Quendale, the majority of quadrats are within 400m of the sea (72.4%, cf. 66.8% in ST1 and 78.8% in ST2), the modal distance being the 200-400m zone with 34.1%. In ST4, 11.7% of the quadrats are within 50m of HWMST (cf. ST1 with 12.4%, ST2 with 14.7% and ST3 with 17.7%).

Soil Types

The soil types in ST4 seem to be an extension of the trend noted from ST1 to ST2, i.e. an increase in maturity, as measured by the amount and depth of humus incorporated in the profile. Thus the most common soil types are Deep Sandy Soil DS6, with 53% of quadrats (cf. ST1=42% and ST2=45%), and DS7, with 13% (cf. ST1=8% and ST2=14%). The semi-mature Deep Sandy Soil DS5 has a frequency of 22% (cf. ST1 with 15% and ST2 with 14%). Along with 1% of DS8, semi-mature and mature sandy soils account for 89% of the quadrats in ST4, which does not leave much scope for other types. Immature sands DS2 (1%), DS3 (3%) and DS4 (1%) account for a further 5% and Peaty Soils PS2, PS3 and PS5, total 3%.

Boundaries

The boundaries of most of the sites are rather arbitrarily drawn in relation to the croftland. The land tends to be quite intensively used and enclosed, with some fences running right down to the shoreline. It is difficult to tell the extent of blown sand from the maps and in some cases it may be more extensive than the area surveyed, e.g. the Plain of Fidge at Overbister or round Bea Loch at Holland. These omissions may cause the proportion of Duneland vegetation types (D1 and D4) to be somewhat exaggerated, simply because areas likely to contain Grassland types (G1 mainly) have been left out of the site.

The boundary at Sinclairs Bay is limited by a golf course in the south whilst north of the river it does not follow any obvious feature.

Land-use

Farming activity, with the land broken up into quite small fields, is the main feature of the sites on Orkney and Shetland. The mainland site, Sinclairs Bay, is rather different. Signs of cultivation were recorded in 4.1% of quadrats, this factor being most important at Overbister, with 10.0%. In addition, three quadrats were abandoned because they had a standing crop at the time of survey and three more with a crop were actually surveyed. As might be expected with relatively intense agricultural use, grazing intensities are high, with only 4.6% of quadrats ungrazed, 27.7% lightly grazed, 48.5% moderately grazed and 19.3% heavily grazed (cf. ST1 with 12.6%, 52.3%, 21.9% and 13.2% and ST2 with 13.5%, 40.8%, 31.4% and 14.3% respectively). In this respect ST4 is more like ST3, with grazing intensities of 9.1%, 32.2%, 24.9% and 33.7% respectively. The most important grazing animal is cattle (52.3%), with sheep (39.8%). Rabbits were recorded in 88.4% of quadrats (a high figure, cf. ST1=60.0%, ST2=54.2% and ST3=76.2%) and horse in 7.0% (20.0% at Scousburgh). Other man related activities recorded in ST4 were embankment (1.3%), wall (1.9%), fence (13.0%), vehicle track (18.0%), unsurfaced path (25.9%) and rubbish (26.9%). Aquatic habitats make a very modest contribution to ST4, with loch (1.3%, all at Scousburgh), dried-up rut (1.8%) and dried-up pond (1.2%) (cf. the much higher figures for ST1).

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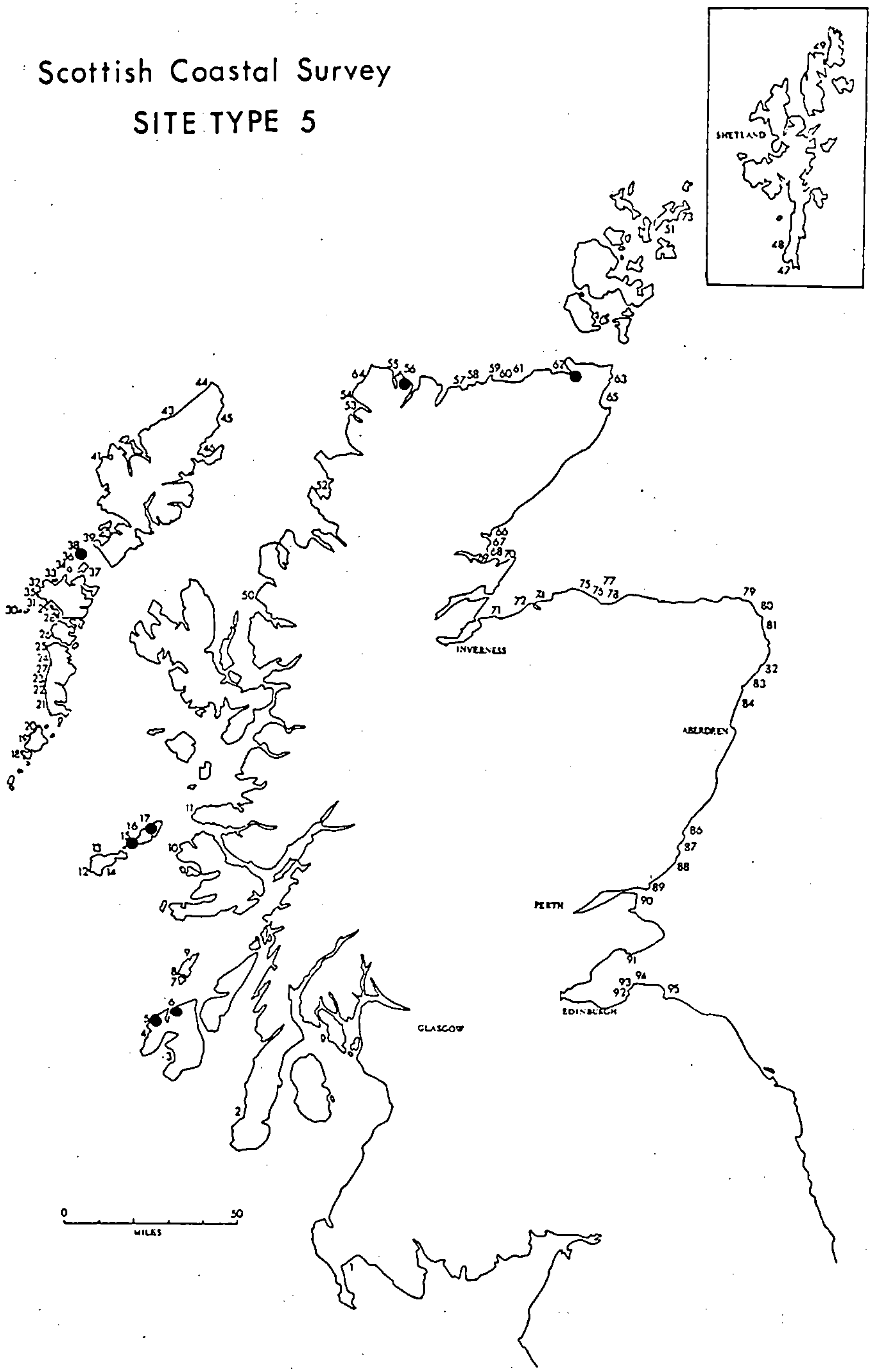
SITE TYPE 5



8.4.5 Site Type 5

Name - North and West Coast, acid heath type

List of Sites in ST5

Site no. & name	Geographical region	Size (ha)
5 Saligo Bay	*Colonsay, etc.	80
6 Gruinart	*Colonsay, etc.	560
15 Crossapol & Gunna	**Tiree, etc.	800
17 Gallanach	**Tiree, etc.	368
38 Pabbay	Barra & Uists	496
56 Faraid Head	North Sutherland	228
62 Dunnet	Caithness	789

*Colonsay, Islay and Kintyre
**Tiree, Coll, Mull and Ardnamurchan

General Description and Relationship with other Site Types

In some ways it would be more convenient to deal with ST6 before ST5. This is because the trend over the remaining four types on the negative side of the first division of the site classification (ST5-ST8) is that of increasing influence by acidic and wet conditions (as opposed to base-rich and dry). ST6 - North Coast, bayhead, well drained type is at the beginning of the trend, being somewhere intermediate between ST2, ST3 and ST6. The similarity with ST2 is through the presence of base-rich habitats, i.e. ST6 has 45% of D1, with ST3, because of an unstable element, i.e. ST6 has 3% of B, 3% of C and 15% of D3 or total of 21%, and ST5, because it includes some quite acid habitats, i.e. ST6 has 7% of G2, 4% of G3 and 3% of G7 or a total of 14%. ST5 - North and West Coast acid heath type, is similarly related to three other types. It is related to ST2 by virtue of base-rich habitats, i.e. ST5 has 40% of D1, with ST6 though the presence of acid habitats, i.e. ST5 has 7% of G2, 2% of G3 and 4% of G6, and with ST7 because of a small proportion of peat, i.e. ST5 has 7% of P1.

ST5 has seven sites (7.4%) allocated to it. All of these sites are large (over 200ha), with exception of Saligo Bay (80ha), with a mean area for the type of 474ha (cf. 366ha for ST1, the next highest mean thus far). The geographical distribution of the type is widespread, with two sites on Islay, two more on Coll, one on Pabbay (an island situated between North Uist and Harris) and two sites on the north coast, Faraid Head in North Sutherland and Dunnet in Caithness. It is perhaps significant that the first five sites are on islands. The presence of rocky outcrops, with shallow dry soils on them, is also a feature of the site type but whether these two observations are connected in some way is not clear.

The sites in ST5 have quite well developed Ammophila covered dunes but, because the sites are so large, this habitat only covers quite a small proportion of the total area, e.g. D3=6% and C=3%. Along with 2%

of B, this gives a total of 11% unstable habitats (cf. ST2=13%, ST3=34% and ST6=21%).

The distinction between ST5 and its companion in the site classification key has already been discussed above (Section 8.3.2, step 10). The conclusion is that ST2 is characterized by species indicative of wet, acid habitats, e.g. Carex echinata, Carex nigra, Cynosurus cristatus, Erica tetralix, Eriophorum angustifolium, Molinia caerulea and Sieglingia decumbens. The species that are preferential to ST6 are more difficult to interpret, e.g. Achillea millefolium, Centaurea nigra, Rumex acetosa and Thalictrum minus, but most are tall herbs. Turning now to the relationship between ST5 and ST2, there is a surprisingly short list of species that are preferential to ST2 and they also lack a strong, common theme, e.g. Anthyllis vulneraria, 22.0% in ST2 and 0.0% in ST5, Daucus carota (32.4% and 5.8%), Heracleum sphondylium (22.1% and 7.5%), Rhinanthus minor (26.7% and 8.0%) and Senecio jacobaea (60.6% and 28.6%). Conversely, species preferential to ST5 are numerous and their interpretation is relatively easy. In general, they are divided into acid-loving species, e.g. Agrostis tenuis, 26.8% in ST5 and 10.0% in ST2, Anthoxanthum odoratum (46.9% and 13.3%), Calluna vulgaris (15.9% and 4.1%), Festuca ovina (14.4% and 1.4%), and Festuca vivipara (10.1% and 1.4%), and wet, acid-loving species, e.g. Carex echinata (9.2% and 1.9%), Carex pulicaris (14.2% and 4.9%), Erica tetralix (11.4% and 2.2%), Eriophorum angustifolium (9.6% and 1.7%), Molinia caerulea (17.6% and 6.2%), Nardus stricta (10.1% and 2.4%), Parnassia palustris (12.3% and 0.4%), Potentilla erecta (25.6% and 5.4%) and Sieglingia decumbens (26.8% and 7.6%). The comparison between ST5 and ST7 in terms of preferential species is dealt with in detail in the context of the latter type but the general trend is towards an increase in wet, acid-loving or bog species in ST7.

Vegetation Types

The vegetation type profile for ST5 clearly demonstrates its relationship with the other site types. Once again, the most common vegetation type is base-rich dune grassland D1, with 40% of quadrats (cf. ST2=58%, ST6=45% and ST7=23%). The next most common type is slightly acid, damp grassland G1, with 15% of quadrats (cf. ST2=7%, ST6=10% and ST7=19%). No other vegetation type achieves a mean frequency over 10% but the increase in acid, damp grassland G2 (7%) follows the trend (cf. ST2=3%, ST6=7% and ST7=15%) and G3 (2%) and G6 (4%) follow suit. Peatland types are represented by transitional peat bog P1, in 7% of quadrats (cf. ST2=2%, ST6=0% and ST7=10%). Indicative of drier, slightly acid conditions is slightly acid dune grassland D2, with a frequency of 4% (cf. ST2=+, ST6=0% and ST7=1%). This is basically an east coast vegetation type. Less acid, wet habitats are represented by D4 (2%), D5 (2%), M1 (1%) and M2 (2%). As already noted, unstable habitats occupy about 11% of the sites (D3=6%, C=3% and B=2%).

There is quite high within-type uniformity in the proportion of the various vegetation types in ST5. Gruinart can be seen as the least stable site, with 10% of D3 and 12% of C (total 22% compared with a mean of 11%) and Pabbay as the most acid site, with only 24% of D1 (mean 40%), but made up by 23% of G1 (mean 15%), 13% of G2 (mean 7%) and 23% of P1 (mean 7%). Gruinart also contains 7% of Saltmarsh types (S1=3% and S4=4%).

Perhaps one of the most significant features of ST5 is the wide range of vegetation types it contains, e.g. 20 out of the 29 types or 15 out of 29 with a frequency of 1% or more. What is more, all sites in ST5 contain a minimum of nine vegetation types (Gruinart contains no less than 16 types).

Vascular Plants

ST5 is the most species-rich site type described so far, with a mean of 24.7 species per quadrat (cf. ST2=22.5, ST6=21.0, ST7=27.4) and with 40 species with a frequency of 20% or more (cf. ST2=36, ST6=33 and ST7=51). The most common species in ST5 are Festuca rubra (85.6%), Plantago lanceolata (80.5%), Trifolium repens (78.4%), Holcus lanatus (74.5%) and Lotus corniculatus (74.2%). Ammophila arenaria occurs in 46.5% of quadrats (cf. ST2=43.2%, ST6=33.5% and ST7=17.8%).

Despite the wide geographical distribution of these sites in ST5, there are few of the species discontinuities seen in ST4. One notable exception is Veronica chamaedrys which was only recorded in the south-west. Leontodon taraxacoides shows a similar distribution and Gentianella amarella is the converse, only being recorded in the two sites on the north coast.

Cover Types

Vascular plants were recorded in 97.9% of quadrats in ST5 with a mean cover of 98.3%. The most important species contributing to this cover are Festuca rubra (22.8%, cf. ST2=20.5%, ST6=15.3% and ST7=18.2%), Ammophila arenaria (11.3%, cf. ST2=6.5%, ST6=12.2% and ST7=6.0%), Holcus lanatus (3.8%), Molinia caerulea (3.7%) and Trifolium repens (3.2%). Bryophytes were recorded in 90.7% of quadrats with a mean cover of 10.3% (cf. ST2 with 81.7% and 7.6%, ST6 with 82.5% and 2.2% and ST7 with 87.0% and 3.4%). Equivalent figures for lichens are 32.5% and 0.2%. The most important non-living cover category is bare sand, in 27.8% of quadrats and with mean cover of 7.1% (cf ST2 with 40.8% and 12.5%, ST6 with 57.6% and 17.8% and ST7 with 37.0% and 11.0%). Boulders and solid rock appear in quadrats with a frequency of 5.5% and 7.5% respectively and with mean cover of 0.5 and 1.8%. Freshwater was recorded in 5.3% of quadrats with a mean cover of 0.7%.

Landforms

Most of the sites in ST5 are characterized by a fringe of dunes along bayhead shores and there are often several separate beaches in a site (Saligo Bay = 1, Gruinart = 2, Crossapol and Gunna = 7, Gallanach = 3, Pabbay = 3, Faraid Head = 5 and Dunnet = 1). Between the beaches there are often rocky headlands. The exceptions are Dunnet, consisting of a large, single bayhead system, and Saligo Bay, which is small - and, arguably, has two beaches anyway. In addition to the headlands, many sites have other outcrops of rock jutting through the blown sand. There are numerous areas where humus is accumulating, often culminating in peat formation, and these habitats support appropriate vegetation types. Some of these areas are quite extensive, occupying flat areas between rocks or hollows on the rock outcrop itself.

General aspect shows a slight bias towards west (41.2%) and local aspect shows a similar trend, with west and north together accounting for 56.5% of quadrats. Slopes are moderate to steep with only 18.6% of quadrats in the less than 1 degree category (cf. ST2=23.4%, ST6=8.2% and ST7=7.1%). Slopes of 1-5 degrees are the majority type, in 49.3% of quadrats, with 5-15 degrees in 28.8% and over 15 degrees in 3.3%. These proportions are closely similar to ST2 with 50.7%, 23.2% and 2.6% respectively. ST5 is less steep than ST6 (8.2%, 39.2%, 46.3% and

6.3%) and ST7 (7.1%, 39.7%, 36.6% and 16.7%). Surface types in ST5 are 28.1 plane, 49.4% simple undulating, 17.7% complex undulating and 4.8 broken (cf. ST2 with 32.4%, 45.0%, 15.0% and 7.6% respectively). The rock outcrops, so typical of ST5, lead to a wide range of altitude up to 500ft OD. Only 45.3% of quadrats are under the 50ft contour (cf. 75.0% in ST2), 34.9% are in the 50-100ft zone (cf. 6.9% in ST2). There are, however, only 1.6% of quadrats over 250ft OD. Pabbay is the site which contains the widest range of altitudes (up to the 450-500ft zone) and Saligo Bay and Gruinart are the most low-lying with no quadrats over the 50ft contour. Most of the sites are quite deep in a landward direction, with 6.9% of quadrats 1500m+ from the sea. Faraid Head is the shallowest site with no quadrats further than 400m from the sea, and Dunnet is the deepest, with an unprecedented 48.4% of quadrats over 1500m inland. Only 11.4% of quadrats are within 100m of HWMST (cf. 14.7% in ST2) and modal distance is 200-400m with 29.8% (cf. 25.1% in ST2).

Soil Types

As with ST1, ST2 and ST4 the dominant soil type in ST5 are mature Deep Sandy Soils. The most common type is DS6, with 31% of quadrats, and this is followed by DS7 with 22%. With addition of 1% of DS8, these types combine to account for 54% of quadrats. Less mature Deep Sandy Types are headed by DS5 (17%) but also present are DS2 (3%), DS3 (1%) and DS4 (+). Several Thin Soil types that overlie rock or high water table are present in ST5, e.g. TS7=3%, TS8=1%, TS9=3%. Peaty soils are also well represented, with PS1=1%, PS2=7%, PS3=2%, PS4=3% and PS5=1% or a total of 13% (cf. ST2 with 10% of peaty types, ST6 with 16% and ST7 with 31%). In general, the proportion of the various soil types is in good agreement with the vegetation type profile.

In terms of within-type variation, Saligo Bay is seen as being rather different by virtue of having a higher proportion of immature Deep Sandy Soils, e.g. DS5 with 57% (mean 17%). Pabbay and Faraid Head are more peaty than average, with 26% and 30% of Peaty Soils respectively (mean 13%). Finally, Dunnet has the most uniform soils, with 36% of DS6 (mean 31%) and 48% of DS7 (mean 22%) occupying a total of 84% of the site.

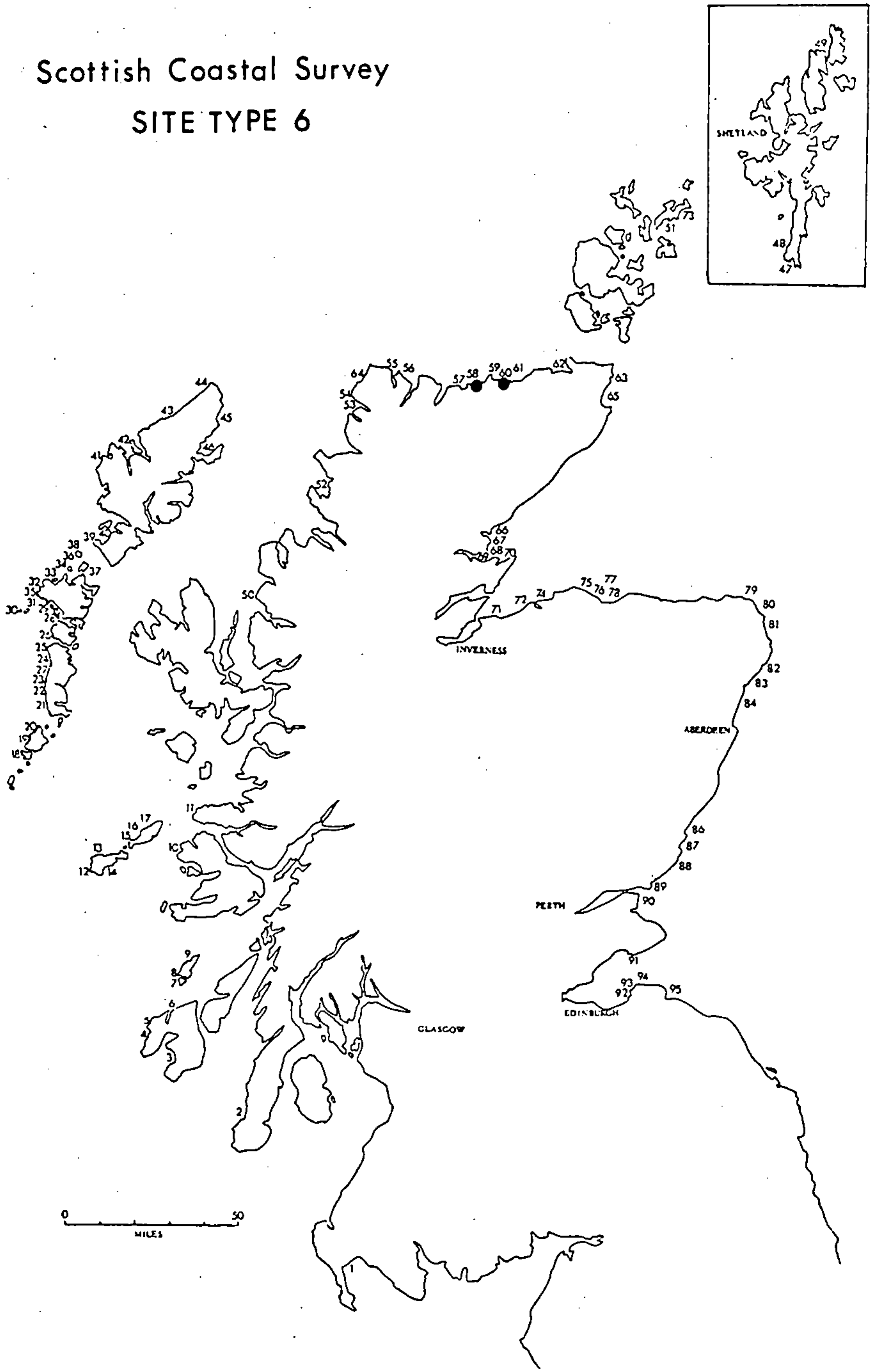
Boundaries

The effect on the site classification of the way in which the site boundaries have been drawn is probably minimal in ST5. In most cases the full extent of blown sand has been covered. The rocky areas included within the boundaries are an integral part of the site and there can be no grounds for their exclusion, even though they hardly qualify as "soft coast". Whilst man-made features have often been used as the site boundary, these usually coincide with some natural feature, such as a break in slope or a water course. All sites include some bayhead dune formation and a well developed hinterland. There are streams in most sites and rocky outcrops in all sites with the exception of Dunnet.

Land-use

Land-use in ST5 is mainly agricultural but, in contrast to the previous types, there is comparatively little evidence of arable activity which was only recorded in 1.1% of quadrats (Crossapol and Gunna, Gallanach and Pabbay only). This can be compared with ST1=27.1%, ST2=4.7%, ST3=3.9%, ST4=4.1%, ST6=0.0% and ST7=10.1%). Only one quadrat at Sanna was lost due to a standing crop being present at the time of survey - and then only a hayfield. Grazing in ST5 is quite heavy, with no grazing in 7.4% of quadrats, light grazing in 24.6%, moderate grazing in 52.7% and heavy grazing in 15.3% (cf. ST2 with 13.5%, 40.8%, 31.4% and 14.3%, or ST6 with 5.3%, 5.8%, 33.3% and 55.6%, the latter site type being exceptionally heavily grazed). The proportion of grazing animals is cattle (70.6%), sheep (77.5%) and rabbit (59.2%). These figures may be compared with 54.2%, 48.5% and 54.2% for ST2 and 29.3%, 56.5% and 89.3% for ST6. Man-made features of note in ST5 are wall (2.1%), fence (2.9%), vehicle track (7.6%), unsurfaced path (11.0%), spent cartridge (1.0%), planted trees (1.2%) and rubbish (12.0%, this is a very low figure). Aquatic habitats are relatively common in ST5 with ditches and streams of various types being most frequent, e.g. loch (1.1%), stream (1.5%), flush/spring (1.1%), dried-up rut (1.7%), dried-up ditch (5.2%, but nearly all at Dunnet in 32% of quadrats!) and dried-up saltmarsh pan or creek (1.3%).

Scottish Coastal Survey
SITE TYPE 6



8.4.6 Site Type 6

Name - North Coast, bayhead, well drained type

List of Sites in ST6

Site no. & name	Geographical region	Size (ha)
58 Farr Bay	North Sutherland	29
60 Melvich	North Sutherland	42

General Description and Relationship with other Site Types

This type comprises only two sites (2.1%), located close together (only separated by Strathy) on the North Sutherland coast. The sites are small, Farr Bay 29ha and Melvich 42ha (mean 35ha). Both sites are bayhead systems with dune development confined to the central part of the bay. In both cases there is a stream (at Melvich quite a large river) skirting round one side of the dune system to discharge into the sea. The stream is on the west side at Farr and on the east at Melvich, the opposite side having sand built up against the hillside and extending quite a long way up the slope. Alluvial areas round the streams support trees and shrubs in an almost carr type of community.

As already noted, ST6 is intermediate between ST2, ST3 and ST5. It resembles ST2 by virtue of its base-rich habitats, as exemplified by having 45% of base-rich dune grassland D1 (Farr Bay also has 4% of D4). ST6 is related to the truncated, active sites in ST3 by having a moderate proportion of unstable habitats - B=3%, C=3% and D3=15% with a total of 21% (cf. 13% in ST2, 34% in ST3 and 11% in ST5). Finally, it is part way along the acidic trend to ST5 (and thence to ST7, ST8, ST10 and ST9) as evidenced by the presence of a small proportion of acidic vegetation types, e.g. G2=7%, G3=4% and G7=3%. Examined individually, Farr Bay is seen to be more similar to ST2 and ST3, with 68% of D1 and fewer acid vegetation types, whereas Melvich is closer to ST5, with only 21% of D1 and a larger, more varied complement of acid types.

The difference between ST6 and ST5 in terms of preferential species have already been discussed in Section 8.3.2 (step 10). An examination of the preferential species for the comparison with ST2 leads to the same conclusion as that drawn from the vegetation types (see above). Preferential to ST2 are such species as <u>Anthyllis vulneraria</u>, 22.0% in ST2 and 5.5% in ST6, <u>Carex nigra</u> (23.5% and 3.9%), <u>Cynosurus cristatus</u> (28.0% and 11.7%), <u>Luzula campestris</u> (32.7% and 14.9%), <u>Polygala vulgaris</u> (22.3% and 5.5%), <u>Prunella vulgaris</u> (46.8% and 20.2%), <u>Rhinanthus minor</u> (26.7% and 5.0%) and <u>Trifolium pratense</u> (51.2% and 22.4%). Several of these species have markedly western, as opposed to northern, distributions. Conversely, preferential to ST6 are such species as <u>Agrostis tenuis</u> 35.5% in ST6 and 10.0% in ST2, <u>Anthoxanthum odoratum</u> (33.2% and 13.3%), <u>Centaurea nigra</u> (48.2% and 17.7%), <u>Dactylis glomerata</u> (25.8% and 3.7%), <u>Primula veris</u> (21.8% and 0.0%) and <u>Ranunculus repens</u> (21.7% and 10.8%).

The other valid comparison is with ST3. Preferential to ST3 are such species as Campanula rotundifolia, 25.2% in ST3 and 10.0% in ST6, Carex arenaria (41.9% and 16.5%), Cirsium arvense (43.2% and 19.5%), Cirsium vulgare (26.0% and 5.6%) and Taraxacum spp. (46.0% and 17.1%). Other less frequent preferentials for ST3 are "weed" species, e.g. Geranium molle, Myosotis arvensis, Plantago major, Poa annua and Sagina procumbens. Conversely, preferential to ST6 are a long list of species, the higher frequency ones being Anthoxanthum odoratum, 33.2% in ST6 and 16.4% in ST3, Daucus carota (24.1% and 0.5%), Plantago maritima (28.4% and 6.0%), Potentilla erecta (16.0% and 2.0%), Primula veris (21.8% and 5.1%), Rumex acetosa (44.1% and 13.6%) and Thalictrum minus (32.9% and 13.0%). Other less common species which mark the difference are Draba incana, Gentianella amarella, Knautia arvensis and Oxytropis halleri.

Despite the obvious similarity of the two sites in ST6, there are quite large within-type differences. With such a small sample for ST6, it is necessary to be cautious about drawing too firm conclusions about its characteristics. In practical terms, the attitude to be adopted towards the type depends on whether there are additional sites, not included in the survey, that would fit into this site type. Because the sites in ST6 tend to be small, the answer to this question is yes, there may be further sites of this type but they are likely to be found only on the north coast of Scotland.

Vegetation Types

As already noted, base-rich dune grassland D1 is still the most common vegetation type in ST6, with 45% of quadrats allocated to it (cf. ST2=58%, ST3=33% and ST5=40%). The second most common type is semi-stable dune grassland D3, with 15% of quadrats (cf. ST2=6%, ST3=25% and ST5=6%). Slightly acid, damp grassland G1 has a frequency of 10% (cf. ST2=7%, ST3=7% and ST5=15%). Other more acid Grassland types are G2 (7%), G3 (4%) and G7 (3%). Damp, base-rich dune grassland D4 occurs in 2% of quadrats (Farr Bay only) and wet, slightly acid dune grass D5 in 9%, this latter type being associated with the streams. Minority types are one quadrat of M1 at Farr Bay and one of S2 at Melvich.

Attention has already been drawn to differences in the proportion of vegetation types at the two sites, with Farr Bay having more D1 (68%, compared with a mean of 45%) and Melvich having less (21%). The difference in the latter site is made up by Grassland types G1 (18%, mean 10%), G2 (14%, mean 7%), G3 (8%, mean 4%) and G7 (5%, mean 3%). The unstable vegetation types are closely similar in the two sites (see Table 4).

Vascular Plants

ST6 is moderately species-rich, with a mean of 21.0 species per quadrat and 33 species with a frequency of 20% or more. The most common species are Festuca rubra (84.6%), Trifolium repens (76.8%) and Plantago lanceolata (75.3%). Ammophila arenaria occurs in 33.5% of quadrats (cf. ST2=43.2%, ST3=53.2% and ST5=46.5%).

There is a fair degree of comparability between the frequency of species in the two sites. Interesting exceptions are Taraxacum spp. 30% at Farr and 4% at Melvich, Cerastium atrovirens (33% and 0%), Pimpinella saxifraga (33% and 0%), Ononis repens (31% and 0%), and Knautia arvensis (23% and 0%). In the other direction, common (or indeed exclusive) in Melvich but less so at Farr are Juncus effusus

(28% and 4%), Potentilla erecta (32% and +), Festuca ovina (27% and 4%), Galium saxatile (27% and 4%), Vicia sepium (26% and 4%) and Cirsium palustre (28% and 0%). The species that are characteristic of Farr Bay can be interpreted as mostly reflecting cultivation and disturbance (see Land-use below) whereas those more frequent in Melvich are clearly related to the higher proportion of acidic habitats in that site.

Cover Types

Vascular plants were recorded from 97.0% of quadrats in ST6 with a mean cover of 86.3%. Species contributing most to this cover are Festuca rubra (15.3%), Ammophila arenaria (12.2%), Agrostis stolonifera (5.8%), Agrostis tenuis (4.2%) and Plantago lanceolata (3.7%). Bryophytes were recorded in 82.5% of quadrats with a mean cover of 2.2% (cf. ST2 with 81.7% and 7.6%, ST3 with 81.7% and 7.0% and ST5 with 90.7% and 10.3%). Equivalent figure for lichens are frequency 22.0% and cover 0.1%. As usual, the most important non-living cover category is bare sand, in 57.6% of quadrats and with mean cover of 17.8% (cf. ST2 with 40.8% and 12.5%, ST3 with 54.9% and 14.0% and ST5 with 27.8% and 7.1%). Gravel (14.0%), cobbles (22.8%) and boulders (14.6%) all have quite high frequency in ST6 but amount to little cover (0.3%, 0.8% and 0.9% respectively). However, this is the first site type in which these cover categories have frequencies exceeding 10% (with the exception of cobbles in ST4=11.0%).

Landforms

Both sites are situated in small, steep sided valleys with a river that skirts the dune formation at the mouth before entering the sea. Blown sand extends up the valley sides even reaching the top of quite high sea cliffs. Some of the landforms present suggest a glacial origin.

General aspect is heavily biased towards north and east (79.8% combined). Local aspect is less extreme but with north and east still dominant (56.0% combined). Slopes are quite steep, with only 8.2% under 1 degree, 39.2% in the 1-5 degree category, 46.3% in the 5-15 degree category and 6.3% over 15 degrees. Surface types are surprisingly uniform, with 9.0% plane, 63.3% simple undulating, 24.6% complex undulating and 3.1% broken. Elevation ranges up to 200ft OD but 64.2% of quadrats are under the 50ft contour, 24.7% in the 50-100ft zone, 1.8% in the 100-150ft zone and 9.2% in the 150-200ft zone, this double peak being due to a plateau effect (found exclusively at Farr Bay). No quadrats are more than 600m from the sea, the majority (80.0%) being within 200m of HWMST. The strong maritime influence is emphasized by 34.6% of quadrats being less than 50m from the sea.

Soil Types

The more mature Deep Sandy Soil types (DS6-8) are somewhat reduced in ST6. The most common sandy type is the semi-mature DS5, with 21% of quadrats. Other immature types represented are DS1 (1%), DS2 (10%) and DS3 (9%). Mature sandy soils are still present in the form of DS6 (14%), DS7 (10%) and DS8 (2%). There is a fair complement of Sandy Cobble Soils at Melvich (CS2, CS3, CS4 and CS6), totalling 18% in that site but they are not present at all in Farr Bay. There are a few Thin Soils at both sites (totalling 9%) but the residue of quadrats are occupied by Peaty Soils - PS2 (8%), PS3 (2%), PS4 (4%) and PS5 (2%)

for a total of 18% (cf. ST2 with 10%, ST3 with 7% and ST5 with 14%).

Boundaries

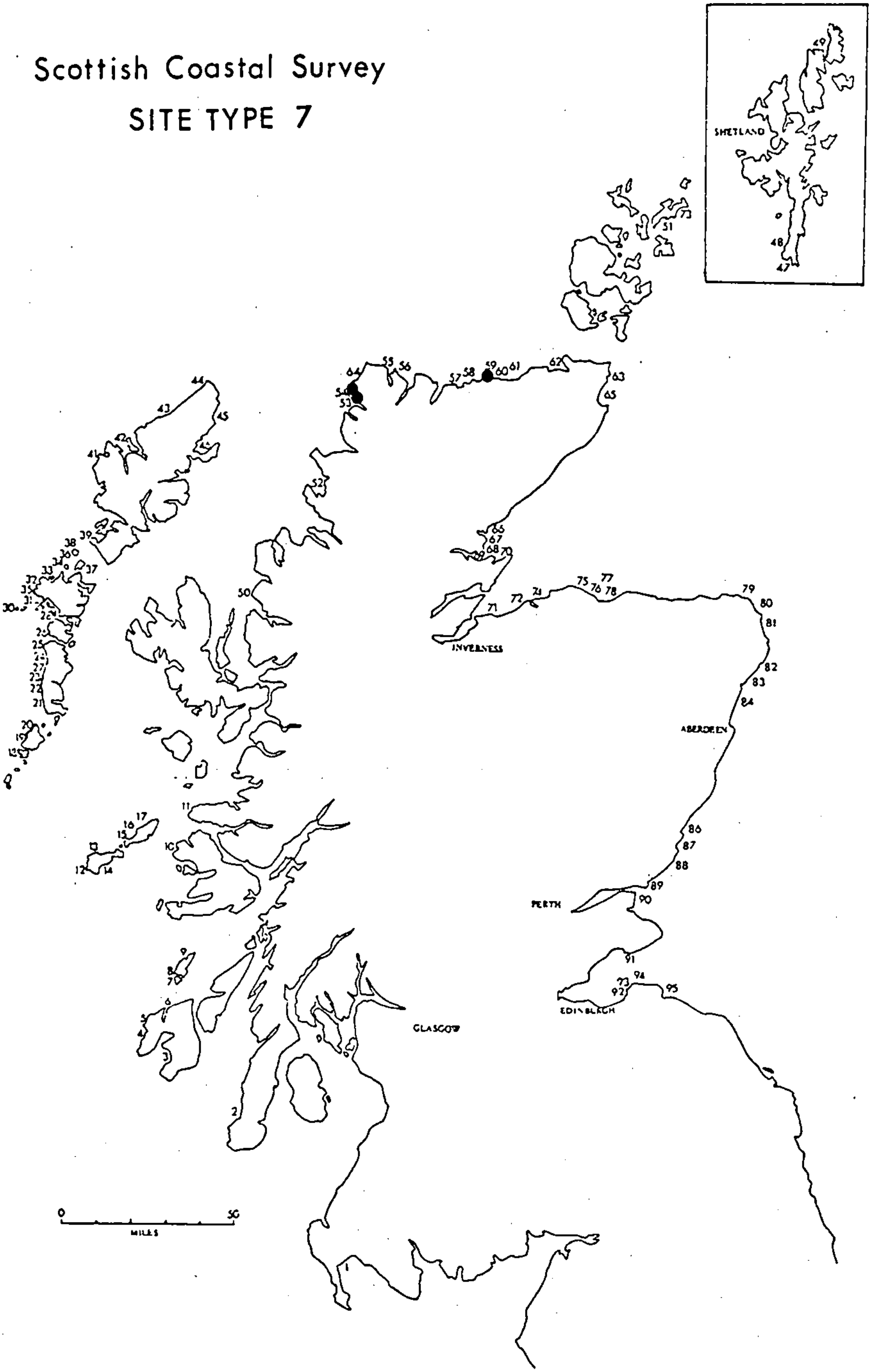
The boundaries of both sites in this type seem to have been rather arbitrarily drawn, cutting across the adjacent croftland rather than following natural or man-made features. At Melvich, the site covers only half the valley floor, omitting the spit by the Big House. At the north end, the site extends up on to the cliff but then the boundary cuts across croftland and probably does not follow the limits of the blown sand. Further south, the boundary drops down the cliff to the valley floor but then rises again to cross an actively worked gravel pit in glacial deposits. At Farr Bay, the site boundary follows an equally vague course. On the west slope, it cuts across the middle of fields and the village, with some houses and the churchyard being included. On the east side, the boundary, runs across the hillside but does not reach the upper limits of the blown sand, with the result that an area almost as large as the delimited site has been omitted from the survey.

Land-use

Both sites are grazed by crofters and there is enclosed croftland adjacent to the sites. Grazing intensity for the two sites is similar, with no grazing in 5.3% of quadrats, light grazing in in 5.8%, moderate grazing in in 33.3% and heavy grazing in in 55.6%. The main grazing animals are cattle (29.3%), sheep (56.5%) and rabbit (89.3%). Other man-made effects recorded in ST6 are wall (2.4%), fence (13.4%), tarmac road (1.2%), dirt road (1.8%), vehicle track (9.7%), unsurfaced path (22.9%), sand quarrying (1.1%), fire evidence (6.2%, the first time this feature has achieved a significant level), recent cultivation (3.7%), old cultivation (2.9%) and rubbish (26.0%). Most of the recorded cultivation was at Farr Bay (11.0% combined). Several aquatic habitats were recorded in ST6 and, in particular, puddle (1.1%), saltmarsh pan (1.1%), stream (4.3%), river (2.7%) and loch (1.1%).

Scottish Coastal Survey

SITE TYPE 7



8.4.7 Site Type 7

Name - North-west Coast, bog type

List of Sites in ST7

Site no. & name	Geographical region	Size (ha)
53 Oldshore More	North Sutherland	117
54 Sheigra	North Sutherland	19
59 Strathy	North Sutherland	48

General Description and Relationship with other Site Types

The three sites allocated to this type (3.2%) are very different in size, from the small Sheigra (19ha) to the much larger Oldshore More (117ha), the mean area for this type being 61ha. All sites are located in North Sutherland. Oldshore More and Sheigra are on the west facing coast, just south of Cape Wrath, and Strathy is in the middle of the north coast (between Farr Bay and Melvich). The sites in ST7 are characterized by having a relatively small area of Ammophila dune near the shore and sometimes this is associated with tall herb communities.

As already noted, ST7 is part of an increasingly acidic trend in soil and vegetation types from ST2 to ST5 and then on beyond to ST8, ST10 and ST9. ST3 and ST6 also follow this trend but are set aside by being somewhat less stable, i.e. the relationship is parallel rather than linear. This means that ST7 is most closely related to ST5 (less acidic) and ST8 (more acidic) and it is with these types that comparisons are most informative. The relative proportion of base-rich dune grassland D1 in the three types illustrates the above interpretation - ST5=40%, ST7=23% and ST8=16%. Similar, but reversed, trends can be seen in slightly acid, damp grassland G1 (ST5=15%, ST7=19% and ST8=28%) and acid, damp grassland G2 (ST5=7%, ST7=15% and ST8=16%). The term "bog" in the type name is justified by presence of 10% of transitional peat bog P1.

The relationship between ST7 and ST8 in terms of indicator and preferential species has already been discussed in Section 8.3.2 (step 11). There is a long list of preferential species for ST7, a fair number of these being exclusive. Most can be interpreted as being bog or marsh species but a number of tall herbs are also included. Some of the more frequent preferentials for ST7 are Carex panicea, Centaurea nigra, Erica tetralix, Heracleum sphondylium, Juncus articulatus, Molinia caerulea, Rumex acetosa, Senecio jacobaea, Vicia cracca and Vicia sepium.

A similar comparison can be made between ST5 and ST7. Preferential to ST5 is a fairly limited list of species with rather varied affinities, e.g. Ammophila arenaria, in 46.5% of quadrats in ST5 and 17.8% in ST7, Carex flacca (28.5% and 6.8%), Cynosurus cristatus (45.2% and 14.8%), Lolium perenne (34.0% and 0.3%), Luzula campestris (45.5% and 16.5%) and Ranunculus bulbosus (21.2% and 1.1%). The interpretation of some of these species is obvious but, for others, it is less so. By contrast, there is a long list of species preferential to ST7 and most of them are easily interpreted. Bog and marsh species are in the majority, e.g. Achillea ptarmica, 16.3% a in ST7 and 4.2% in ST5, Caltha palustris (11.9% and 5.6%), Filipendula ulmaria (16.6% and 7.1%), Juncus articulatus (29.4% and 14.7%), Phragmites communis (11.7% and 0.0%), Pedicularis sylvatica (9.1% and 4.4%), Pinguicula vulgaris (10.3% and 3.2%), Plantago maritima (46.4% and 22.5%), Stachys palustris (5.5% and 0.0%) and Succisa pratensis (51.7% and 23.1%). Other species are tall herbs, perhaps reflecting the reduced grazing intensity in ST7 (see Land-use below), e.g. Angelica sylvestris (29.6% and 6.3%), Centaurea nigra (60.1% and 11.8%) and Heracleum sphondylium (29.9% and 7.5%). Additional species that show an interesting preference for ST7, probably because of the presence of a number of specialized habitats, include Anthyllis vulneraria (26.9% and 0.0%), Carex capillaris (6.3% and 0.1%), Carex serotina (15.7% and 3.0%), Coeloglossum viride (15.2% and 4.1%), Dactylorchis spp. (19.8% and 9.0%), Gentianella amarella (38.8% and 8.9%), Gentianella campestris (5.7% and 2.0%), Hieraceum spp. (10.5% and 0.9%), Hypericum pulchrum (6.1% and 1.6%), Listera ovata (7.3% and 0.1%), Primula veris (16.9% and 0.0%), Rhinanthus minor (33.8% and 8.0%), Scilla verna (8.0% and 1.0%), Selaginella selaginoides (24.2% and 3.4%), Vicia cracca (21.4% and 5.8%) and Vicia sepium (20.1% and 6.2%).

Vegetation Types

The most common vegetation type in ST7 is still base-rich dune grassland D1, with 23% of quadrats (cf. ST5=40% and ST8=16%), and this is closely followed by slightly acid, damp grassland G1 with 19% (cf. ST5=15% and ST8=28%). The closely related acid, damp grassland G2 is the next most common type, with 15% of quadrats (cf. ST5=7% and ST8=16%). The still more acidic vegetation type, transitional peat bog P1, was recorded in 10% of quadrats (cf. ST5=7% and ST8=5%). Unstable vegetation types amount to 14% (cf. ST5=11% and ST8=22%), with D3 (10%), C (1%) and B (3%). Wetter vegetation types are well represented by slightly acid, wet grassland G2 (15%), wet, slightly acid dune grassland D5 (6%) and wet marsh M2 (4%). Of intermediate status, damp, base-rich dune grassland D4 has a mean frequency of 5% (cf. ST5=2% and ST8=2%). Finally, there is just a trace of D2 and the maritime vegetation types F1, S1 and S3.

With just three sites in a type it is difficult to identify deviations from the type profile. Oldshore More has an abnormally high proportion of D1 (46%, cf. mean 23%) and D4 (8%, cf. 5%), suggesting an enhanced base-rich influence, but this site also has a higher than average proportion of P1 (16%, cf. mean 10%). Also missing from Oldshore More are most of the wetter, less extreme, acidic types G6, D5 and M2. Sheigra is dominated by G1 (19%) and G2 (28%) and there is also a considerable contribution from wetter, less extreme acidic types, e.g. G6 (4%), D5 (5%) and M2 (11%). Even Strathy can not really be regarded as typical, with a high proportion of D3 (21%, cf. mean 10%) and B (3%), i.e. 24% of unstable types as compared with the mean of 14%.

Vascular Plants

ST7 is the most species-rich site type in the survey, with an average of 27.4 species per quadrat and 51 species with a frequency of 20% or more. (cf. ST5 with 24.7 and 40 and ST8 with 23.6 and 41 respectively). The most common species in ST7 are Festuca rubra (83.4%), Plantago lanceolata (81.6%), Lotus corniculatus (73.0%), Ranunculus acris (72.3%) and Trifolium repens (70.1%). The comparatively low number of species with a frequency of 70% or more is a result of the extreme diversity of habitats and vegetation types in these sites. A closer examination of the distribution of species frequency within the three sites in type reveals that Sheigra is the odd man out. For example, it has no Ammophila arenaria recorded in it, and this despite having 8% of D3! The explanation here, is that it is the disturbance form of D3 (see Section 7.4.3). A number of other species follow this trend, being quite common at Oldshore More and Strathy but much less common or absent altogether at Sheigra, e.g. Heracleum sphondylium 23% at Oldshore More, 62% at Strathy and 5% at Sheigra, Thalictrum minus (52%, 28% and 4%), Taraxacum spp. (37%, 28% and 2%) Vicia sepium (32%, 28% and 1%), Campanula rotundifolia (27%, 24% and 0%) and Cerastium atrovirens (23%, 14% and 0%). The majority of species do have a similar frequency in all three sites but a few are commoner at Sheigra, e.g. Potentilla anserina, 8% at Oldshore More, 3% at Strathy and 39% at Sheigra, Achillea ptarmica (7%, 7% and 34%), Juncus effusus (7%, 7% and 21%), Phragmites communis (4%, 0% and 31%) and Leontodon taraxacoides (0%, 0% and 27%). It is difficult to provide a satisfactory explanation for some of these differences. For technical reasons connected with the method of sampling employed in 1975 (when Sheigra was surveyed), the distribution of samples in this small and narrow (from side to side) site was not ideal and this may have had some influence. However, the most likely cause is the level of disturbance at Sheigra. This explanation is supported by the form of semi-stable dune grassland D3 that was recorded (see above) and, more directly, by the level of cultivation found on the site. Recent cultivation was recorded in 5% of quadrats and old cultivation in 15% giving a total of 20%.

Cover Types

Vascular plants were recorded in 97.2% of quadrats in ST7 with a mean cover of 99.3%. Species contributing most to this high cover of vascular plants are Festuca rubra (18.2%, cf. ST5=22.8% and ST8=14.9%), Ammophila arenaria (6.0%, cf. ST5=11.3% and ST8=10.4%), Phragmites communis (4.5%, but 15% at Sheigra), Carex panicea (4.2%), Molinia caerulea (3.5%), Plantago lanceolata (3.4%) and Centaurea nigra (3.4%). Bryophytes were recorded in 87.0% of quadrats with a mean cover of 3.4%. Again, it may be significant that bryophytes are somewhat reduced in Sheigra, with a frequency of 71.0% and 1.0% cover. These figures may be compared with those for ST5 with 90.7% and 10.3% and ST8 with 81.5% and 10.1%. Equivalent figures for lichens are 32.6% and 0.6%. As usual the most important non-living cover category is bare sand, in 37.0% of quadrats and with mean cover of 11.0%, but gravel (7.2% and 0.4%), cobbles (6.2% and 0.3%), boulders (10.1% and 1.0%) and solid rock (10.4% and 1.3%) are all worthy of note, particularly as they are often associated with presence of specialized habitats of various kinds. Freshwater was recorded in 12.8% of quadrats with a mean cover of 0.8%.

Landforms

All three sites in this type consist of a bayhead dune system set at the seaward end of a fairly steep sided valley where there is dune formation. The dunes may be developed on same sort of glacial deposit, although the free calcium carbonate content (presumably in the form of shell sand) shows that there must be some marine contribution, at least in those parts of the site that are close to the sea. Oldshore More has 71.3% calcium carbonate, Sheigra has 24.1% and Strathy 19.5%. At Sheigra there is a substantial shingle and boulder bank, through which the stream draining the valley flows. Oldshore More and Strathy also have streams which have cut a channel through the dunes. In the flatter valley bottoms there is marsh formation, e.g. Phragmites marsh at Sheigra, but there are similar habitats in all three sites. Peat formation has taken place on the surrounding hillsides, particularly on local flatter areas. There is often rock outcropping through the peat. Some sea cliffs are included in the sites.

The general aspect of the sites is either south or west (90.4% combined) but local aspect is rather different, showing south (33.9%) and north (29.3%) to be most common. As might be expected on this type of landform, the slopes are quite steep, with only 7.1% under 1 degree. Slopes in the range 1-5 degrees (39.7%) and 5-15 degrees (36.6%) dominate the sites, with 16.7% steeper than 15 degrees. Despite the steep slopes, surface types tend to be quite simple and smooth, with 35.8% plane and 45.6% simple undulating (81.4% combined) and only 14.7% complex undulating and 3.9% broken. Unlike the previous site types, in which a high proportion of quadrats are under the 50ft contour, there is quite a wide distribution of elevation in ST7, with only 34.6% under 50ft (cf. ST5=45.3% and ST8=26.1%, the latter type being even further along the trend), 50-100ft with 23.3%, 100-150ft with 13.3%, 150-200ft with 16.8%, 200-250ft with 7.0% and 250-300ft with 4.9%. Oldshore More is the most elevated site and Sheigra the most low lying, with no quadrats over 100ft OD. Despite the small size of the sites in ST7, they extend quite a long way back from the sea, i.e. up to 1000m, with 5.0% of quadrats. The majority of quadrats are in the 100-400m zone (51.8%).

Soil Types

In ST7 there is quite a marked shift from soils formed on sandy substrates to those composed largely of organic matter, i.e. peats. Mature Deep Sandy Soils are still quite common in ST7, with DS6 (14%) and DS7 (18%). Less mature Deep Sandy Soils also account for a fair proportion of quadrats, with DS1 (2%), DS2 (8%) DS3 (1%) and DS5 (13%). The total for Deep Sandy Soils in ST7 (56%) can be compared with that for ST5 (75%) or even with the more extreme ST2 (79%) and ST4 (95%). Most of the remainder of quadrats in ST7 are occupied by peaty soils of various types. The genuine Peaty Soils account for most quadrats, e.g. PS1=1%, PS2=10%, PS3=3%, PS4=7% and PS5=10%, a total of 31%. Various Thin Soils, all with peat present or with peaty associations, make up the residue - TS7=2%, TS8=3%, TS9=5% and TS10=1% for a total of 11%. As its name implies, ST7 has the largest complement of peaty soils of any site type.

Boundaries

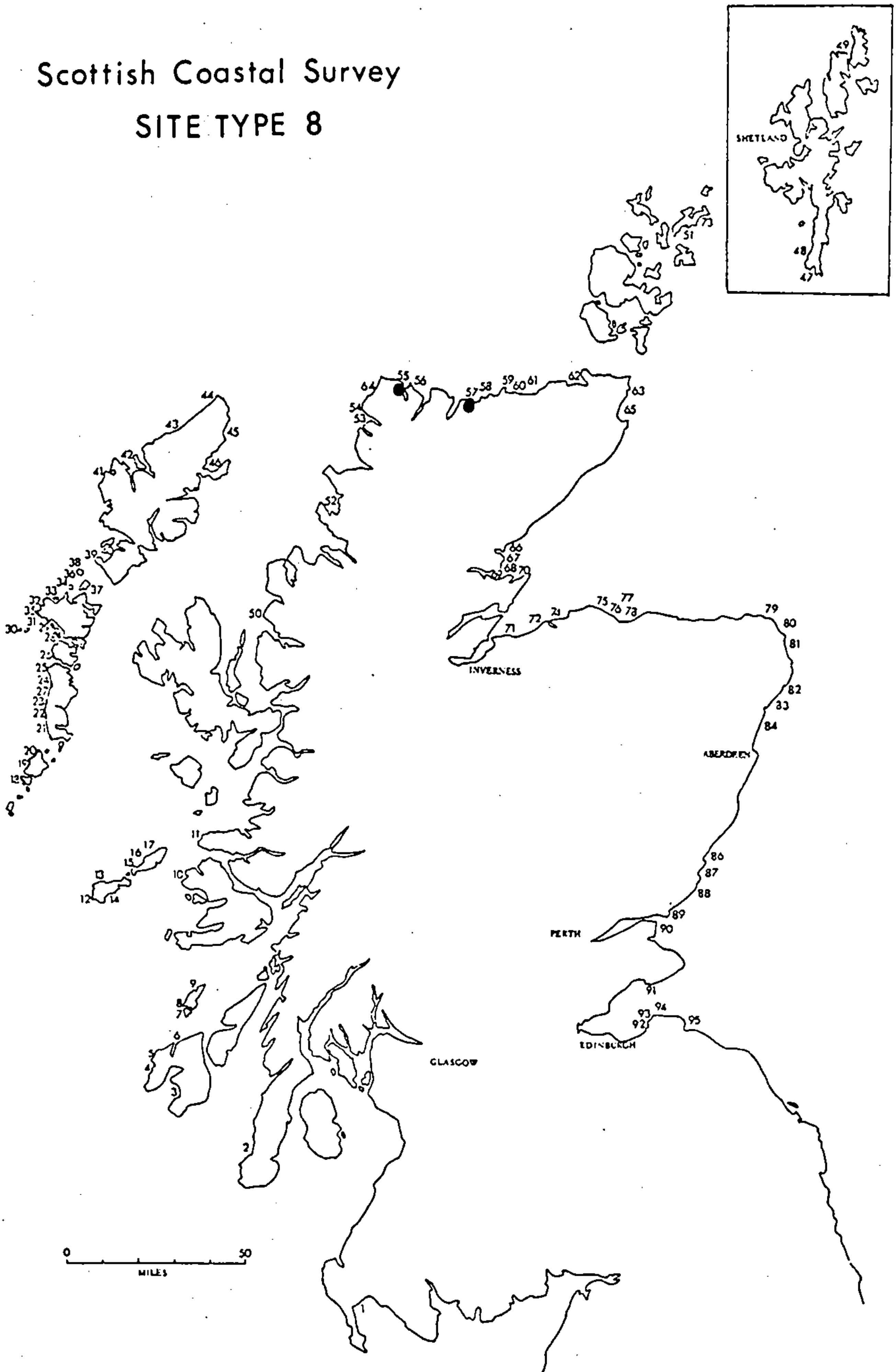
The boundaries of the three sites in ST7 are not very consistent. In some cases enclosed croftland has been included in the site and in others it has been left out. At Oldshore More, some unenclosed, cultivated land has been included within the site boundary. At Sheigra there is also a good deal of arable land in the site but at Strathy it seems to have been, as far as possible, excluded. In all sites considerable areas of peat have been included. At Strathy, peat soils on top of the cliff at about 200ft OD have intercalated bands of sand in the profile and, presumably, this is of wind blown origin.

Land-use

The main land-use for the sites in ST7 is crofting. There is a good deal of arable use in these sites and 10.1% of quadrats were recorded as showing signs of cultivation (2.7% recent and 7.4% old). This activity was most intense at Sheigra, with 20% of quadrats involved. Strathy is the site least affected (3%) but, as already noted, land on which cultivation is most likely was deliberately excluded from this site. Grazing intensity is somewhat reduced compared with ST5, with no grazing in 12.8% of quadrats (cf. ST5 with 7.4%), light grazing in 34.2% (cf. 24.6% in ST5), moderate grazing in 33.5% (cf. 52.5% in ST5) and heavy grazing in 19.4% (cf. 15.3% in ST5). Grazing is still lighter in ST8, with figures of 15.2%, 51.2%, 21.2% and 12.4% respectively. The main grazing animal in ST7 is the sheep, with signs recorded from 76.3% of quadrats. Rabbits are also present in similarly high numbers (81.0%) but cattle are much less important (18.2%, and not all in Sheigra). At Oldshore More, 11.0% of quadrats showed signs of use by horses but there were none in the other sites. Moles were particularly prominent at Strathy, being recorded in 24% of quadrats, but again none in the other two sites. Man-made features of note are embankment (1.2%), wall (1.3%), fence (7.7%, but not at Strathy), dirt road (1.2%), vehicle track (5.7%), unsurfaced path (8.2%), spent cartridges (3.7%, all at Oldshore More with 11.0% of quadrats) and rubbish (18.3%). A range of aquatic habitats occur in ST7, e.g. puddle (4.9%), rut (1.2%), ditch (3.7%), pond (2.4%), flowing ditch (2.6%), stream (8.7%), river (1.3%), flush/spring (5.7%) and dried-up puddle (2.5%).

Scottish Coastal Survey

SITE TYPE 8



8.4.8 Site Type 8

Name - North-west Coast, montane type

List of Sites in ST8

Site no. & name	Geographical region	Size (ha)
55 Durness	North Sutherland	240
57 Bettyhill	North Sutherland	176

General Description and Relationship with other Site Types

This site type has just two sites (2.1%) allocated to it. Both sites are quite large, Durness 240ha and Bettyhill 176ha (mean 208ha), and they are located fairly close together on the western half of the north coast (North Sutherland). The type is characterized by having a high proportion of blown sand over rock but, despite the high cover of bare sand (nearly 20% and higher than any other site type), Ammophila is fairly sparse, occurring in 45.9% of quadrats with a mean cover of 10.4%. As the name suggests, there is a strong montane element in the flora. In the case of Bettyhill, quite a large area of the site (approximately 15%) is over 250ft OD (maximum elevation 375ft) but Durness is a good deal lower, with a maximum elevation of just over 175ft. The occurrence of montane species fairly near sea level at Durness may be a reflection of high exposure at a site that is not far from Cape Wrath. In general, the vegetation of ST8 tends to be rather acidic, e.g. 5% of D2, 28% of G1, 16% of G2, 5% of G3 and 5% of P1. There are dry, acidic soils of variable depth over rock and there are also areas of flushing related to the drainage pattern on the sites.

The differentiation of ST8 from its companion in the site key has already been discussed in Section 8.3.2 (step 11). There is a very long list of preferential species for the species-rich ST7 and these are mostly bog or marsh species, e.g. Caltha palustris, Juncus articulatus, Juncus effusus, Filipendula ulmaria, Erica tetralix and Molinia caerulea, or tall herbs, e.g. Centaurea nigra, Heracleum sphondylium and Senecio jacobaea. One of the most conspicuous preferential species for ST8 is Ammophila arenaria, with 45.9% in ST8 as compared with 17.8% in ST7. Others preferentials indicate dry, acid conditions, e.g. Antenaria dioica, Campanula rotundifolia, Empetrum nigrum, Erica cinerea, Pteridium aquilinum, Veronica chamaedrys and Veronica officinalis. Montane species which are preferential to ST8 include Arctostaphylos uva-ursi, Dryas octopetala, and Juniperus communis.

Following the acid trend still further, a valid comparison can also be made with ST10 - West Coast, acid, dwarf shrub type. The peaty element is much more important in ST10, as indicated by such preferential species as Calluna vulgaris, 45.6% in ST10 and 17.5% in ST8, Carex echinata (14.3% and 3.1%), Drosera rotundifolia (9.8% and 0.0%), Erica tetralix (36.4% and 3.1%), Eriophorum angustifolium (17.0% and 1.5%), Eriophorum vaginatum (5.1% and 0.0%), Juncus effusus (11.9% and 0.0%), Juncus squarrosus (16.0% and 0.0%), Molinia caerulea (35.9% and 7.7%), Myrica gale (12.6% and 1.5%), Nardus stricta (22.3% and 4.6%), Narthecium ossifragum (11.7% and 1.5%), Potentilla erecta (50.6% and

23.7%), and Trichophorum cespitosum (15.7% and 1.5%). Conversely, species preferential to ST8 are rather similar to those for the comparison between ST7 and ST8, e.g. dry, acid-loving species and montane species. Quite a number of species in the comparison are exclusive to ST8, e.g. Anthyllis vulneraria (14.9%), Carex capillaris (13.1%), Coeloglossum viride (19.9%), Dryas octopetala (9.6%), Gentianella campestris (16.4%), Gymnadenia conopsea (23.4%) and Listera ovata (13.4%).

In summary, although it is clear that ST8 is easily distinguished from its related site types, there are also quite big differences between the two sites that constitute the type. This will be illustrated in greater detail below but, in general terms, Durness has greater affinities with ST5 or ST7 whereas Bettyhill shows some feature found in ST10.

Vegetation Types

For the first and only time on the negative side of the site classification (ST1-8), base-rich dune grassland D1, in 16% of quadrats, is not the most common vegetation type in ST8. This role is assumed by slightly acid, damp grassland G1, with 28% of quadrats, but it should be noted that the two sites are very different in this respect, Durness has 53% of G1 and Bettyhill has 3%. Similar quantitative differences occur for nearly all the vegetation types although, qualitatively, the two sites are quite similar, i.e. the same main vegetation types are present but in different amounts. Base-rich dune grassland D1, for example, has a frequency of 23% at Durness but only 9% at Bettyhill (mean 16.0%). Acid, damp grassland G2 is also quite common, with 10% at Durness and 21% at Bettyhill (mean 16%). Bettyhill also has 9% of acid, dry grassland G3 but this vegetation type was not recorded at Durness. Transitional peat bog P1 occurs in 5% of quadrats (Durness with 3% and Bettyhill with 6%). The wetter Duneland types, damp, base-rich dune grassland D4 (3%) and wet, slightly acid dune grassland D5 (3%), both occur only at Durness. Perhaps the most striking difference between the two sites is in the unstable vegetation types, where Bettyhill is seen to have no less than 18% of D3, 21% of C and 3% of B and Durness has none. The dry acid element, but of a less extreme type than G3, is exemplified by slightly acid dune grassland D2 with 5% of quadrats (Durness 3% and Bettyhill 6%). Finally, Bettyhill contains a small amount of saltmarsh as represented by 3% of fringing, mixed saltmarsh S2.

Vascular Plants

ST8 is moderately species-rich, with 23.6 species per quadrat (cf. ST7 with 27.4 and ST10 with 16.6) and 39 species with a frequency of 20% or more (cf. ST7 with 51 and ST10 with 28). The most common species in ST8 are Festuca rubra (86.4%), Plantago lanceolata (75.3%) and Thymus drucei (74.8%). Like ST7, there are relatively few species with a frequency of 70% or more, simply because there is such a wide range of vegetation types present.

As might be expected from what has already been said about the within-site type variation, there are also some fairly striking differences in species frequency between the two sites. Most of these are directly related to the different proportions of vegetation types G1 and D1. Common in Durness, but less so in Bettyhill, are such species as Succisa pratensis (82% and 12%), Achillea millefolium (73% and 12%), Trifolium pratense (83% and 0%), Campanula rotundifolia (67% and 12%), Gymnadenia conopsea (47% and 0%), Rhinanthus minor (43% and

0%), Veronica chamaedrys (43% and 0%), Helictotrichon pubescens (40% and 0%) and many others. Conversely, there are many fewer species that are common in Bettyhill and less so in Durness and the absolute frequency level is much lower, e.g. Cerastium atrovirens (30% and 3%), Empetrum nigrum (21% and 7%) and Juniperus communis (27% and 0%). Generally, the species that are more common in Durness are related to specialized habitats present in that site. Despite the vast difference in unstable vegetation types, i.e. D3, C and B combined total 42% at Bettyhill and 0% at Durness, the frequency of Ammophila arenaria is closely similar, 48% and 43% respectively. Ammophila has quite a high frequency in D1 (56.3%), D2 (85.8%), D4 (22.6%) and G3 (31.6%), so perhaps this is not so surprising, but the similarity of cover in the two sites, Durness (10%) and Bettyhill (11%), is rather unexpected.

Cover Types

Vascular plants occur in 98.5% of quadrats in ST8 with a mean cover of 77.2% (cf. ST7=99.3% and ST10=82.4%). However, it should be noted that the mean cover at Bettyhill is only 55%, whereas at Durness it is 99%. The species which contribute most to this cover are Festuca rubra with a mean cover of 14.9% (26% at Durness and 4% at Bettyhill), Ammophila arenaria (10.4%, Durness 10% and Bettyhill 11%), Festuca ovina (5.7%) and Succisa pratensis (3.2%). Festuca ovina is the converse of Festuca rubra by having higher cover at Bettyhill (8%) than at Durness (3%). Bryophytes occur in 81.5% of quadrats with a mean cover of 10.1% (cf. ST7 with 87.0% and 3.4% and ST10 with 86.1% and 12.2%) and both sites are quite similar in this respect. Lichens have a frequency of 50.9% and cover of 0.4%. Non-living cover types are particularly important in ST8, with bare sand in 51.4% of quadrats (Durness 30% and Bettyhill 73%) and with mean cover of 19.8% (Durness 1% and Bettyhill 38%), gravel (20.0% and 3.3%), cobbles (26.2% and 1.9%), boulders (29.8% and 1.1%) and solid rock (3% and 0.3%). Freshwater occurs in 1.5% of quadrats with minimal cover.

Landforms

Both sites in ST8 are bordered laterally by rivers. To the west of Durness, is the Kyle of Durness, into which flow the rivers Dionard and Grudie. To the east are the lochs Borralie and Croispol, with Loch Lanlish actually in the site, all of which drain into the sea at the north-east corner of the site. Bettyhill has the River Borgie to the west and the River Naver to the east. Both these rivers and the Kyle of Durness contain extensive sandbanks which are exposed at low tide. The most important feature of both sites is the steeply sloping ground (mostly solid rock) over which sand has been blown. Bettyhill is much steeper than Durness but, despite this fact, sand has been blown to a considerable height, probably to the top of Bettyhill at 375ft OD. It is on this higher ground that the montane species are found. There are numerous rock outcrops or scattered rock fragments of various sizes and in some hollows there is peat development but not to the same extent as in ST7 or ST10. The deeper sand is usually at lower levels, particularly round the base of the "hill" that gives rise to the name, Bettyhill. There are also cliff tops to the north and west of Durness but these tend to be rocky, presumably because sand and other fine particles are stripped by the wind in this highly exposed situation. There is little proper dune development in the type, and then only at Bettyhill. Caves and blow holes are a feature at Durness, presumably dissolved out of the underlying limestone and comparable to the nearby Smoo Cave. It is not clear what effect the calcium carbonate derived from Durness Limestone has on this site, i.e. whether the calcium carbonate in the soil is limestone fragments or shell. The calcium carbonate content of sand near to the beach at Durness is 20.9% and at Bettyhill 8.0%.

Because of the landform, the general aspect of ST8 tends to be either east (37.9%) or west (36.5%) but local aspect is less well defined, with only south (14.4%) being a comparatively rare feature. Slopes are moderate to steep, with 67.3% being in the range 1-5 degrees, and 23.5% in the 5-15 degree category. Only 9.2% of quadrats had a slope of under 1 degree but, curiously, none over 15 degrees were actually sampled. Surface types are mostly quite simple, with plane (44.2%) and undulating simple (38.6%). Most quadrats occur under 150ft (79.6%) but they extend up to the 300-350ft zone (4.5%). The majority of quadrats lie in the zone 100-600m from the sea (69.5%) but there are some up to 800-1000m zone (5.0%). There are no quadrats within 10m of the HWMST and only 9.5% in the 10-50m zone.

Soil Types

In contrast to ST7, ST8 is dominated by mature Deep Sandy Soils, DS6 (21%), DS7 (28%) and DS8 (5%) or a total of 54% (cf. ST7 with 14%, 18% and 0% respectively and a total of 32%). As might be expected, mature soils are more important at Durness (69%) than Bettyhill (36%). The converse is true of less mature Deep Sandy Soils, with mean of DS1 (5%), DS2 (12%) and DS5 (10%) or a total of 27% (cf. ST7 with a total of 24%) but occupying 45% of quadrats at Bettyhill. There are occurrences of Sandy Cobble Soils (CS5=2% and CS6=3%) and Thin Soils (TS3=3% and TS5=5%) in both sites. Peaty Soils account for 8% of quadrats in ST8 (PS1=3%, PS2=3% and PS4=2%) and this can be compared with ST7 with 31% and ST10 with 21%.

Boundaries

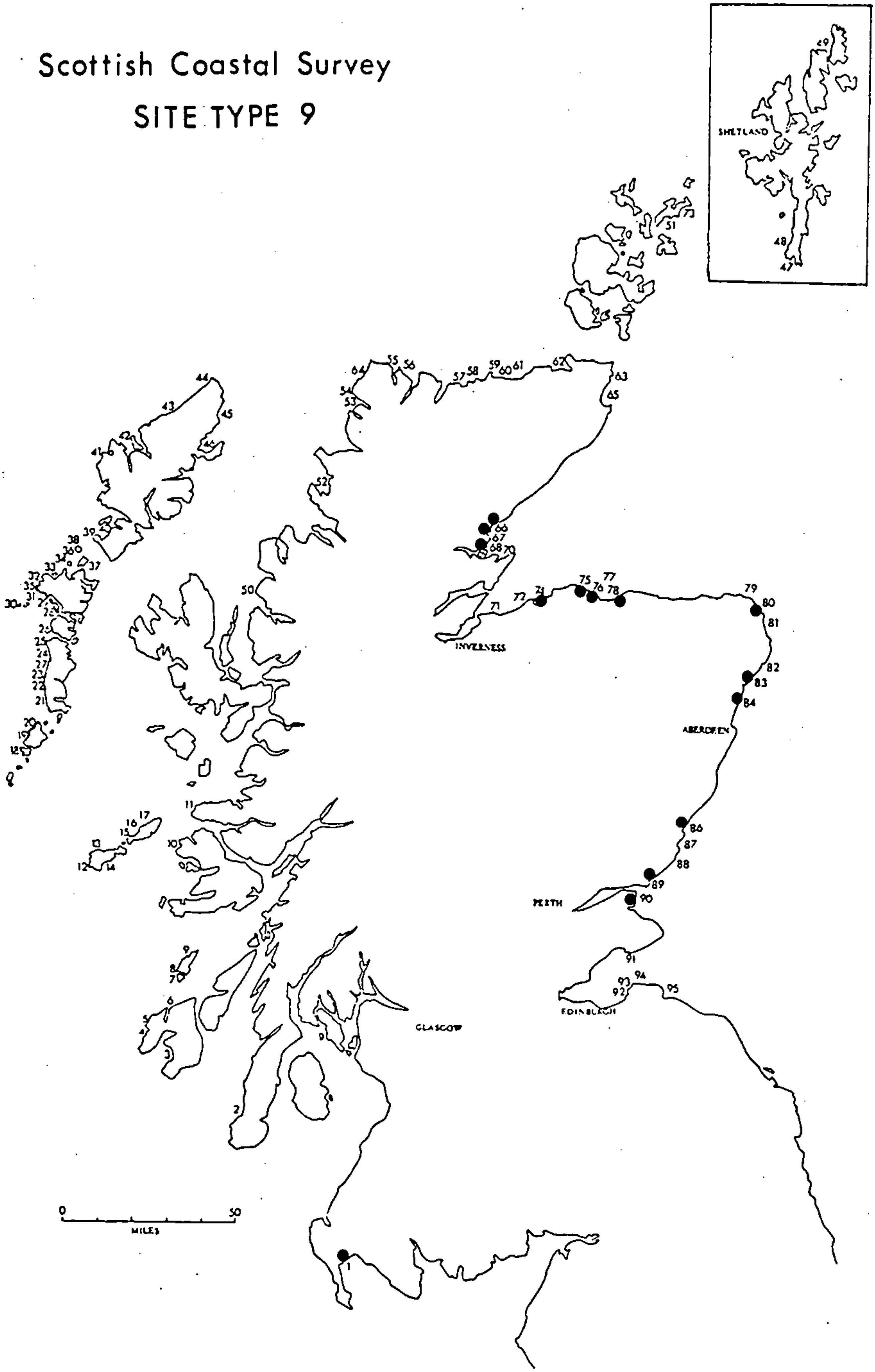
At Durness, most of the area affected by blown sand seems to have been included in the site. However, for the sake of completeness the boundary should have been extended to the margins of Loch Croispol and Loch Borralie. The boundary of Durness near Balnakeil comes very close to that of Faraid Head (ST6). The boundary of Bettyhill is presumably that of the NNR and it does seem to include all the important features of the site.

Land-use

There are no signs of cultivation at either of the sites in ST8 (cf. ST7 with 10.1% and ST10 with 1.0%). The main agricultural activity on both sites is sheep grazing, Durness (50%) and Bettyhill (70%), with a mean of 59.8%. Cattle (mean 40.8%) are also quite common at Durness (63%) but less so at Bettyhill (18%), which is not surprising in view of the terrain. Rabbits were recorded in 49.5% of quadrats (Durness 57% and Bettyhill 42%). Grazing intensity is fairly light in ST8, with no grazing in 13.8% of quadrats, light grazing in 64.2%, moderate grazing in 12.9% and heavy grazing in only 9.1%. Virtually all man-made features are are relatively infrequent in this site type, e.g. wall (1.5%), vehicle track (1.5%), unsurfaced path (1.5%), fire evidence (3%, all at Bettyhill 6%) and rubbish (4.5%), the latter being the lowest value for any site type. No rubbish at all was recorded at Durness. The only aquatic habitat recorded was a stream in two quadrats at Bettyhill (6%).

Scottish Coastal Survey

SITE TYPE 9



8.4.9 Site Type 9

Name - East Coast, main type

List of Sites in ST9

Site no. & name	Geographical region	Size (ha)
1 Torrs Warren	Galloway	881
66 Ferry Links	Moray Firth	200
67 Coul Links	Moray Firth	167
69 Clashmore	Moray Firth	106
74 Findhorn	Moray Firth	199
75 Lossiemouth	Moray Firth	834
76 Spey Bay (West)	Moray Firth	127
78 Spey Bay (East)	Moray Firth	53
80 Strathbeg	Aberdeenshire	512
83 Forvie	Aberdeenshire	720
84 Don to Ythan	Aberdeenshire	464
86 St Cyrus & Montrose	Angus, Fife & Lothian	448
89 Barry Links	Angus, Fife & Lothian	993
90 Tentsmuir	Angus, Fife & Lothian	704

General Description and Relationship with other Site Types

For anyone reading through the site types descriptions sequentially, it would, in some ways, be more logical to deal with ST10 - West Coast, acid, dwarf shrub type, before ST9. This is because many features of ST10, including its geographical distribution, render it more similar to the western and northern site types (ST1-ST8). The reasons why ST10 has been allocated to the predominantly eastern part of the site classification are discussed in context.

East Coast, Main type ST9 is the second most common type in the survey, with 14 (14.9%) sites allocated to it. The size of the sites seems to be bimodal, with a number of sites in the 100-200ha range and others in excess of 500ha. The smallest site is Spey Bay (East) on the Moray Firth, with 53ha and the largest Barry Links in Fife with 993ha. Mean for the type is 453ha and is only exceeded by ST5 with a mean of 474ha. With the exception of Torrs Warren in the south-west of Scotland, all the sites in the type are on the east coast but avoiding the more extreme, deep estuarine situations.

The sites in ST9 are all mainly low-lying with over 90% of the land surface under the 50ft contour (the main exception is Forvie, see Landforms below). In this respect it is very similar to ST1 - West Coast, Hebridean, machair type. The sites are also generally flat but are not so plane as those in ST1. Most of the slopes in ST9 are meso-topographic in scale, i.e. they can be contained within the 200 sq m quadrat (14.1m sides), and have their origin in the process of dune formation. In some respects, the sites in ST9 are typified by their hinterland rather than by the coastal strip and many of the sites extend a long way back from the coast. Five of the bigger sites, Torrs Warren, Strathbeg, Forvie, Barry Links and Tentsmuir, have substantial areas over 1500m from HWMST. Other sites, and particularly those round the Moray Firth, are much more limited in depth, with

Ferry Links, Coul Links, Clashmore, Spey Bay (West), Spey Bay (East) and Don to Ythan extending no further than 800m inland. Some of the smaller sites may not cover the full extent of blown sand but it is difficult to separate the effects of truncation and inherent instability.

The shell content of the sand has an important bearing on ST9. Only three of the sites have an appreciable proportion of free calcium carbonate - Ferry Links (9.6%), Coul Links (8.0%) and Strathbeg (16.6%). Barry Links and Tentsmuir yielded samples with just over 1% calcium carbonate but all the rest are under 1%. The samples used for analyses were taken from quadrats as near to the sea as possible, with the added stipulation that there should be little or no organic content. However, because these are the only samples which have been so far analysed, it is not certain how far inland high calcium carbonate levels extend and how important are the effects of leaching. In the case of Strathbeg and Coul Links, there is, however, good evidence that the effect is more than coastal. Both sites contain a small proportion of base-rich dune grassland D1 (Strathbeg has 14% and Coul Links has 3%), the only sites in ST9 which support this primarily western and northern vegetation type. Further investigation using the ordination of sites shows that Strathbeg and Coul Links are rather extreme within ST9, having some overall similarities with ST6 - North Coast, bayhead, well drained type. The common factor here is presumably the combination of base-rich and moderately acid habitats along with free drainage. There are also some similarities with the related types ST5 and ST7. Despite the moderate calcium carbonate content of the coastal sand at Ferry Links, there is no evidence that its influence extends inland or has any effect on the status of this site within ST9.

The differentiation of ST9 from its companion type in the site key, ST10, has already been discussed in Section 8.3.2 (step 12) in terms of the indicator and preferential species. It was noted that most of the species preferential to ST9 are indicative of dry, acid conditions and, to some extent, disturbance, e.g. <u>Agrostis tenuis</u>, <u>Carex arenaria</u>, <u>Galium saxatile</u>, <u>Hypochoeris radicata</u>, <u>Rumex acetosella</u>, <u>Senecio jacobaea</u> and <u>Ulex europaeus</u>. Conversely, preferential to ST10 there is a long list of species some of which are indicative of wetter, peaty conditions, e.g. <u>Agrostis canina</u>, <u>Carex nigra</u>, <u>Carex panicea</u>, <u>Erica tetralix</u>, <u>Euphrasia officinalis agg</u>., <u>Molinia caerulea</u>, <u>Nardus stricta</u> and <u>Succisa pratensis</u>, whilst other species are more generally indicative of western, oceanic conditions and high calcium carbonate soils, e.g. <u>Bellis perennis</u>, <u>Linum catharticum</u>, <u>Plantago lanceolata</u>, <u>Prunella vulgaris</u> and <u>Thymus drucei</u>.

Because ST9 is at the extreme end of the dry, acid trend in the site classification (ST10 is a combination of wet acid and base-rich oceanic) there is no other closely related site type with which a valid comparison can be made. Both the other east coast types, ST12 - East Coast, truncated type and ST13 - East Coast, Firth type, are primarily coastal sites with little of the hinterland that typifies ST9. ST12 is characterized by instability (with 66% of unstable vegetation types) and ST13 by saltmarsh (with 30% of Saltmarsh vegetation types). The residue of quadrats in these types is made up mainly by slightly acid dune grassland D2 along with lesser amounts of acid, dry grassland G3, the vegetation type that is so typical of ST9 (occupying 53% of quadrats).

Vegetation Types

As already noted, the most common vegetation type in ST9 is dry, acid grassland G3 with 53% of quadrats. Other site types on the positive side of the site classification (ST9-ST14) contain only comparatively small amounts of this vegetation type - ST10=12%, ST12=1% and ST13=6%. Although primarily an eastern vegetation type, G3 does occur in small amounts in the western and northern side of the site classification (ST1-ST8) - ST1=+, ST2=0%, ST3=1%, ST4=1%, ST5=2%, ST6=4%, ST7=0% and ST8=5%. The next most common vegetation type in ST9 is slightly acid dune grassland D2, with 11%. Again this is a primarily eastern type but with some examples in the south-west, e.g. ST3 with 10%. Unstable vegetation types D3 (10%), C (8%) and B (2%) account for 20% of the quadrats in ST9 (cf. ST8 with 22% or ST12 with no less than 66%). All other vegetation types have frequencies of less than 5%. Base-rich dune grassland D1 (1%) occurs in just two sites, Coul Links (3%) and Strathbeg (14%) (see discussion above). Damp, base-rich dune grassland D4 (+) occurs only in the same two sites with 3% in each and further confirms the influence of calcium carbonate rich sand in these sites. Other Duneland vegetation types which have low frequencies in ST9 are D5 (+) and D6 (1%). Slightly acid, damp grassland G1, which so typified the more acid northern sites, e.g. ST5=15%, ST6=10%, ST7=19% and ST8=28%, is relatively unimportant in ST9 (1%), occurring in just four sites. Acid, damp grassland G2 is similar, with a mean frequency of 1%. It only occurs in three sites, but, interestingly, one of these is Coul Links with 10% (cf. ST5=7%, ST6=7%, ST7=15% and ST8=16%). Acid, wet grassland G7 has a frequency of 3% in ST9 (in seven sites), a feature that is shared with ST6 - North Coast, bayhead, well drained type. Apparently sites in ST6 and ST9 both contain the rather specialized habitat that supports G7 but why this should be so is not clear. Very acid, damp grassland G4, (3%) is exclusive to ST9, i.e. it occurs in no other site types, and, what is more, it only occurs in the larger sites in the type. The status of this vegetation type is discussed in Section 7.4.4. The wetter edaphic conditions required for the development of Peatland types are not found to any extent in ST9, e.g. P1 (+), P2 (+) and P3 (1%) (cf. ST10 with P1=18%, P2=14% and P3=1%). The two common Marshland vegetation types M1 (1%) and M2 (4%) are both found in ST9 but the contribution from M2 occurs mainly in two sites, Spey Bay (West) with 26% and Strathbeg with 19%. M3, with a mean of 1%, occurs in four sites. Both Foredune types, F1 (+) and F2 (+), and all five Saltmarsh types, S1 (+), S2 (+), S3 (+), S4 (+) and S5 (+), occur in ST9 but in relatively small amounts and show no consistent pattern.

Turning now to those sites that differ significantly from the vegetation type profile for ST9, Strathbeg, with only 5% of G3 (mean 53%), can immediately be singled out as a rather atypical site. As already discussed, there is evidence of base-rich sand at Strathbeg and this is thought to be the most likely explanation for the 14% of D1 and 3% of D4 recorded there. Strathbeg is unusual in having 19% of M2 (mean 4%) and is also relatively unstable with 38% of unstable vegetation types (D3=14%, C=22% and B=2%) compared with a mean for the type of 20%. Spey Bay (West) is also rather atypical of ST9, with only 18% of G3 (mean 53%) but made up by an above average proportion of wetter vegetation types, G7 (18%, cf. mean 3%), M1 (4%, cf. mean 1%), M2 (26%, cf. mean 4%) and M3 (4%, cf. mean 3%). Extensive gravel workings are probably at the root of this feature. Don to Ythan is a rather unstable site, with 11% of D3 (mean 10%), 32% of C (mean 8%) and 2% of B (mean 2%) giving a total for unstable vegetation types of 45% (cf. mean 20%). Finally, Spey Bay (East), with 83% of G3 (mean 53%), is seen as the most extreme (dry acidic) site in ST9. It is also the least diverse, containing only five vegetation types. However, this is hardly a surprising result for a site that has no coastline and consists entirely of hinterland with a pine plantation occupying much of it.

Vascular Plants

Compared with the western and northern site types on the negative side of the classification (ST1-ST8) which all have a mean of at least 20 species per quadrat, ST9 is relatively species poor, with 14.2 species per quadrat. This is typical of the eastern site types (ST9-14, i.e. the positive side of the site classification) - ST10=16.6, ST11=7.8, ST12=17.7, ST13=13.6 ST14=16.7. Similarly, the number of species with a frequency of 20% or more is equally low, with only 22 species in ST9 (cf. ST10=28 ST11=13, ST12=25, ST13=19 and ST14=24). In the previous site type descriptions, the convention adopted was that all "constant" species, i.e. those with a frequency of 70% or over, were listed at this point in the text. However, ST9 has no species that qualify according to this definition. The most common species are Agrostis tenuis (62.2%), Poa pratensis (50.1%), Carex arenaria (50.0%), Festuca rubra (47.3%), Holcus lanatus (46.5%), Festuca ovina (41.7%), Anthoxanthum odoratum (41.4%) and Calluna vulgaris (41.3%). Ammophila arenaria was recorded in 36.8% of quadrats with a fair degree of uniformity across the site type, except that it was totally absent from Spey Bay (West) and Spey Bay (East) and also occurred in only 14% of quadrats at the adjacent Lossiemouth. Spey Bay (West), for some reason, also lacks Carex arenaria. In general, the two Spey Bay sites and Strathbeg exhibit most of the anomolous species frequencies, or actual omissions, but this is only to be expected in view of their rather atypical status within ST9 (see above).

Cover Types

Vascular plants were recorded from 98.1% of quadrats in ST9 with a mean cover of 88.7% (cf. ST10 with 96.8% and 82.4% respectively). Species which contribute most to this cover are Calluna vulgaris (9.9%, but only present in 41.3% of quadrats), Ulex europaeus (8.0%, but only present in 23.9% of quadrats), Ammophila arenaria (6.9%), Festuca rubra (6.1%), Agrostis tenuis (5.1%), Pinus sylvestris (4.5%) but only common at two sites - Ferry Links, with 21% cover and Lossiemouth, with 38%), Festuca ovina (4.4%) and Carex arenaria (3.8%). There are comparatively large between-site cover differences for many species, e.g. Calluna vulgaris with 21% cover at Torrs Warren, Ferry Links (22%), Coul Links (10%), Clashmore (23%), Findhorn (18%), Lossiemouth (9%) Spey Bay (East) (5%) and Forvie (23%), whereas in the rest of the sites in ST9 it does not exceed 2% cover. There is a similar situation with Ulex - Clashmore (16%), Spey Bay (West) (24%) and Spey Bay (East) (45%) and in the rest of the sites cover is 5% or less. The cover of Ammophila arenaria is more evenly distributed but that for Festuca rubra is less so. Other extreme examples are Pinus contorta with 30% cover at Spey Bay (East) and Pinus nigra with 17% at Lossiemouth. The cover of all three pine species is largely a man-made effect.

Landforms

As already noted, the sites in this site type are either large, over 500ha, or somewhat smaller, in the 100-200ha range, with a mean size of 453ha. With the exception of Torrs Warren in the south-west, the sites are distributed over most of the length of the east coast, from the Moray Firth to the Firth of Forth. In the Moray Firth most of the sites are smaller and, with the exception of Lossiemouth, are 200ha or less. The Moray Firth sites contain raised beach deposits composed primarily of fairly coarse shingle but may also include a variable proportion of sandy material. These deposits are thought to have originated when the sea level was higher than it is now. The maximum elevation in all these rather flat sites is under 50ft and most of them have sand blown up against or on to the top of the raised platforms. This results in the presence of arenicolous vegetation well above sea level. By contrast, the three sites on the northern coast of Aberdeenshire, Strathbeg, Forvie and Don to Ythan, are less flat (Torrs Warren is similar). The extreme example of this type is Forvie, where only 18.4% of quadrats are under the 50ft contour (23.0% in the 50-100ft category, 55.2% in 100-150ft and 3.4% in 150-200ft). The three sites still further south, St Cyrus and Montrose, Barry Links and Tentsmuir, are again of the flat type, with no land over the 50ft contour. Most sites in ST9 have an area of wetland behind the dune ridge and, indeed, several have lochs, e.g. the Loch of Strathbeg. However, the amount of wetland varies from site to site. It is high at Spey Bay (West) and Strathbeg and low at Coul Links, Clashmore, Findhorn, Forvie and St Cyrus and Montrose. There are fairly major rivers, usually with associated tidal sandbanks, adjacent to or cutting through all sites with the exception of Spey Bay (East).

General aspect of the sites is heavily biased against west (3.1%), with the other cardinal points being more or less equal. Local aspect is similar but less polarized, with 19.4% west. Slopes are fairly gentle with 31.1% under 1 degree, 48.4% in the 1-5 degree category, 19.4% in the 5-15 degree category and 1.1% over 15 degrees. The steeper slopes occur mainly on dune ridges rather than being a major topographic feature. This is in sharp contrast to site types such as ST7 and ST8 where the slopes are associated with much larger scale landforms. Surface types in ST9 are mostly simple, with 38.9% plane, 42.7% simple undulating, 16.0% complex undulating and only 2.5% broken. As already noted above, the sites are divided into two types with respect to height, those that are entirely under the 50ft contour and those that contain higher categories of land. Overall, ST9 has 91.4% of quadrats under the 50ft contour, 4.3% in the 50-100ft category and 0.2% in 150-200ft. The distance from the sea to which the sites extend inland has already been discussed above (General Description). It was concluded that the type was characterized more by the hinterland than by the coastal area. Sites round the Moray Firth tend to be less "deep" (about 800m) than those elsewhere (over 1500m). For the site type as a whole, 1.5% of quadrats are within 10m of HWMST and 6.8% are in the 10-50m zone. At the other extreme, 7.9% are 1000-1500m from the sea and 5.1% 1500m+. Modal distance is 200-400m with 25.2% of quadrats.

Soil Types

The most common soil type in ST9 is the semi-mature Deep Sandy Soil DS5, with 30% of quadrats. Other less mature types account for a further 12% (DS1=3%, DS2=5%, DS3=3% and DS4=1%). More mature Deep Sandy Soils are also common, with DS6 (17%), DS7 (10%) and DS8 (3%). It is in ST9 that the Sand Cobble Soils achieve their greatest importance, being most common in the Moray Firth Sites. This series of soil types accounts for 14% of quadrats (CS1=1%, CS2=1%, CS3=+, CS4=10%, CS5=2%, CS6=1%). The occurrence of the Sandy Cobble Soils is usually associated with the presence of raised beaches within the site. All other soil types make a fairly nominal contribution to ST9 - BD2 (1%), TS3 (2%), TS8 (2%) and TS9 (1%). All the Peaty Soil types (PS1-5) are present with a frequency of 1%. The different substrate types that occur within this site type mean that the within-site proportions of many soil types varies a good deal. Spey Bay (West) and

Spey Bay (East) are probably the most anomolous sites, with well above average proportions of Sandy Cobble Soils (51% and 54% respectively). Torrs Warren has the most mature soils with 80% of quadrats (DS6=49% and DS7=31%) and Strathbeg is the least mature with 66% of quadrats (DS1=14%, DS2=13%, DS3=3% and DS5=36%).

Boundaries

In general, the sites in ST9 have quite reasonable boundaries that include most of the soft deposits (mud, sand, gravel and cobbles). Several of the sites contain forestry plantations (mostly pines) and some tree dominated quadrats were recorded in the first year of the survey. It has already been argued (see Section 8.3.4) that this has had little influence on the site classification because the ground vegetation in the plantations seems to have retained its essential characteristics in terms of species complement. On the otherhand, cover may be markedly changed but the classification does not depend on this feature. At Spey Bay (East), the presence of a golf course has meant that the coastal shingle bank has been excluded and this site has no actual coastline in it. The boundaries of the sites are mostly quite natural or are the result of a coincidence between man-made and natural features.

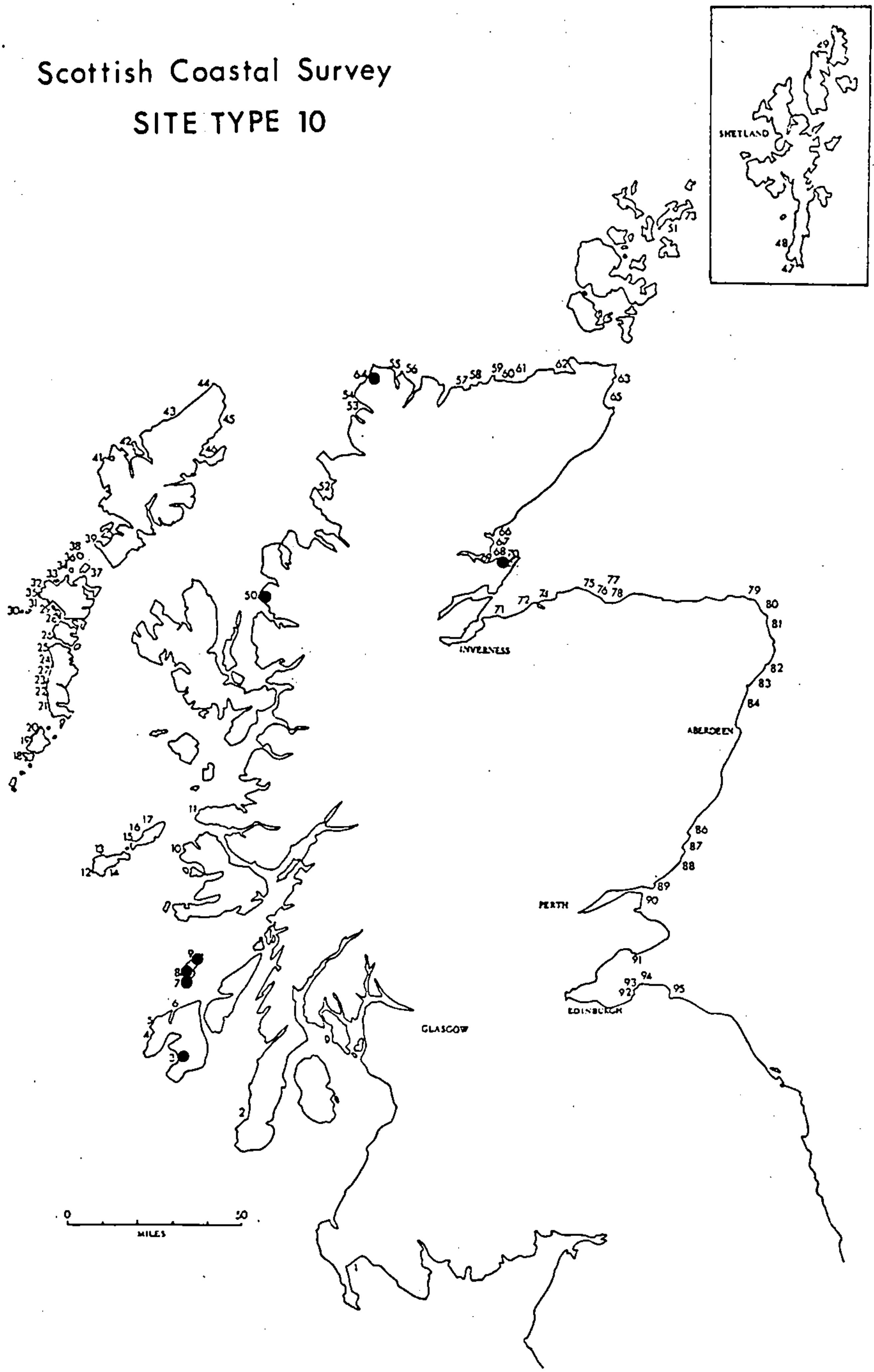
Land-use

For the first time in the site classification, agriculture is not the dominant activity in ST9. If the full extent of the blown sand is considered, and that includes areas not surveyed, then forestry and recreation are the most important land-uses. Farmland comes up to the edge or even encroaches on the sandy area but this use is nowhere near as intensive as on the croftlands in the west and north of Scotland. Large areas of coniferous plantation have been established on several of the sites, e.g. Ferry Links, Findhorn, Lossiemouth, Spey Bay (East) and Tentsmuir, and other sites have smaller areas of trees. In some cases, trees, both coniferous and deciduous, are invading parts of the site by natural regeneration. Recreational use of the beaches, the construction of golf courses and other facilities such as football pitches, caravan parks and camping sites, are all present. Near to the larger towns, e.g. Montrose, industrial and residential developments are encroaching on the dunes.

Reduced agricultural use is reflected in the survey records. Recent cultivation was recorded in 0.1% of quadrats and old cultivation in 0.5%. Only three sites, Torrs Warren, Clashmore and Tentsmuir, are involved with this activity. Grazing intensity is generally low, with no grazing in 15.2% of quadrats, light grazing in 51.2%, moderate grazing in 21.2% and heavy grazing in 12.4%. Coul Links, Clashmore and Tentsmuir are more heavily grazed than average. The records of domestic grazing animals are both low and variable, with a mean for cattle of 15.7% and sheep 14.1%. There are no records for domesticated herbivores on some sites, e.g. Clashmore, Lossiemouth and Forvie. Rabbits seem to be the most consistent feature, being recorded in 80.5% of quadrats and with a high degree of uniformity within the site type (only Spey Bay (West), with 53%, is rather low). Signs of deer were recorded in 7.3% of quadrats, the main sites being Torrs Warren (14%), Ferry Links (33%), Lossiemouth (27%) and Spey Bay (West) (15%). As might be expected, a number of man-made features were recorded in ST9 - embankment (2.5%), fence (3.0%), dirt road (2.4%), vehicle track (10.4%), unsurfaced path (7.4%), sand quarrying (1.7%), spent cartridge (2.4%), other armament (2.3%), fire evidence (8.0%), planted trees (16.9%), and rubbish (32.5%). Particular attention should be drawn to fire which seems to be a feature of this site type. Further discussion of the interpretation of fire evidence and role of this factor in determining several of the vegetation types appears in Section 7.4.5. in connection with wet peat bog P2. Finally, there are a few records of various aquatic habitats in ST9 but only dried-up ditch (1.1%) exceeds a mean of 1%. Certain sites are, however, conspicuous for containing a range of such habitats in small amounts, e.g. Torrs Warren, Coul Links, Spey Bay (West), Spey Bay (East), Don to Ythan and Barry Links.

Scottish Coastal Survey

SITE TYPE 10



8.4.10 Site Type 10

Name - West Coast, acid, dwarf shrub type

List of Sites in ST10

Site no. & name	Geographical region	Size (ha)
3 Laggan Bay	*Colonsay, etc.	352
7 Oronsay	*Colonsay, etc.	352
8 Garvard	*Colonsay, etc.	256
9 Kiloran Bay	*Colonsay, etc.	112
50 Redpoint	Wester Ross	122
64 Sandwood	North Sutherland	91
70 Morrich More	Moray Firth	817

*Colonsay, Islay and Kintyre

General Description and Relationship with other Site Types

There are seven sites (7.4%) allocated to ST10, the mean area of which is 283ha. Most sites are of moderate size, in the range 100-400ha, but the extremes are Sandwood with 91ha and Morrich More with 817ha. This is one of the site types that does not have a discrete geographical distribution and, in this respect, it is like ST3 and ST5. Four out of the seven sites are located in the south-west (Islay and Colonsay), two more are on the north-west coast of the Scottish mainland and the last site is on south side of the Dornoch Firth on the east coast. The common factor in this distribution is oceanic climate, all the sites being located in Birse's Hyperoceanic sub-section (01), although the boundary of this climatic type actually cuts across Morrich More on the east coast.

As with ST9, the sites in ST10 are typified by their hinterland rather than by the coastal fringe. They are also similar to ST9 with respect to the inland extent of the sites, the minimum depth of the sites being 600m with a maximum of 1500m+ at Morrich More. This feature is not so pronounced as in ST9, where five out of the 14 sites have substantial areas (up to 25%) over 1500m from the sea. The sites in ST10 are not nearly so low-lying and flat as those in ST9 (with the exception of Forvie) and only Morrich More has all its surface under the 50ft contour. Kiloran Bay and Redpoint are most extreme in this respect, with about 75% of their surface above the 50ft contour (see Landforms below). There is a strong acidic, peaty element in ST10, with high frequencies of a number of Ericaceous shrubs but lacking the taller shrubs and trees that are quite common in ST9. There is a marked development of Peatland vegetation types in parts of the sites - P1 with 18%, P2 with 14% and P3 with 1%, giving a total of 33% for the type. This is higher than for any other site type (cf. ST5 with a total of 7%, ST7 with 10%, ST8 with 5% and ST9 with 1%). This peaty element is supplemented by some drier, acidic habitats, e.g. G3 with 12% of quadrats and the mildly acidic D2 with 6%. However, despite these strong, acidic influences, which combine to cause the largely western, oceanic ST10 initially to be classified with the eastern types (on the positive side of the first division of the site classification), there are also base-rich habitats present, e.g. D1 with 11%. None of the sites has coastal sand that is devoid of free calcium carbonate but the value for three of the sites is quite low - Laggan Bay (2.1%), Redpoint (4.1%) and Morrich More (5.1%). Other sites have much higher values, e.g. Oronsay (60.8%) and Garvard (64.1%).

The comparison between ST10 and ST9 in terms of indicator and preferential species has already been discussed in the description of the latter site type (see Section 8.4.9). It was noted that there was a very long list of species preferential to ST10 most of which reflect the wetter and peaty conditions in this type, e.g. Agrostis canina, Carex nigra, Carex panicea, Erica tetralix, Euphrasia officinalis agg., Molinia caerulea, Nardus stricta and Succisa pratensis, whilst others are generally indicative of western oceanic conditions and high calcium carbonate sands, e.g. Bellis perennis, Plantago lanceolata, Prunella vulgaris and Thymus drucei.

The other related site type, with which ST10 may be compared, is ST8 (and to a lesser extent ST7). There is a long list of preferentials for ST8, a number of which do not have a ready interpretation. Some of the species preferential to ST8 are indicative of specialized habitats, e.g. the montane conditions that are present in this rather rare and localized site type. The high frequency preferential species (20% or more) are Achillea millefolium, 42.7% in ST8 and 16.6% in ST10, Antennaria dioica (29.4% and 1.3%), Campanula rotundifolia (39.4% and 16.0%), Carex nigra (58.5% and 24.4%), Euphrasia officinalis agg. (50.2% and 23.9%), Festuca rubra (86.4% and 40.9%), Galium verum (60.0% and 24.5%), Gentianella amarella (37.0% and 2.7%), Gymnadenia conopsea (23.4% and 0.0%), Helictotrichon pubescens (20.0% and 1.6%), Hieracium pilosella (30.5% and 6.5%), Hypochoeris radicata (24.1% and 9.4%), Koeleria cristata (37.5% and 18.6%), Linum catharticum (59.6% and 18.7%), Plantago lanceolata (75.3% and 35.8%), Plantago maritima (38.2% and 15.3%), Polygala vulgaris (46.4% and 12.1%). Prunella vulgaris (60.0% and 20.7%), Ranunculus acris (47.3% and 11.1%), Rhinanthus minor agg. (21.7% and 1.9%), Taraxacum spp. (36.1% and 14.6%), Thymus drucei (74.9% and 34.9%), Trifolium pratense (41.7% and 1.8%), Veronica chamaedrys (21.7% and 9.3%) and Viola riviniana (68.2% and 21.9%). Most interesting of the rather specialized species that are also preferential to ST8 are Arctostaphylos uva-ursi (6.1% and 0.9%), Carex capillaris (13.1% and 0.0%), Coeloglossum viride (19.9% and 0.0%), Dryas octopetala (9.6% and 0.0%), Juniperus communis (13.7% and 1.3%), Listera ovata (13.4% and 0.0%), Parnassia palustris (8.2% and 0.9%), Selaginella selaginoides (17.9% and 5.1%) and Trifolium campestre (5.0% and 0.0%). Conversely, those preferential to ST10 are mostly species that are indicative of peaty conditions, e.g. Calluna vulgaris, 45.6% in ST10 and 17.5% in ST8, Carex echinata (14.3% and 3.1%), Carex panicea (33.8% and 12.9%), Drosera rotundifolia (9.8% and 0.0%), Erica cinerea (15.9% and 6.1%), Erica tetralix (36.4% and 3.1%), Eriophorum angustifolium (17.0% and 1.5%), Eriophorum vaginatum (5.1% and 0.0%), Galium saxatile (13.6% and 3.1%), Juncus effusus (11.9% and 0.0%), Juncus squarrosus (16.0% and 0.0%), Molinia caerulea (35.9% and 7.7%), Myrica gale (12.6% and 1.5%), Nardus stricta (22.3% and 4.6%), Narthecium ossifragum (11.7% and 1.5%), Potentilla erecta (50.6% and 23.7%), and Trichophorum cespitosum (15.8% and 1.5%). Of the seven sites in ST10, Morrich More and Kiloran Bay are most closely related to ST8. Morrich More also has some similarities with ST9.

Vegetation Types

The most common vegetation type in ST10 is transitional peat bog P1, with 18% of quadrats, and this is closely followed by wet peat bog P2, with 14%. With the addition of 1% of flushed peat bog P3, Peatland types account for 33% of quadrats in ST10 (cf. ST5=7%, ST7=10% and ST9=1%). The drier, acidic element in ST10 is represented by dry, acid grassland G3, with 12% (cf. 53% in ST9), which is primarily an east coast type. The still less acid and damper grassland types, G2 (6%) and G1 (4%), are also present in significant quantity. The two wetter Grassland types, slightly acid, wet grassland G6 (2%) and acid, wet grassland G7 (1%), are present in smaller amounts. Base-rich dune grassland D1, which is the basic vegetation in most western site types, e.g. ST1=52%, ST2=58%, ST3=33% and ST5=40%, occupies 11% of quadrats (cf. ST8=16% and ST9=1%) but does not occur in two out of the seven sites (Redpoint and Morrich More). Slightly acid dune grassland D2, an eastern and south-western type, has a mean frequency of 6%. The presence of marshy (as opposed to peat bog) conditions is indicated by wet, slightly acid dune grassland D5 (2%) and wet marsh M2 (1%). Unstable vegetation types occupy 18% of quadrats in ST10, with D3 (7%), C (8%) and B (3%). This can be compared with ST8 with 22% of unstable types and ST9 with 20%. Finally, all five Saltmarsh vegetation types occur in ST10 but with low frequencies, S1 (1%), S2 (1%), S3 (+), S4 (2%) and S5 (+).

In terms of its vegetation type profile, Morrich More is seen to be the exception in ST10. This site only contains 9% of Peatland vegetation types (all P1), compared with a mean of 33%, and this is balanced by an increase in Grassland types - 28% of G3 (mean 12%), 9% of G6 (mean 2%) and 16% of G1 (mean 4%). Both D1, which is absent from Morrich More (mean 11%), and D2, in 2% of quadrats (mean 6%), are below average for the type. However, several of the Saltmarsh types are well above average, e.g. S1 with 6% (mean 1%), S2 with 5% (mean 1%) and S4 with 11% (mean 2%). In this respect Morrich More has similarities with ST13 - East Coast, Firth type, but lacks the high degree of instability that is found in this site type, with 33% of unstable vegetation types (7% at Morrich More). Further discussion of the status of of this site appears in Section 8.3.6. The most extreme acid, peaty site in ST10 is Redpoint with no less than 53% of peaty vegetation types (mean 33%) and 16% of G3 (mean 12%). There is also no base-rich dune grassland D1 at Redpoint although the coastal sand does contain 4.1% of free calcium carbonate.

Vascular Plants

In common with the eastern site types, ST10 is comparatively species poor, with only 16.6 species per quadrat and 28 species with a frequency of 20% or more. There is also only one species with a frequency of over 50%, namely Potentilla erecta in 50.1% of quadrats. This is mainly the result of the wide range of vegetation types that occurs in ST10; from deep peat at one extreme, through base-rich habitats and on to the other extreme of saltmarsh. Not even the versatile Festuca rubra can encompass this range. Other common species in ST10 are Anthoxanthum odoratum (46.6%), Calluna vulgaris (45.6%), Trifolium repens (43.9%), Lotus corniculatus (41.3%) and Festuca rubra (40.9%). Ammophila arenaria occurs in 29.0% of quadrats in ST10 (cf. ST8=45.9% and ST9=36.8%). Generally, species frequency is fairly consistent across the seven sites that make up the site type. The most obvious exception is Redpoint which, as the most extreme acidic site in the type, has low values for some species and a few are even absent, e.g. Galium verum (0.0% cf. mean 29.5%), Bellis perennis (9%, cf. mean 24.3%) and Linum catharticum (2%, cf. mean 18.7%).

Cover Types

Vascular plants were recorded in 96.8% of quadrats in ST10 with a mean cover of 82.4%. Species which contribute most to this cover are Calluna vulgaris (11.3%), Molinia caerulea (8.2%), Ammophila arenaria (6.3%), Festuca rubra (6.2%) and Festuca ovina (6.0%). Bryophytes are quite an important component in ST10, with a frequency of 86.1% and a cover of 12.2% (cf. ST8 with 81.5% and 10.1% respectively and ST9 with 85.8% and 11.5%). Lichens are also relatively important, occurring in 42.3% of quadrats with a mean cover of 0.8%. For non-living cover types, bare sand is the most common category, being recorded in 33.6% of quadrats with a mean cover of 12.6% (cf. ST8 with 51.4% and 19.8% and ST9 with 41.4% and 11.3%). All the "harder" substrate types (gravel, cobbles and boulders) are present in small quantities but only solid rock, with a frequency of 11.6% and cover of 2.8%, is worthy of note. Freshwater was recorded in 3.1% of quadrats with a mean cover of 0.7%.

Landforms

The presence of peat formations is the most distinctive feature of ST10. This process requires reasonably flat ground with sufficient moisture or poorly drained hollows. The area where peat formation is to take place must also be reasonably free from the effects of sand blow which may either raise the ground level and improve the drainage or increase the pH by its shell content. At Laggan Bay and Morrich More peat formation has occurred on reasonably flat, low-lying ground but at Redpoint most of the peat lies on a raised platform, just over 50ft OD. At the other sites the peat occurs mostly amongst rock outcrops in the higher parts of the site and well away from the influence of blown sand. Most sites have relatively small sandy bays set amongst rocks, the exceptions being Laggan Bay and Morrich More which have much longer beaches and few rocks. The shores usually have Ammophila covered dunes associated with them and there may also be quite extensive shingle deposits. Smooth machair plain surfaces are not well developed except at Oronsay and short machair type vegetation (mainly D1 and G1 but can be D2) is usually limited to relatively small areas within the site.

Aspects are variable in ST10 but there is a tendency for south (32.1%) and west (30.9%) to predominate. This trend is largely lost at the scale of individual quadrats but west (30.5%) is slightly more common as the local aspect than the other directions. The sites in ST10 are rather variable with respect to slope, varying from the very flat Morrich More, with 86.3% of quadrats under 1 degree slope, to the steeply sloping Sandwood, with only 10.7% of quadrats in this slope category and with 63.0% in the 5-15 degree range. Overall ST10 appears as a site type which is characterized by steep slopes, with only 29.6% under 1 degree, 34.7% in the 1-5 degree category, 29.4% in the 5-15 degree category and 6.3% over 15 degrees. Surface type tends to be either plane 43.2% or simple undulating 32.2% with more complex types totalling 24.5% of quadrats. Altitude ranges up to 250-300ft with 0.4% of quadrats but with 69.5% under the 50ft contour. Morrich More is the most low lying site, with no quadrats over the 50ft contour and Kiloran Bay is the most variable with 24.2% in the 0-50ft zone, 21.2% in 50-100ft, 21.2% in 100-150ft, 21.2% in 150-200ft, 9.1% in 200-250ft and 3.0% in 250-300ft. Redpoint is characterized by having 25.0% in the 0-50ft category and the rest (75.0%) in the 50-100ft zone (presumably some sort of platform effect). As already discussed, the sites in ST10 extend a fairly long way from the sea, with a minimum depth of 600m and a maximum of 1500m+. Modal distance is 200-400m with 25.1% of quadrats and the 100-600m zone accounts for 56.1%.

Soil Types

Mature and immature Deep Sandy Soils are almost equally balanced in ST10. Immature or semi-mature types, DS2 (4%), DS3 (1%) DS4 (1%) and DS5 (20%), account for 26% of quadrats and mature types, DS6 (15%), DS7 (5%) and DS8 (1%) total 21%. Most of the other soils in ST10 are peaty or have peaty influences. Overtly peaty soils, PS1 (2%), PS2 (4%), PS3 (1%), PS4 (9%) and PS5 (5%), total 21% and Thin Soils (most of them over rock or with a high water table), TS6 (1%), TS7 (7%), TS9 (2%) and TS10 (2%), account for a further 12%. There are a few occurrences of Beach Deposits and Sandy Cobble Soils but none of these are particularly characteristic of the site type (cf. ST13 with BD types (7%) and CS types (8%)). Finally, it should be noted that it was not possible to dig any soil pits at Morrich More because of the possible danger from unexploded bombs and shells (see Table 5, where NS=not sampled) and this amounts to 14% of quadrats in ST10.

Boundaries

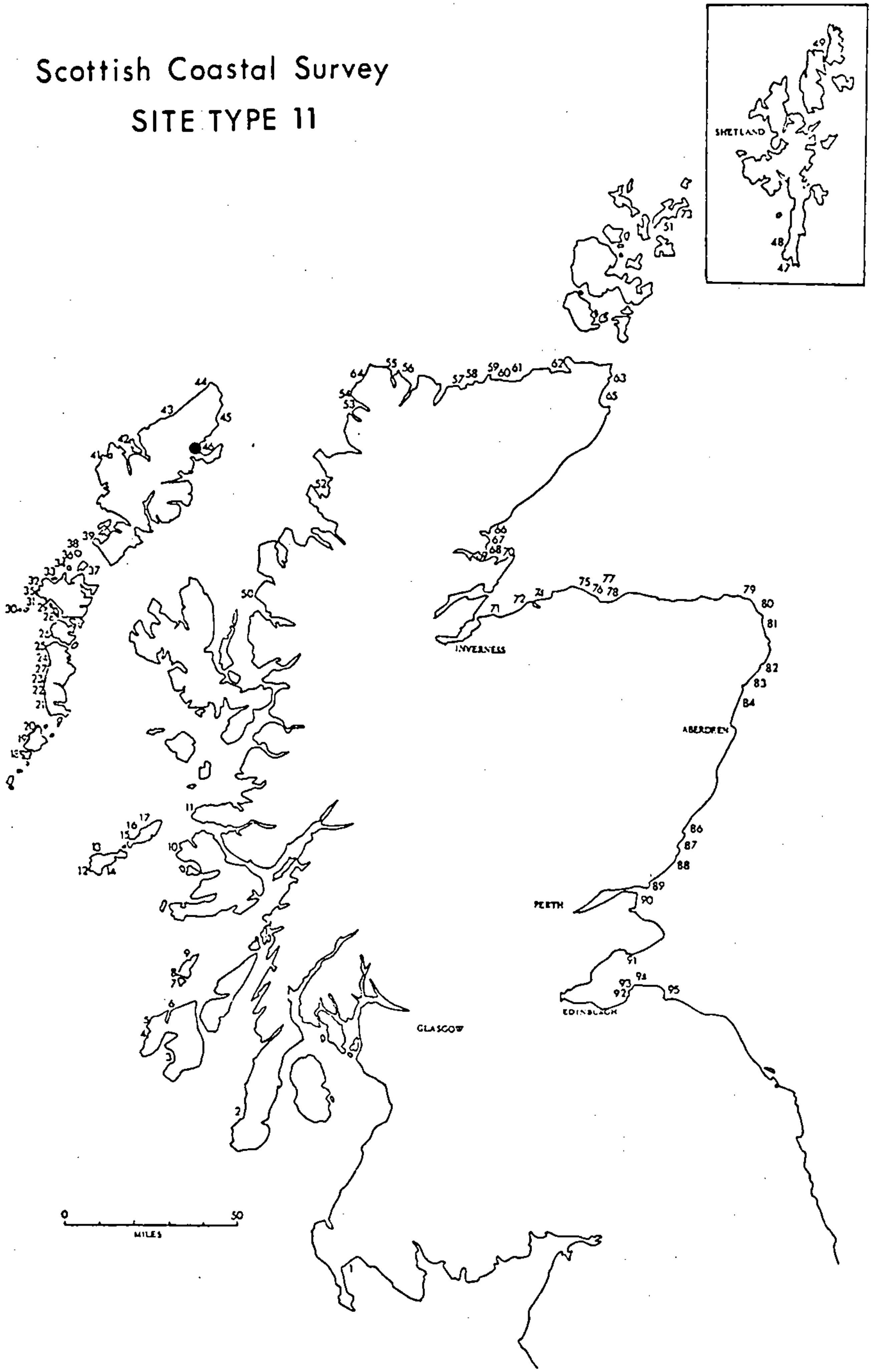
The boundaries of several sites in this site type do not reach the limits of the blown sand and it is not clear whether this has had any significant effect on the site classification. As already noted (see Section 8.3.4), there is quite a large area of blown sand on the hillside to the north-east of the existing site at Sandwood. This hillside contains populations of Dryas octopetala and other montane species and it is possible that Sandwood would have allocated to ST8 - North-west Coast, montane type, had this area been included in the site. The boundaries at Redpoint are also rather arbitrary. However, because it is not easy to determine the limits of the blown sand in some sites from maps alone, in most cases a reasonably sensible boundaries have been drawn. Laggan Bay and Morrich More are mostly bounded by enclosed farmland and the rest by a mixture of man-made boundaries, rock outcrops and steep slopes.

Land-use

The major land-use in ST10 is sheep grazing with signs of this animal being recorded from 82% of quadrats (and fairly consistent across all sites in the type). Cattle are rather less common, with 39.3% of quadrats (not present at Sandwood), but rabbits are obviously important, being recorded in 73.8% of quadrats. Despite the high proportion of sheep and rabbits, grazing intensity in ST10 is only moderate grazing, with no grazing in 9.2%, light grazing in 38.7%, moderate in 26.0% and heavy grazing in 26.1%. This rather odd distribution of grazing intensity, with a high proportion of quadrats lightly grazed but still with over a quarter heavily grazed, probably demonstrates the contrast between relatively unpalatable vegetation, e.g. dwarf shrubs, and the more grassy quadrats which are in the minority but subject to considerable grazing pressure. This type of grazing pattern can be contrasted with a site type in which a most of the vegetation types are relatively palatable, e.g. ST2 with none 13.5%, light 40.8%, moderate 31.4% and heavy 14.3% respectively or ST4 with 4.6%, 27.7%, 48.5% and 19.3% respectively. It should be noted that signs of deer were recorded in 10% of quadrats at Laggan Bay (mean for the type 1.4%). Cultivation (old) was recorded in only 1% of quadrats (3% at Garvard and 4% at Redpoint - reclamation to grass is the source in this latter site) thus emphasizing the comparative unimportance of arable farming in ST10. Man-made features recorded in ST10 include embankment (2.9%, but mostly at Laggan Bay), wall (2.0%), fence (3.0%), vehicle track (3.8%), unsurfaced path (11.7%), spent cartridge (1.2%), other armament (3%, all at Morrich More in 21% of quadrats!), fire evidence (4.6%) and rubbish (18.5%). Aquatic habitats are quite common in ST10 with a wide variety of types being recorded, e.g. puddle (1.8%), ditch (2.4%), stream (2.4%), flush/spring (1.2%), dried-up puddle (2.4%), dried-up rut (2.9%), dried-up ditch (2.9%) dried-up stream (2.6%) and dried-up pond (1.2%).

Scottish Coastal Survey

SITE TYPE 11



8.4.11 Site Type 11

Name - Hebridean Saltmarsh type

List of Sites in ST11

Site no. & name	Geographical region	Size (ha)
46 Tong	Harris & Lewis	104

General Description and Relationship with Other Site Types

There is just one site (1.1%) in ST11, namely Tong on the east coast of Lewis, with an area of 104ha. As this is the only site in a site type that is not closely related to any other, few comparisons are possible and the following is a rough description of the site in question.

Tong is devoid of any dune communities and consists mostly of saltmarsh developed on highly organic, silty sand. The saltmarsh is backed by damp pasture which, in turn, grades into wet peatland. The reasons for drawing the site boundaries to include only the coastal fringe, are not known. However, it seems likely that, whatever the boundary, Tong would remain very different from any other site in the survey. There appears to be no significant area of blown sand around the Sands of Tong and the inclusion of some of the peatland on the west side of the bay would not really make it similar to any other site.

As already noted (Section 8.3.2), ST11 is separated from ST9 and ST10 in step 6 of the key on the basis of 10 positive indicators, all of them saltmarsh species. With a threshold for the division of 4, 5 or more positive indicators are required for allocation to ST11. It has also been argued that ST11 appears on the positive side of the site classification because the only tenuous affinity it has is with ST13 - East Coast, Firth type, which contains 30% of Saltmarsh vegetation types.

Vegetation Types

There is just one quadrat (3%) of slightly acid, damp grassland G1 in Tong. It is located in a slightly raised area of upper saltmarsh S4 in the Laxdale estuary. There are three quadrats (10%) of bare ground B, all of them located on the spits that separate the Sands of Tong from Melbost Sands. The remainder of the quadrats are occupied either by upper saltmarsh S4 (60%) or lower saltmarsh S1 (27%). No quadrats containing mixed or transitional saltmarsh types S2 and S5 were recorded in the survey and this is probably because there are no sharp changes in level at Tong and the chance of finding heterogeneity occurring within a 25 sq in quadrat is low.

Vascular Plants

As might be expected, Tong is the most species-poor site in the entire survey with only 7.8 species per quadrat and 13 species with a frequency of 20% or more. The most common species are Glaux maritima (76.7%), Armeria maritima (73.3%), Plantago maritima (73.3%) and Puccinellia maritima (73.3%). Non-obligate saltmarsh species include Festuca rubra (56.7%), Leontodon autumnalis (46.7%), Agrostis stolonifera (26.7%), Agrostis tenuis (20.0%) and Trifolium repens (13.3%) - some of these will doubtless be saltmarsh ecotypes. No Ammophila arenaria was recorded at Tong.

Cover Types

Vascular plants were recorded in 90.0% of quadrats, with a mean cover of 72.6%. Species which contribute most to this cover are Plantago maritima (17.4%), Festuca rubra (12.7%), Juncus gerardii (12.4%), Puccinellia maritima (7.8%), Glaux maritima (7.4%) and Armeria maritima (5.6%). Bryophytes occur in 13.3% of quadrats with a mean cover of 0.2% and equivalent figures for lichens are 6.7% and no significant cover. Saltmarsh mud is the most important non-living cover category, being present in 46.7% of quadrats with a mean cover of 7.6%. Bare sand is next most common, 26.7% and with cover of 10.5%. Silt, gravel and cobbles are also present but in very small amounts. Saline water has a frequency of 33.3% with a mean cover of 3.3%.

Landforms

Tong comprises a tidal inlet with spits enclosing the entrance and salt and freshwater marshes on the inland side. The inlet dries out at low tide, exposing extensive mud and sand flats. A small river feeds into the north end of the inner bay and to the south there is the larger River Laxdale. The courses of these rivers wind across the Sands of Tong to combine and exit at the south end. Melbost Sands are on the seaward (eastern) side of the bay and the outer spit is largely occupied by lower saltmarsh S1.

General aspect of the site is east (100%) but, at a quadrat scale, only 46.7% face in this direction. Slopes are naturally very gentle, with 70.0% under 1 degree and the rest (30%) in the 1-5 degree range (probably the lower end of the range too). Surface type is dominated by 90.0% plane. The whole of the land surface of Tong is under the 50ft contour. Most quadrats are not far from HWMST, 10.0% are less than 10m, 43.3% in the 10-50m zone, 26.7% in the 50-100m zone, 20.0% in the 100-150m zone and none further than this.

Soil Types

According to the soil classification that was prepared from the field data collected in the survey (see Section 9) the majority of soils at Tong are peaty. Peaty Soil PS5 occupies 57% of quadrats and PS2 has 3% (total of 60%). This situation has arisen because most of the site is occupied by highly organic silt with a relatively small proportion of sand. According to the method of recording, the saltmarsh soils have all the textural and colour characteristics of peat and this is really quite a sensible result in the circumstances. A further 17% of quadrats are occupied by the mature Deep Sandy Soil DS6. The peaty TS8 (3%) and TS9 (7%) account for a further 10% of quadrats and one example of CS7 (3%) makes up the residue.

Boundaries

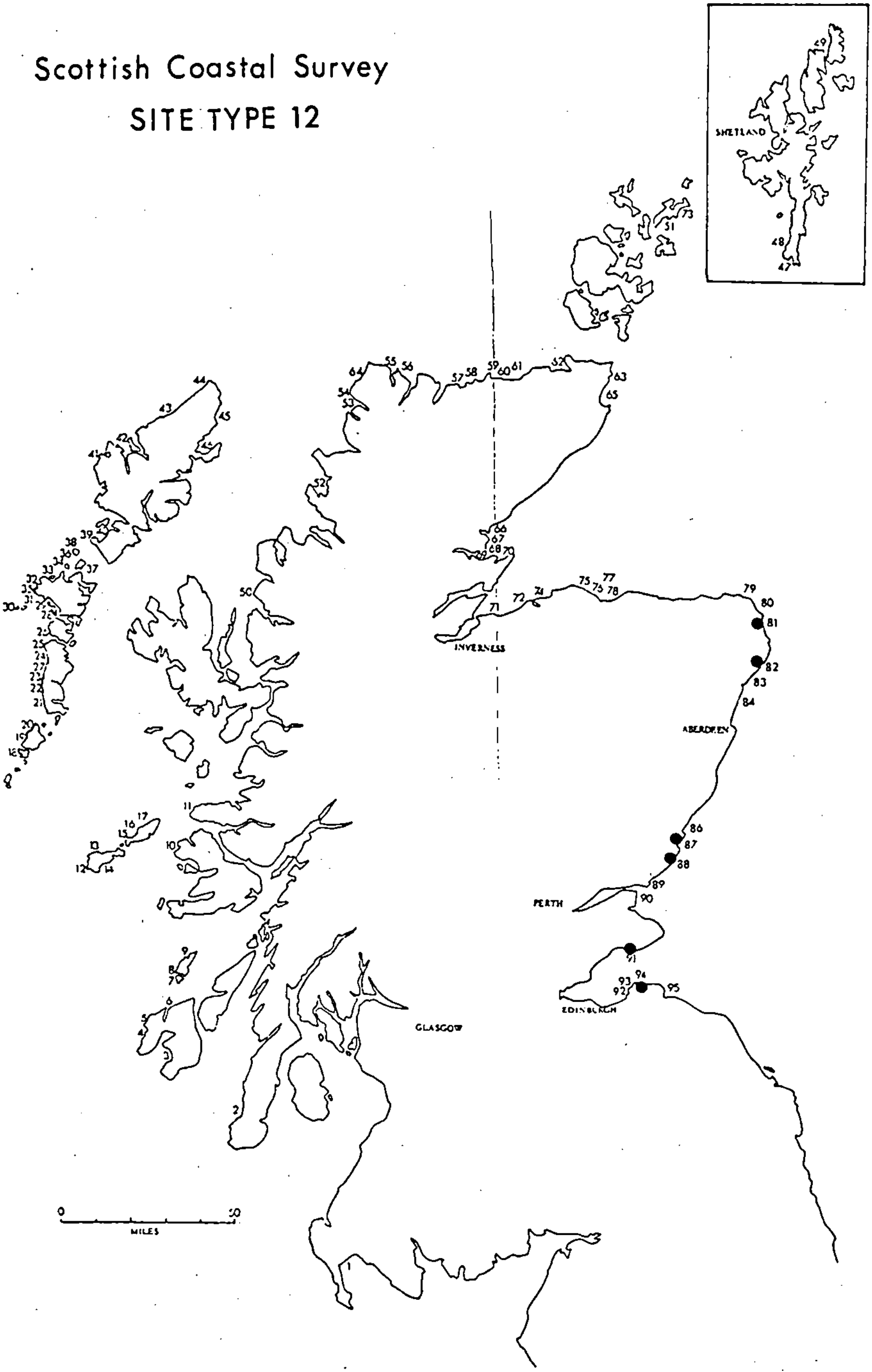
The boundaries of Tong were drawn on the map to include only the soft deposits that form the saltmarsh and associated spits. Possibly a little more of the rough, wet pasture between the two rivers could have been included but, strictly speaking, these do not seem to be coastal in nature.

Land-use

The only land-use recorded at Tong is grazing. The intensity is moderate to light, with no grazing in 23.3% of quadrats, light grazing in 36.7%, moderate grazing in 26.7% and heavy grazing in 13.3%. The main grazing animal is sheep (76.7%), with cattle (43.3%) and rabbit (30.0%) being rather less important. The only man-made features recorded at Tong were unsurfaced path (3.3%), oil deposit (10.0%) and rubbish (16.7%). Various aquatic habitats were also recorded, e.g. rut (6.7%) and river (3.3%), but saltmarsh habitats, e.g. saltmarsh pan or creek (43.3%), were in the majority.

Scottish Coastal Survey

SITE TYPE 12



8.4.12 Site Type 12

Name - East coast, truncated type

List of Sites in ST12

Site no. & name	Geographical region	Size (ha)
81 St Fergus	Aberdeenshire	368
82 Cruden Bay	Aberdeenshire	16
87 Lunan Bay	Angus, Fife & Lothian	68
88 Arbroath	Angus, Fife & Lothian	29
91 Dumbarnie	Angus, Fife & Lothian	160
94 Yellowcraig	Angus, Fife & Lothian	36

General Description and Relationship with other Site Types

There are six sites (6.4%) allocated to this site type. The sites in ST12 vary considerably in size, from the smallest, Cruden Bay with 16ha, to the largest, St Fergus with 368ha (mean area 113ha). All the sites are located on the southern half of the east coast, between Kinnairds Head in north Aberdeenshire and St Abbs Head on the south side of the Firth of Forth. None of the sites occupy deep estuarine situations. As indicated by the type name, the sites in ST12 are truncated. Unlike ST9, which occurs in roughly the same geographical region, the sites do not extend far inland. In some cases, the inland part of the site has been lost to agriculture or other land-uses, such as a golf course or forestry plantation. Other sites, however, seem always to have been narrow, coastal strips, e.g. St Fergus and Lunan Bay. In terms of vegetation, ST12 is characterized by a high proportion of unstable vegetation types - D3 (51%), C (8%) and B (7%), giving a total of 66%. This can be compared with the other eastern site types ST9 with 20% and ST13 with 34%. ST12 may also be compared with its western and northern equivalent, ST3 - North and West Coast, truncated type, which, by coincidence, also has 34% of unstable vegetation types. Ammophila dune is the most important habitat in ST12, with this species occurring in 69.7% of quadrats and with a mean cover of 22.6%.

The comparison between ST12 and its companion in the site key, ST13, has already been dealt with in Section 8.3.2 (step 13), with an interpretation of the indicator and preferential species that mark this division. There is a long list of preferential species for ST12 and it includes such tall grasses as Agropyron repens and Arrhenatherum elatius, which are usually indicative of low grazing intensity. Other species seem to reflect, at least in part, the difference in the proportion of certain habitats in ST12 as compared with ST13, e.g. the high proportion of saltmarsh in the latter type. Preferential to ST12 are such species as Centaurea nigra, Cirsium vulgare, Dactylis glomerata, Galium verum, Heracleum sphondylium, Koeleria cristata, Plantago lanceolata and Trifolium repens. As might be expected, the species preferential to ST13 are mostly saltmarsh types but also some "weeds", e.g. Geranium molle and Veronica arvensis.

The other valid comparison is with ST3 and this has been discussed previously at some length (see Section 8.4.3). The conclusion is that ST3 is differentiated by having a long list of preferential species that are typical of the western machairs, e.g. Bellis perennis, Leontodon autumnalis, Linum catharticum, Prunella vulgaris, Ranunculus acris, Ranunculus bulbosus, Ranunculus repens, Trifolium pratense and Trifolium repens. There are fewer species preferential to ST12. Again the two tall grasses, Agropyron repens and Arrhenatherum elatius, seem to be particularly characteristic if ST12. Also present is a range of other species that are limited to, or are more common in, eastern Scotland, e.g. Astragalus danicus, Briza media, Echium vulgare, Ononis repens, Torilis japonica and Viola hirta. Both Agropyron junceiforme and Elymus arenarius are preferential to ST12.

Vegetation Types

As already noted, semi-stable dune grassland D3 is the most common vegetation type in ST12, with 51% of quadrats. This is the highest proportion in any site type (cf. ST3=25%, ST6=15% and ST13=22%). With the addition of the other unstable types, colonizing communities C (8%) and bare ground B (7%), unstable vegetation types account for 66% of quadrats in ST12 (cf. ST3=34%, ST6=21%, ST8=22%, ST9=20% and ST13=34%). The second most common vegetation type in ST12 is slightly acid dune grassland D2, with 17% (a type with a marked eastern and south-western geographical distribution). Other duneland types present are base-rich dune grassland D1 (9%, usually a western and northern type), damp, base-rich dune grassland D4 (1%) and wet, slightly acid dune grassland D5 (1%). It is noteworthy that neither Cruden Bay nor Lunan Bay contain any D1. This is probably related to the low levels of free calcium carbonate in the coastal sands of these sites, 3.1% and 1.2% respectively. This in contrast to the other sites in ST12, St Fergus (17.9%), Arbroath (10.0%), Dumbarnie (10.1%) and Yellowcraig (20.8%). Grassland vegetation types are conspicuous by their near absence in ST12 (cf. ST9 where this family accounts for over 60% of quadrats), the only examples being G1 (1%), G3 (1%) and G6 (+). Disturbed, wet marsh M1 occurs in 4% of quadrats and may almost be added to the unstable vegetation types. Finally, dry foredune F1 has a frequency of 1% but only occurs at Cruden Bay (3%).

The most unstable site in ST12 is probably Cruden Bay, with D3 (47%), C (10%) and B (37%), i.e. 94% of the site! The adjacent site of Lunan Bay is similar, with 79% of D3. By contrast, the most stable site is Dumbarnie, with D3 (24%) and C (7%), giving a total of 31% (cf. mean 66%). Dumbarnie also has a wet element, with M1 (10%) and D5 (3%). The fact that four out of the six sites in ST12 have some base-rich dune grassland D1 in them, is discussed in Section 8.2.

Vascular Plants

ST12 is reasonably species-rich for an eastern site type, with 17.7 species per quadrat (cf. ST9 with 14.2 and ST13 with 13.6) and 25 species with a frequency of 20% or more (cf. ST9 with 22 and ST13 with 19). The most common species in ST12 are Festuca rubra (81.7%), Poa pratensis (75.4%), Ammophila arenaria (69.7%), Senecio jacobaea (66.9%), Galium verum (66.9%), Plantago lanceolata (54.6%), Carex arenaria (51.6%) and Cerastium holosteoides (50.1%). There is a fair degree of uniformity of species frequency within the site type. The only obvious trend is that the less stable northern sites, i.e. St Fergus, Cruden Bay and Lunan Bay, tend to have lower frequencies for many species (and even absences) as compared with the more stable southern sites.

Cover Types

Vascular plants were recorded in 92.7% of quadrats in ST12 with a mean cover of 92.6%. Species contributing most to this cover are Festuca rubra (23.2%), Ammophila arenaria (22.6%), Festuca ovina (4.4%), Arrhenatherum elatius (3.5%) and Agropyron repens (3.0%). This is the highest frequency and cover for Ammophila in any site type. Bryophytes are present in 72.7% of quadrats with a mean cover of 5.4% (cf. ST9 with 85.8% and 11.5% and ST13 with 56.9% and 3.8%). Equivalent figures for lichens are 14.8% and 0.2%. As might be expected in such an unstable site type, bare sand is the most important non-living cover category in ST12, with a frequency of 51.8% and mean cover of 17.2% (cf. ST3 with 54.9% and 14.0%, ST9 with 41.4% and 11.3% and ST13 with 46.6% and 14.3%). Gravel, cobbles and boulders are all present at low frequencies (under 5%) but contribute little cover. Neither fresh nor saline water were recorded in ST12.

Landforms

The main feature of the sites in ST12 is the substantial formation of dunes at the seaward edge. In many cases this is backed by a fossil cliff that may have the dunes blown against it. Along the coast on which these sites occur there are traces of the "15ft", "25ft" and "100ft" raised beaches. Several of the sites are limited at the landward side by a low cliff, e.g. the southern half of Lunan Bay, or the site itself may be perched on a low plateau, e.g. the northern half of Lunan Bay. Some sites have streams or rivers crossing them.

The general aspect of the sites is east (66.7%) but, because there is such well developed local topography in terms of dunes and dune ridges, local aspect is nearly neutral. Slopes are fairly gentle, with 19.1% under 1 degree, 50.5% in the 1-5 degree category, 28.7% in the 5-15 degree category and 1.7% over 15 degrees. Surface types are also fairly simple, with 31.6% plane, 45.6% simple undulating, 18.2% complex undulating and 4.6% broken. None of the sites in ST12 has quadrats over the 50ft contour and the majority are quite close to the sea, e.g. 41% within 50m. Most quadrats are in the 10-200m zone (82.0%). Dumbarnie is the site that extends furthest inland (800m).

Soil Types

As might be expected, immature or semi-mature Deep Sandy Soils are the dominant type in ST12, with DS5 (56%) being the most frequent. To this must be added DS1 (3%), DS2 (9%), DS3 (4%) and DS4 (4%), giving a total of 76%. More mature Deep Sandy Soils DS6 (7%) and DS7 (9%) account for a further 16% (total 92%). The remaining quadrats are occupied by a range of soil types - Beach Deposits (1%), Sandy Cobbles (5%), Thin Soils (3%) and Peaty Soils (1%).

Boundaries

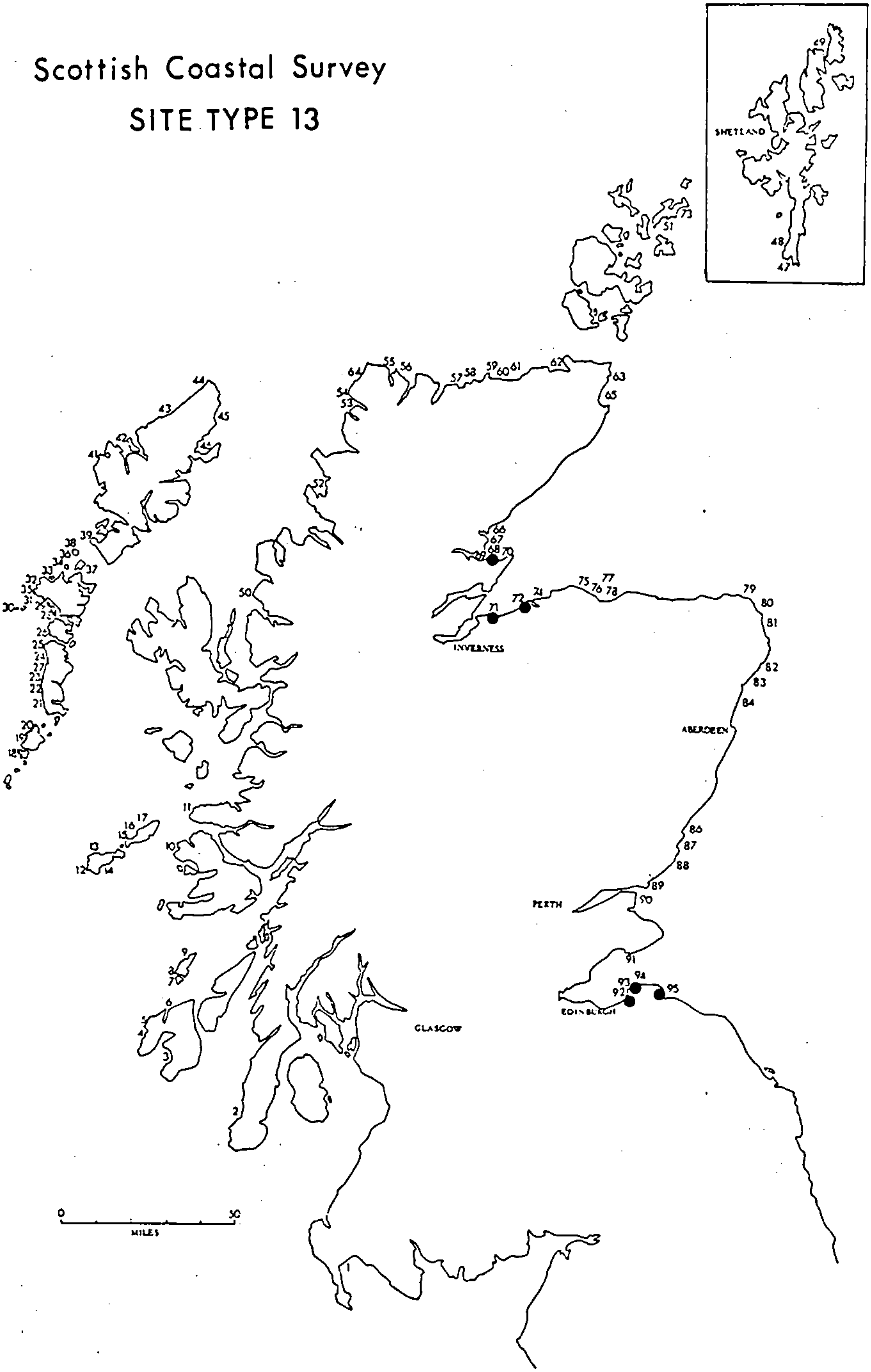
As already noted, St Fergus and Lunan Bay are thought to have fairly natural boundaries which include most of the blown sand. The other sites all appear to have been truncated to some degree by man-made activities: Cruden Bay by a golf course; Arbroath by a railway line backed by a golf course and agriculture; Dumbarnie by a disused railway line and forestry plantation; and Yellowcraig by a golf course and forestry plantations. It is impossible to say how much these losses have affected the sites in question. Some of the sites might be more similar to ST9 if their hinterland was complete but it is difficult to be certain on this point.

Land-use

The main land-use for the sites in ST12 is as rough grazing for the adjacent farms. The grazing intensity is, however, quite light, with no grazing in 23.5% of quadrats, light grazing in 35.0%, moderate grazing in 24.6% and heavy grazing in 16.9%. There are big differences between the sites in this respect, with Cruden Bay being largely ungrazed (93% of quadrats with no grazing recorded) and Dumbarnie quite heavily grazed (52% of quadrats heavily grazed). The most important domestic herbivore is cattle, recorded in 30.2% of quadrats (but none at Cruden Bay or Yellowcraig). Sheep are virtually absent from this site type, with a mean of only 1.2% (all at St Fergus with 7%). Rabbits are very common in ST12, with a mean of 78.5% (but only 7% at Cruden Bay). No signs of cultivation were recorded in ST12 but at Lunan Bay no less than 12 quadrats were abandoned because they bore an arable crop at the time of survey (probably more or less permanent cultivation). Other man-made features recorded in the type are embankment (1.7%, but all at Arbroath), fence (6.1%, but none at Dumbarnie or Yellowcraig), vehicle track (6.7%), unsurfaced path (35.6%, a measure of recreational pressure), spent cartridge (2.7%), fire evidence (1.5%), planted trees (2.6%), rubbish (50.1%). The value for rubbish is the highest in the survey. Occasional aquatic habitats were recorded in ST12, mostly in the dried-up (at the time of survey) category.

Scottish Coastal Survey

SITE TYPE 13



8.4.13 Site Type 13

Name - East Coast, Firth type

List of Sites in ST13

Site no. & name	Geographical region	Size (ha)
68 Dornoch	Moray Firth	77
71 Whiteness	Moray Firth	67
72 Culbin Bar	Moray Firth	121
92 Aberlady	Angus, Fife & Lothian	128
93 Gullane	Angus, Fife & Lothian	135
95 Tyninghame	Angus, Fife & Lothian	103

General Description and Relationship with other Site Types

This site type has six sites (6.4%) allocated to it with mean area of 105ha. The size of the sites within the type is remarkably uniform, from the smallest, Whiteness with 67ha, to the largest, Gullane with 135ha. ST13 is characterized by containing quite a high proportion of Ammophila covered dune, e.g. D3 (22%), C (7%) and, to some extent, D2 (20%). Unstable vegetation types (D3, C and B) account for 34% of quadrats in ST13. The maritime influence is the other feature of this site type, with 30% of quadrats belonging to the Saltmarsh family of vegetation types. Like ST12, most of the sites in ST13 seem to be somewhat truncated, either by anthropogenic factors, e.g. golf course construction or agriculture, or naturally by spit formation, as at Whiteness and Culbin Bar. The type is confined to the east coast where the sites occur in two distinct groups; three sites on the Moray Firth and another three on the south side of the Firth of Forth - hence the type name. The comparatively deep estuarine situation that is the typical location of the sites in ST13 is associated with relatively low beach energy and extensive tracts of tidally exposed sand.

The difference between ST13 and its companion in the site key, ST12, has already been discussed in the context of the latter type. The species which are preferential to ST13 are mostly saltmarsh plants, e.g. Armeria maritima, Aster tripolium, Carex extensa, Cochlearia officinalis, Glaux maritima, Juncus gerardii, Plantago maritima, Puccinellia maritima, Salicornia spp., Spergularia media, Suaeda maritima and Triglochin maritima. Other preferential species are indicative of a significant contribution from dry, acidic habitats that are not present in ST12, e.g. Aira caryophyllea, Calluna vulgaris, Sedum acre, Teucrium scorodonia and Veronica officinalis. There is also a "weed" or disturbance species element in ST13, e.g. Cerastium atrovirens, Geranium molle, Valerianella locusta and Veronica arvensis.

Apart from ST12, there is no other site type with which ST13 has a strong relationship. Obviously there is some similarity with ST11 - Hebridean Saltmarsh type, through the presence of Saltmarsh vegetation types, but, as this type is composed of saltmarsh and little else, this is a comparatively superficial comparison. It should also be noted that ST11 contains only the "pure" Saltmarsh types, S1 and S4, whereas ST13 contains all five types (S1-S5).

A closer examination of ST13 reveals that the Moray Firth sites are systematically different from those further south on the Firth of Forth. The northern sites have a stronger dry, acidic element as exemplified by the presence of dry, acid grassland G3 at Whiteness (21%) and Culbin Bar (14%). As a result, these two sites bear some similarity to the less extreme members of ST9, e.g. St Cyrus and Montrose or Barry Links (with 62% and 56% of G3 respectively). In this respect, it is also significant that Whiteness and Culbin Bar have virtually no free calcium carbonate in their coastal sand (0.1% in both cases) whereas the other sites in ST12 have modest amounts - Dornoch (8.6%), Aberlady (6.1%), Gullane (8.4%) and Tyninghame (3.7%).

Vegetation Types

The most common vegetation type in ST13 is semi-stable dune grassland D3 with 22% of quadrats. Along with colonizing communities C (7%) and bare ground B (5%), this gives a total 34% for unstable vegetation types. The next most common vegetation type is slightly acid dune grassland D2, with a mean frequency of 20%. Although this type is present in all sites in the type, its quantity is extremely variable, from 1% at Tyninghame to 62% at Gullane. Other Duneland vegetation types are only present in small amounts, D1 with 9% at Dornoch (mean 2%) and D4 with 3% at Aberlady (mean 1%). Whereas the proportion of D2 in ST13 is similar to that in ST12 (17%), there is quite a big difference for D1 (2% in ST13 and 9% in ST12). The contribution of the Grassland vegetation types to ST13 is rather limited (but not so limited as for ST12), with 6% of dry, acid grassland G3 (but, as already noted, in Whiteness and Culbin Bar only) and a small amount of G5 (+, but only at Whiteness). There are also a few Marshland types in ST13, damp disturbed marsh M1 with 4% of quadrats (the same as in ST12) and wet marsh M2 with 3% of quadrats. Turning attention now to the maritime vegetation types that so characterize ST13, Saltmarsh types account for 30% of quadrats - lower saltmarsh S1 (13%), fringing, mixed saltmarsh S2 (3%), saltmarsh/strandline transition S3 (4%), upper saltmarsh S4 (9%) and upper saltmarsh/dune transition S5 (1%). There are also a few examples of dry foredune F1 at Culbin Bar and Aberlady (mean 2%).

As far as within-type differences in the proportion of vegetation types are concerned, Dornoch with 49% of Saltmarsh quadrats and Whiteness with 43%, are seen to be the two sites with the greatest maritime influence. By contrast, Gullane has no Saltmarsh types, being composed largely of D2 (62%), D3 (27%) and C (9%). The other three sites are intermediate with respect to their proportion of Saltmarsh types - Culbin Bar (32%), Aberlady (22%) and Tyninghame (29%), compared with a mean for the type of 30%. Tyninghame is the most unstable site, with 57% of unstable types (D3, C and B), and is followed in this respect by Gullane with 37% (cf. mean 34%). As already noted, Whiteness and Culbin Bar contain a significant proportion of G3, not found at all in other sites in ST13. Aberlady has quite a strong wetland element, with 10% of M1 and 16% of M2 (total 26%). These two vegetation types are present in all sites, with the exception of Dornoch, and are usually associated with streams or low-lying ground with a high water table.

Vascular Plants

ST13 is quite a species-poor site type, with only 13.6 species per quadrat (cf. ST12 with 17.7) and 19 species with a frequency of 20% or more (cf ST12 with 25). There are no species with a frequency of 70% or more in ST13 but the most common species are *Festuca rubra* (67.4%), Poa pratensis (51.7%), Ammophila arenaria (48.3%, cf. ST12 with 69.7%), Senecio jacobaea (44.9%), Carex arenaria (32.9%), Galium verum (32.3%), Holcus lanatus (31.0%) and Lotus corniculatus (30.4%). There is a fair degree of consistency in the frequency of species within the site type but there is a general tendency for the three northern sites to be different from the three southern ones, e.g. Cirsium arvense 6%, 5% and 6% in the north (Dornoch, Whiteness and Culbin Bar respectively) as opposed to 52%, 60% and 37% in the south (Aberlady, Gullane and Tyninghame) and Cerastium holosteoides 22%, 3% and 17% as opposed to 45%, 56% and 26%. Similarly, most of the "weed" species are more frequent in the southern sites than in the north, e.g. Geranium molle (0%, 0%, 0%, 6%, 17% and 10%), Myosotis arvensis (0%, 0%, 0%, 6%, 10% and 13%) and Erodium cicutarium (0%, 0%, 0%, 6%, 5%, and 15%). Finally, Gullane is conspicuous by virtue of it containing virtually none of the saltmarsh species.

Cover Types

Vascular plants were recorded in 95.2% of quadrats in ST13 with a mean cover of 81.6% (cf. ST12 with 92.7% and 92.6%). The most important cover species in this types are Festuca rubra (18.7%, cf. ST12 with 23.2%), Ammophila arenaria (16.3%, cf. ST12 with 22.6%), Puccinellia maritima (6.1%) and Festuca ovina (3.6%). Bryophytes are less common and yield less cover than in ST12, being recorded in 56.9% of quadrats with a mean cover of 3.8% (cf. 72.7% and 5.4% in ST12). The high proportion of saltmarsh quadrats probably accounts for this difference. Lichens are present in 22.7% of quadrats with a mean cover of 1.4%. These figures show that ST13 is the second most important site type for lichens, being exceeded only by ST9 with 40.4% and 2.3% respectively. Why this should be so is not clear. Non-living cover categories are headed by bare sand and with a frequency of 46.6% and mean cover of 14.3% (cf. ST12 with 51.8% and 17.2%). Gravel was recorded in 13.8% of quadrats with a mean cover of 3.0%, cobbles (11.8% and 4.3%), boulders (2.5% and 0.2%) and solid rock (1.1% and 0.3%). Saltmarsh mud was recorded in 8.8% of quadrats with a mean cover of 1.7%.

Landforms

The presence of Ammophila covered dunes fringing at least part of the shoreline is a feature of the sites in this type. Evidence of former shorelines and raised beach deposits can be observed at several of the sites. Well developed saltmarsh formations and their associated landforms are characteristic of the ST13, being present in all sites with the exception of Gullane. There is a marked similarity between Whiteness and Culbin Bar on the north facing shore of the Moray Firth and Blakeney and Scolt Head Island on the north Norfolk coast.

The most common general aspect in ST13 is north (55.3%) and there are curiously no east facing slopes or coastlines. In terms of local aspect, the trend is entirely lost with south (31.4%) and west (32.4%) being the most favoured aspects. Slopes within the type are fairly gentle, with 40.4% under 1 degree, 37.4% in the 1-5 degree category, 19.8% in the 5-15 degree category and 2.3% over 15 degrees. Surface types are quite simple, with 45.1% plane, 40.5% simple undulating, 10.8% complex undulating and 3.6% broken. Most sites lie entirely under the 50ft contour and only Gullane contains a significant proportion of higher ground (0-50ft with 54.9% and 50-100ft with 45.1%). Overall, ST13 has 91.9% under 50ft and 8.1% in the 50-100ft zone. None of the sites extend far inland with a maximum of 600m. The coastal nature of these sites is emphasized by 20.1% of quadrats being within 10m of the sea and a further 31.6% in the 10-50m zone. With a total of 51.7% of quadrats within 50m of the HWMST, this is the most coastal site type in the survey (cf. 16.7% for ST3 and 41.0% for ST12).

Soil Types

The proportion of immature and mature Deep Sandy Soils is fairly well balanced in ST13. Of the less mature types, DS5 (21%) is the most common, with DS1 (2%), DS2 (9%), DS3 (+) and DS4 (+) in lesser amounts. The mature types comprise DS6 (22%) and DS7 (13%). The total for Deep Sandy Soils is 68% (cf. ST12 with 92%). Various types of Sandy Cobble Soils, CS1 (1%), CS2 (1%), CS4 (7%), CS5 (+), CS6 (+) and CS7 (1%), and Beach Deposits, BD2 (6%) and BD3 (1%), are a feature of ST13. Virtually all the Thin Soil types are present, the most common being TS3 (2%), and TS9 (4%). Two Peat Soils, PS2 (3%) and PS3 (5%), were also recorded and some of these quadrats represent saltmarsh soils with a high organic content.

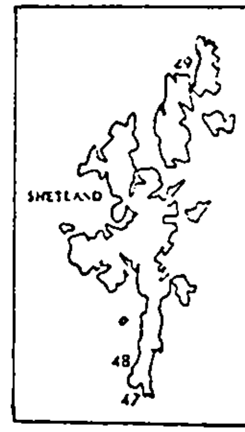
Boundaries

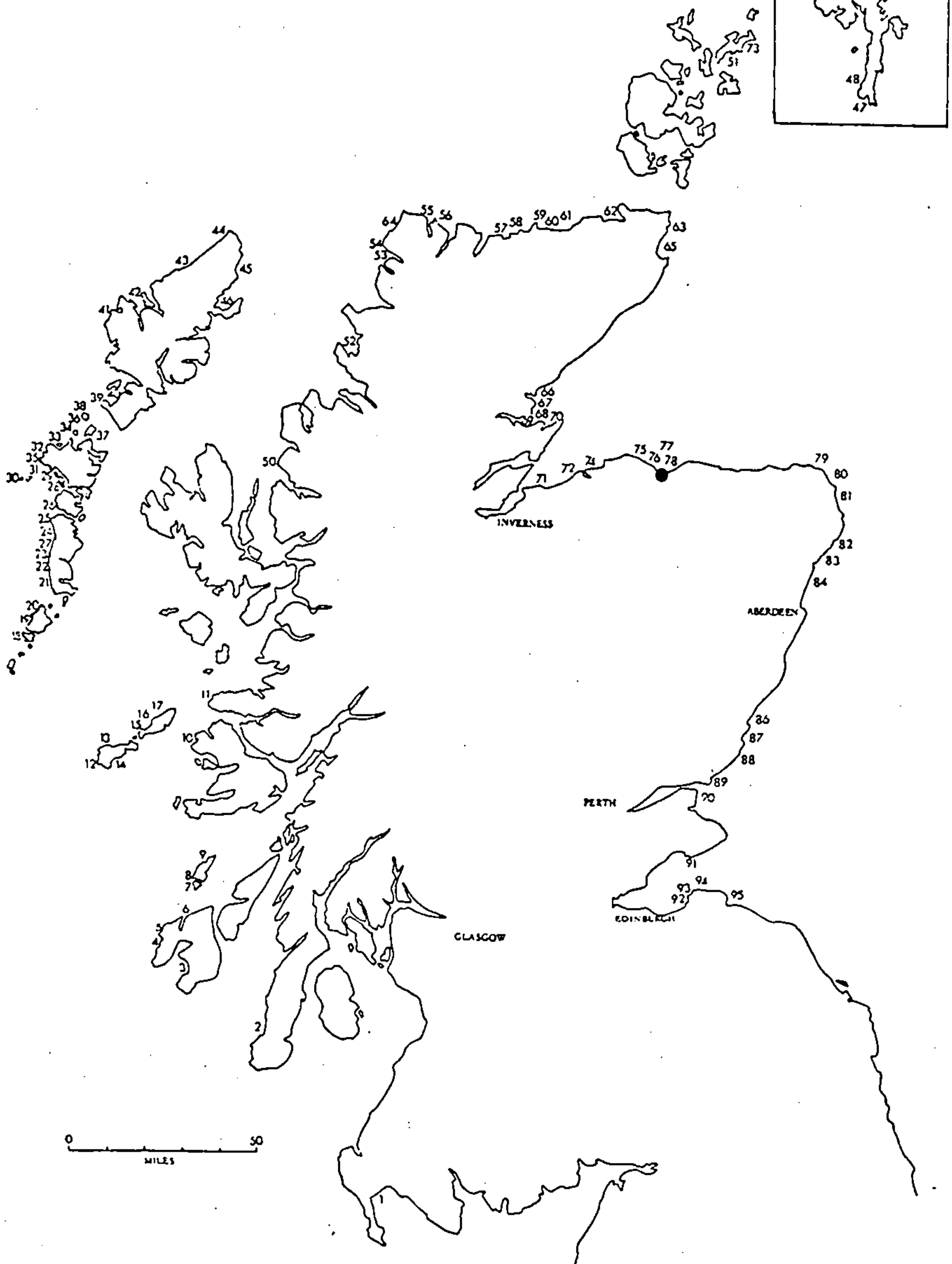
All six sites in ST13 are limited to a fairly narrow coastal strip. The three northern sites are based on spits, on which there is sand dune development with saltmarsh behind. At Dornoch the saltmarsh has become completely terrestrialized and is probably inundated on only the highest spring tides. This site is backed by a golf course that may contain some blown sand. Whiteness and Culbin Bar both have tidal creeks behind the bar. Whiteness comprises the spit only and excludes the mainland formations to the east. The bar at Culbin is linked to the mainland at the centre of the site, behind which is an extensive sandy area now covered by Culbin Forest. A small spit to the east of the main bar is also included in the site. On the Firth of Forth, Aberlady is backed by a golf course but, as this boundary coincides with rising ground, it is not clear how much blown sand is excluded from the site. A similar situation, with a golf course, pertains at Gullane, except that one part of the site is also curtailed by the town of Gullane and another part by a plantation. Finally, at Tyninghame, the site is limited by agriculture and forestry plantations. The spits on either site of the River Tyne are, of course, natural features but it would have been possible to include a much larger sandy area were it not for the plantations. As with ST12, it is not clear how this truncation has affected the site classification. It seems likely that with more hinterland present some of these sites might have shown greater affinities with ST9 (see also the comments above on the relationships of Cruden Bay and Lunan Bay). It is not possible to be more definite than this and, indeed, from a practical viewpoint, there is little need to be so - the sites are as they are at the present time as far as conservation is concerned. However, it is of considerable theoretical interest to understand how the various site types are related. It may also have some practical application when it comes to considering what effect the loss of parts of the existing sites would have on them.

Land-use

The main land-use of the sites in ST13 is recreation, although, having said this, several of them are hardly used at all. Access to Culbin Bar and Whiteness is difficult (yet vehicle tracks were recorded there!). Cultivation is not an important use in ST13, with only 1.4% of quadrats showing signs of this activity. Grazing intensity is also comparatively light, with none being recorded in 19.5% of quadrats, light grazing in 46.5%, moderate grazing in 21.8% and heavy grazing in 12.2%. There are no marked within-type differences in grazing intensity. The grazing record is confirmed by that for the signs of various animals. Cattle are the most common domestic herbivore, with 26.6% of quadrats, but there are considerable differences between sites, Dornoch (67%) and Whiteness (73%) as compared with none in Culbin Bar and Aberlady. Sheep were recorded only at Dornoch (3%), or a mean for the type of 0.5%, and horses were recorded in 2.1% of quadrats. The rabbit seems to be by far the most important grazing animal in ST13, being recorded in 82.4% of quadrats. Man-made features recorded on these sites include fence (1.2%), dirt road (2.7%), vehicle tracks (13.4%, mostly the northern sites), unsurfaced path (19.3%, mostly the southern sites), spent cartridge (4.9%), fire evidence (5.2%), planted trees (2.2%), and rubbish (40.8%, more frequent in the southern sites). A few aquatic habitats were recorded in ST13, the most common being, not unexpectedly, saltmarsh pan (3.5%), saltmarsh creek (3.5%) and dried-up saltmarsh pan or creek (3.7%).

Scottish Coastal Survey
SITE TYPE 14





8.4.14 Site Type 14

Name - East Coast, estuarine shingle type

List of Sites in ST14

Site no. & name	Geographical region	Size (ha)
77 Spey Bay (Central)	Moray Firth	60

General Description and Relationship with other Site Types.

This site type is represented by just one site (1.1%), Spey Bay (Central), with an area of 60ha. This is the middle site of three located in Spey Bay on the southern side of the Moray Firth and, in fact, has the River Spey running through it. The site is situated on estuarine shingles with seaward areas of blown sand and shingle. The mouth of the Spey takes the form of an outwash fan with the river broken up into numerous channels, some of which are dry except during spates. There are extensive areas of ungrazed Festuca rubra grassland within the site. Along the river edges, there are damper communities and woodland, some of which is more akin to carr. The type is characterized by extreme instability but not of the sort which occurs in most other sites, i.e. sand blow. Most of the disturbance in Spey Bay (Central) results from flooding and scouring at times of spate. The disturbance factor is exemplified by the site containing no less than 60% of semi-stable dune grassland D3, although this is largely the disturbance form derived in step 69 (-ve) of the vegetation type key. This form of D3, which encompasses a wide range of variants, some of which are close to being unclassifiable, contains no Ammophila arenaria. Indeed, there are only two quadrats in Spey Bay (Central), close together at the mouth of the river, that actually contain Ammophila. In addition, to the D3, there are 9% of quadrats allocated to bare ground B, giving a total for unstable (or perhaps better, disturbance) types of 69%. Quadrat 13 at Spey Bay (Central) was considered to be unclassifiable, containing just four species - Polygonum cuspidatum, Symphytum tuberosum, Impatiens glandulifera and Calystegia sepium! Although very extreme, this quadrat gives a flavour of the site, which contains all manner of odd species, some of which occur in no other site in the survey.

Spey Bay (Central) has few affinities with any other site in the survey and no valid comparisons are possible. The following is merely a rough description of the site in question, drawing attention to its most salient features.

Vegetation Types

As already noted, Spey Bay (Central) is dominated by semi-stable dune grassland D3 (60%), mostly in its disturbance forms, together with 9% of bare ground B. This gives total for unstable or disturbance types of 69%. The next most common vegetation type is shrub invaded dune grassland D6 (8%, the main occurrence in the survey of this uncommon type), followed by wet, slightly acid dune grassland D5 (3%). The only Grassland type to occur is one quadrat of dry, acid grassland G3 (3%).

Damp, disturbed marsh M1 (disturbance again!) occurs in 5% of quadrats and M2 in 1%. Wet foredune F2 has a frequency of 5% and the upper saltmarsh types S4 and S5 have frequencies of 2% and 1% respectively. In summary, the vegetation of Spey Bay (Central) can be characterized as being disturbed or wet or both.

Vascular Plants

Spey Bay (Central) is reasonably species-rich for an eastern site type, with a mean of 16.7 species per quadrat and 24 species with a frequency of 20% or more. As might be expected, there are no really constant species, i.e. species with a frequency of 70% or more, the most common being Dactylis glomerata (48.5%), Festuca rubra (46.2%), Cirsium arvense (42.9%), Arrhenatherum elatius (40.4%), Ulex europaeus (39.3%), Galium aparine (37.5%), Anthriscus sylvestris (36.9%), Urtica dioica (36.9%), Plantago lanceolata (36.0%), Phalaris arundinacea (35.6%), Holcus lanatus (33.0%), Centaurea nigra (31.5%), Holcus mollis (31.5%) and Poa pratensis (30.8%). Other species which serve to emphasize the unique nature of this site include Symphytum tuberosum (28.8%), Festuca arundinacea (26.8%), Heracleum mantegazzianum (26.2%), Sarothamnus scoparius (25.0%), Luzula sylvatica (24.1%), Rubus idaeus (21.4%), Valeriana officinalis (20.8%), Teucrium scorodonia (18.7%), Impatiens glandulifera (18.1%), Mercurialis perennis (16 1%), Salix cinerea agg. (16.1%), Oenanthe crocata (15.8%), Alnus glutinosa (13.4%), Rubus fruticosus (13.4%), Stachys sylvatica (13.4%), Mimulus guttatus (12.2%) and Aegopodium podagraria (10.7%).

Cover Types

Vascular plants were recorded in 90.5% of quadrats at Spey Bay (Central) with a mean cover of 89.9%. Species contributing most to this cover are Festuca rubra (14.1%), Ulex europaeus (12.2%), Phalaris arundinacea (10.2%), Arrhenatherum elatius (9.9%), Alnus glutinosa (5.4%) and Holcus mollis (4.8%). Bryophytes have a frequency of 64.6% but very little cover (only 0.2%). Lichens are present in only 6.3% of quadrats with negligible cover. Bare sand, in 8.0% of quadrats and with a mean cover of 1.9%, is not the most important non-living cover category in ST14. This role is assumed by cobbles (28.5% and 12.2%) and is closely followed by gravel (18.1% and 8.1%). Curiously, freshwater was not recorded at Spey Bay (Central) but this was only because the survey happened to coincide with a period of dry weather.

Landforms

The structure of the site is a flat valley floor covered by shingle deposits. The River Spey follows an "S"-shaped course through the area, running from south to north. Within the shingle deposit area are dry channels which carry excess water in time of floods. At the seaward side of the site, the channels are tidal and form saltmarsh creeks. The river mouth has recurved spits entering it from both the east and west sides. The larger western spit encloses a lagoon-like area. There are no proper dunes but some mobile sand occurs near the river mouth.

The general aspect of the site is north (100%) but local aspect is somewhat more diffuse, with only 55.7% of quadrats facing north. Slopes are generally slight, with 23.3% under 1 degree, 63.1% in the 1-5 degree category and 2.7% in the 5-15 degree category. There are no slopes over 15 degrees. Surface type is generally plane (55.7%) or simple undulating (41.6%). The entire site is under the 50ft contour and extends up to 1000m from the sea. Because of the complex pattern of tidal-flow within the site, i.e. the line on the OS map denoting HWMST extends about 500m into the site, 47.3% of quadrats are regarded as being less than 50m from the sea, although, in this case, not the open sea. There is a second peak in frequency at 400-600m, with 26.8% of quadrats.

Soil Types

Spey Bay (Central) is dominated by one type of Sandy Cobbles Soil, CS4 with 37% of quadrats. Beach Deposits BD2 contribute another 14%, giving a total of 51% for basically stony soils. Semi-mature Deep Sandy Soil DS5 (13%) is the next most common type and the more mature DS6 (9%), DS7 (5%) and DS8 (3%) make up another 17%. There are also a few examples of Thin Soils, TS3 (7%), TS8 (2%) and TS9 (3%), and some peaty quadrats, PS4 (5%) and PS5 (1%).

Boundaries

The boundaries of Spey Bay (Central) are mostly formed by enclosed farmland. On the west side this is a sharp break in slope and a fall to the river in the valley floor. To the east, the slope difference is less marked but the boundary is still the edge of the valley bottom over which the river channel has meandered in the past. At the southern (inland) end the boundary is formed by a disused railway viaduct.

Land-use

The main land-use at Spey Bay (Central) is golf; the site contains the Garmouth and Kingston Golf Course. No domestic grazing animals were recorded in the site but signs of rabbit and deer were noted in 9.9% and 18.7% of quadrats respectively. Grazing intensity was exceptionally light, with none in 76.8% and light grazing in 23.2% (and no heavier categories). On the other hand, much of the vegetation is largely unpalatable and virtually all the grazing is in the Festuca grassland around the golf course. Man-made features recorded in the site were dirt road (8.0%), vehicle track (8.0%), unsurfaced path (4.7%), oil deposit (2.7%), fire evidence (3.6%) and rubbish (19.7%). Aquatic habitats include ditch (2.7%), stream (2.7%), river (14.2%), dried-up puddle (8.9%), dried-up rut (2.7%), dried-up ditch (8.9%), dried-up stream (5.4%) and dried-up pond (2.7%).

8.5 Use of the Site Type Key

The key to the site classification which follows is derived from the data and analysis described in Sections 6.3 and 8.1. The purpose of a key is to to provide a method by which to generalize the classification as produced on the computer. Basically, it is a set of rules by which new individuals (in this case sites), belonging to the same population to which the classification refers, may be assigned to the established range of types. In the case of ISA, the key takes the form of a series of lists of indicator species which are used to generate a score (a discriminant function) for the negotiation of the steps in a dichotomous key. The value of the score derived from the site data determines to which side (so called negative or positive) of the key an individual is assigned.

As already noted (see Section 6.2), a good (accurate) key is one that can faithfully reproduce the original classification and retain this performance when applied to new individuals from the same population. The problem with the "original" vegetation type key was that it did not generalize the classification with sufficient accuracy. There are no such problems with the site classification key, which contains only one misclassification in the first four levels of division (it occurs in level 3). This misclassification represents a 1% error and, because of the level in which it occurs, it cannot be regarded as serious.

An examination of the ISA from which the site classification was derived, reveals that the key is likely to be robust in practice, i.e. it will not be sensitive to minor, or in some cases major, changes in the estimates of species frequency. This is evidenced by the polarization of indicator score, i.e. for existing sites the indicator score tends to be well below or above the threshold value for most divisions. The practical implications of this are that, at the sampling intensity used in the survey, it is unlikely that the key will make mistakes. Consequently, it may be possible to reduce sampling intensity for new sites without running a serious risk of incurring errors. A reduction in sampling intensity is merely an economy measure if the only aim of the investigation is to classify a site. However, for other reasons, e.g. for determining what vegetation types and species are present and their distribution, NCC may wish to use a higher sampling intensity. The minimum safe sampling intensity is probably about 30 quadrats per site but, in the case of very small or uniform sites, this could be reduced to 20.

It is unlikely that NCC will use the site key as often as the vegetation key as the scope for classifying new sites is rather limited. However, frequency of use is somewhat offset by the relative importance of classifying sites as opposed to small areas of vegetation. The main uses of the site classification are seen as the investigation of:

(a) new sites,

(b) changes in boundary to existing sites, and

(c) disturbance or drastic changes in land-use on sites.

Potential new sites have already been mentioned by Regional Staff - usually asking why a particular site was not included in the original survey. Changes in boundaries to sites can be hypothetical or real. For example, when dealing with a particular site it is possible to investigate the implications of excluding certain parts or incorporating new areas merely by re-calculating the species frequencies appropriately and applying them to the key. Consideration of an extension to a site would, of course, require additional survey in the form of plant records from 25 sq m quadrats. In this case, care must be taken to ensure that a uniform sampling intensity is maintained or that estimates of species frequency are corrected accordingly. The implication of the loss of part of a site, e.g. the construction of a gas terminal, can be investigated by the key. Use (c) is really an example of monitoring, re-surveying the site after some major event, e.g. a drastic change in the agricultural regime, and applying the results to the key to see if it has been substantially modified and, if so, in what direction.

Use of the key for the site classification is best explained through a worked example. Assuming that % species frequencies have been calculated for the site to be classified, these data can now be applied to the key. Each step of the key consists of a list of ten indicator species with their quantitative qualifier or pseudo-species in brackets. The indicators are presented in two lists, labelled negative and positive, and the ten indicators may be divided in any proportion between these two categories. The names negative and positive have no particular significance and are merely a convention connected with the method and the use of a discriminant function that usually ranges from negative to positive values. Similarly, an imbalance in the number of indicators between the negative and positive sides has no special significance. It only means that there are more species which are indicative by their presence on one side than the other. In theory, indicators are equally indicative by their absence but, in practice, this can be a less reliable means of discrimination, e.g. a species may have been overlooked in recording or may be temporarily absent or inconspicuous. The presence of species is only subject to the error of misidentification.

Referring to the first step in the key (step 1), the procedure is to work through the indicators one at a time. If an indicator species is present in the data a -1 is registered for each negative indicator and a +1 for each positive indicator. Taking the ten indicators for the first step in the key, let us assume that the site to be classified had the following species frequencies.

Ranunculus acris = 76%	Prunella vulgaris = 17%
Trifolium repens = 92%	Bellis perennis = 81%
Euphrasia officinalis agg. = 32%	Plantago lanceolata = 89%
Trifolium pratense = 52%	Leontodon autumnalis =27%
Chamaenerion angustifolium = 0%	Rumex acetosella = 40%

The scoring for this step would now go as follows: <u>Ranunculus acris</u> -1, <u>Trifolium repens</u> -1, <u>Bellis perennis</u> -1, <u>Euphrasia officinalis</u> agg. -1, <u>Plantago lanceolata</u> -1, <u>Trifolium pratense</u> -1, <u>Leontodon autumnalis</u> -1 and <u>Rumex acetosella</u> +1. Only <u>Prunella vulgaris</u> and <u>Chamaenerion angustifolium</u> were not present with sufficient frequency to score. The aggregate score is thus -1-1-1-1-1-1-1+1=-6. This value is compared with the threshold for the step 1 (appearing below the list of indicators) and the decision is that -6 is less than -4 and, therefore, a move to step 2 of the key is required. This process is repeated for successive steps of the key until a site type is reached.

8.6 Site Type Key

KEY TO SITE CLASSIFICATION

STEP 1

Indicators:-

Negative	Positive
Bellis perennis (40%+)	Chamaenerion angustifolium (0%+)
Euphrasia officinalis agg. (20%+)	Rumex acetoslla (0%+)
Leontodon autumnalis (20%+)	
Plantago lanceolata (60%+)	
Prunella vulgaris (20%+)	
Ranunculus acris (20%+)	
Trifolium pratense (0%+)	
Trifolium repens (60%+)	

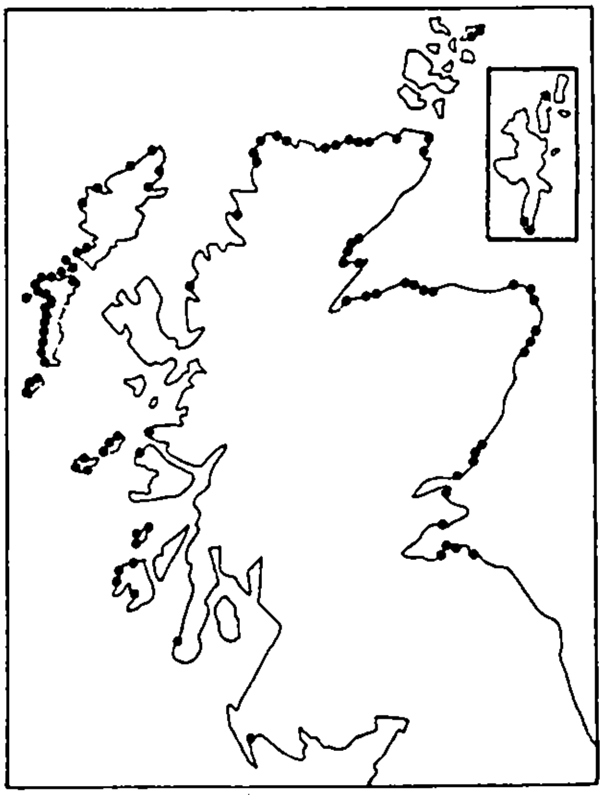
SCORE -4 or less -------- 2

SCORE -3 or more -------- 3

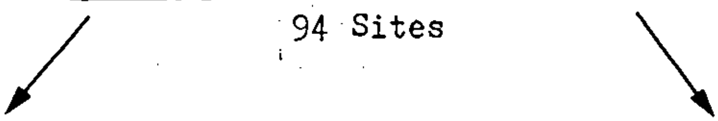
DISTRIBUTION OF SITES INVOLVED

IN DIVISION 1/1

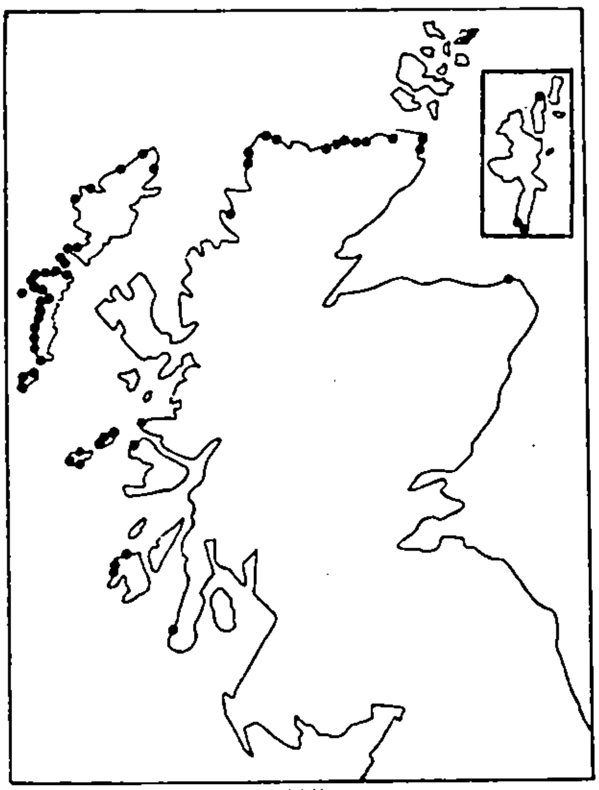
1



94 Sites

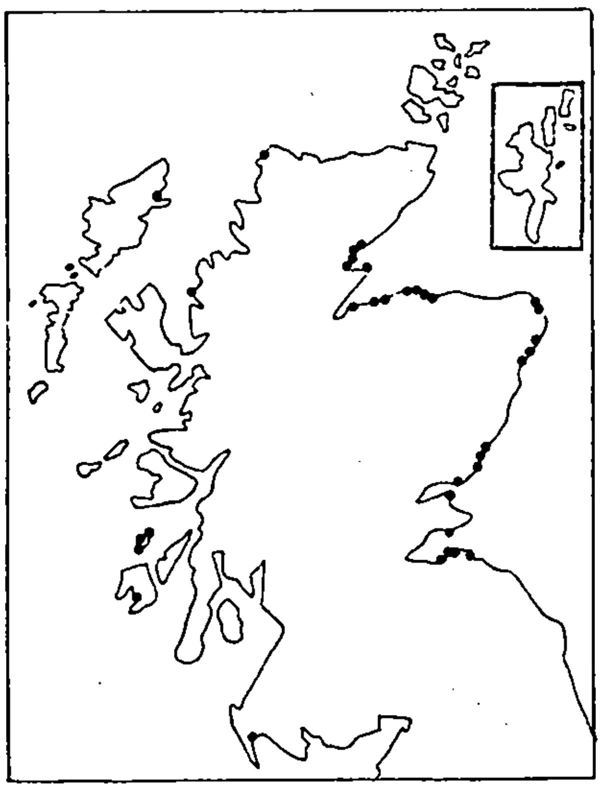


2
(negative)



59 Sites

3
(positive)



35 Sites

STEP 2

Indicators:-

Negative	Positive
Trifolium repens (80%+)	Achillea ptarmica (0%+)
	Agrostis tenuis (20%+)
	Erica tetralix (0%+)
	Festuca ovina (0%+)
	Hieraceum pilosella (0%+)
	Potentilla erecta (20%+)
	Pteridium aquilinum (0%+)
	Sieglingia decumbens(20%+)
	Vicia sepium (0%+)

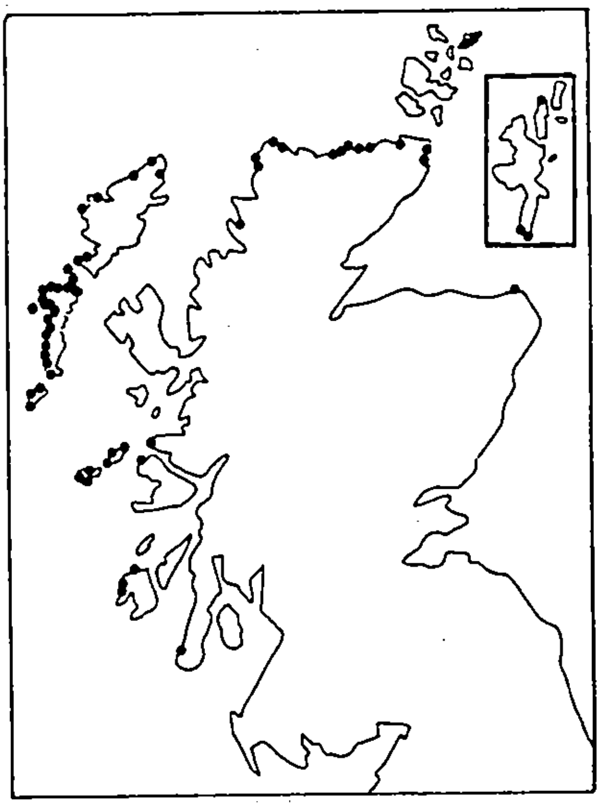
SCORE 4 or less -------- 4

SCORE 5 or more -------- 5

DISTRIBUTION OF SITES INVOLVED

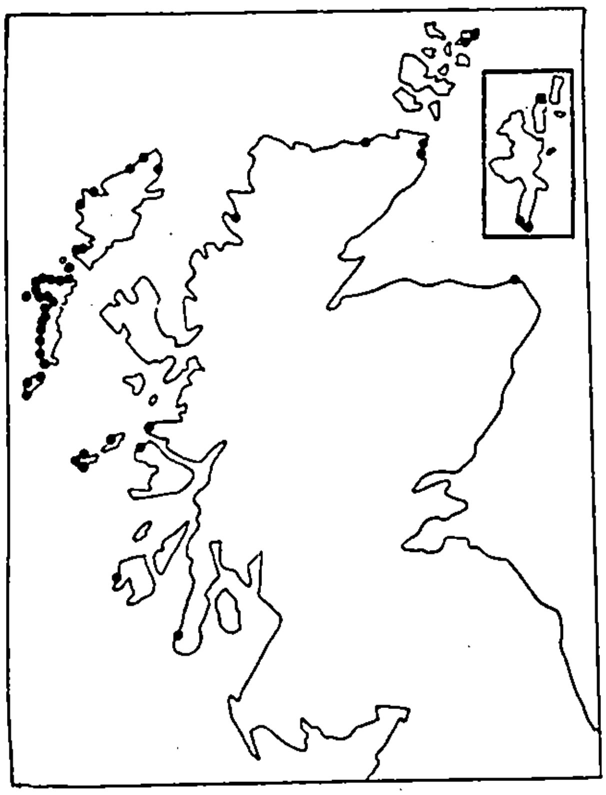
IN DIVISION 2/1

2



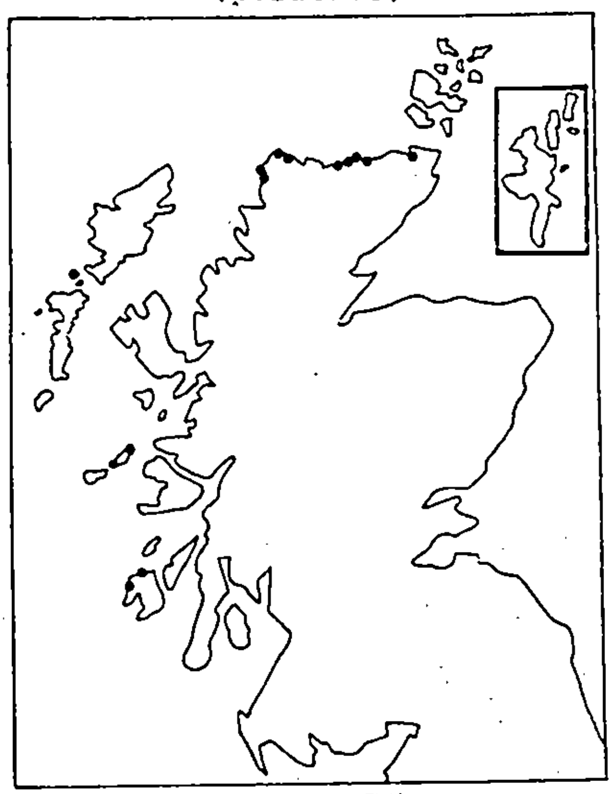
59 Sites

4
(negative)



45 Sites

5
(positive)



14 Sites

STEP 3

Indicators:-

Negative	Positive
Calluna vulgaris (20%+)	Cirsium arvense (20%+)
Erica cinerea (0%+)	
Erica tetralix (0%+)	
Juncus effusus (0%+)	
Luzula multiflora (0%+)	
Nardus stricta (0%+)	
Potentilla erecta (0%+)	
Salix repens (0%+)	
Succisa pratensis (0%+)	

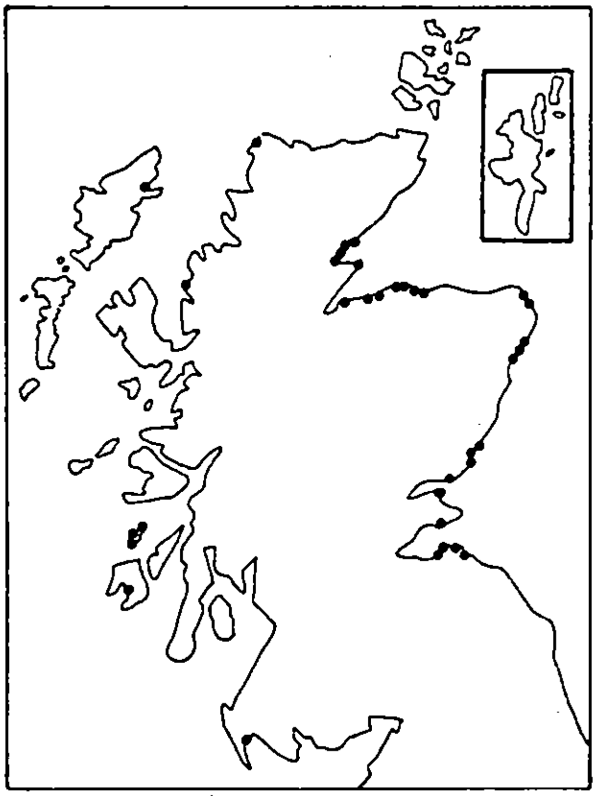
SCORE -3 or less -------- 6

SCORE -2 or more -------- 7

DISTRIBUTION OF SITES INVOLVED

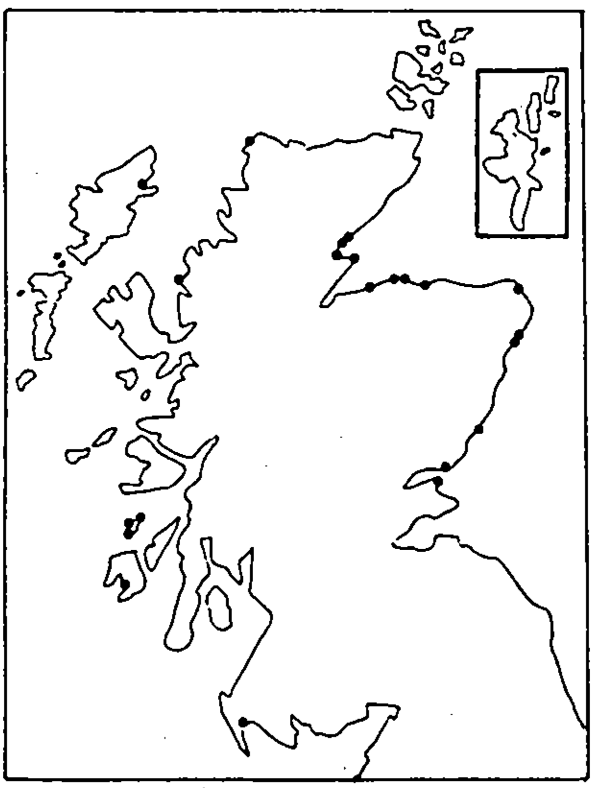
IN DIVISION 2/2

3



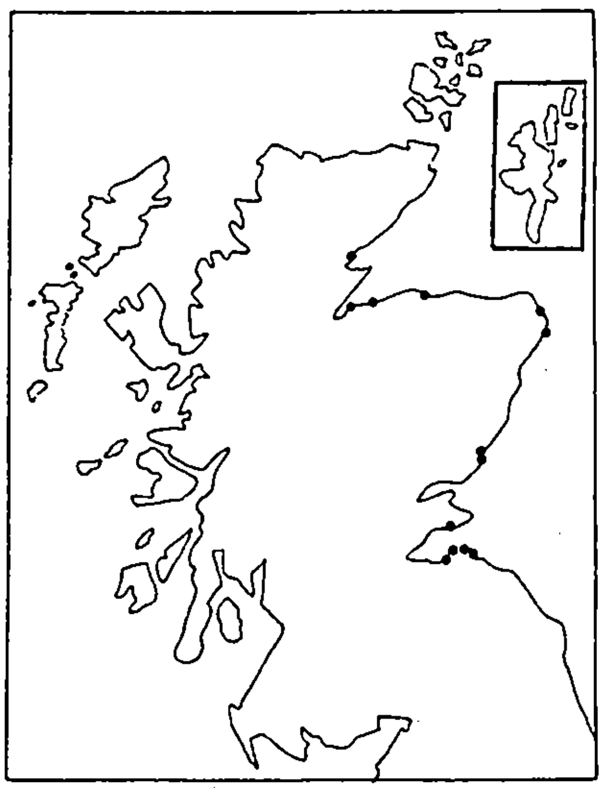
35 Sites

6
(negative)



22 Sites

7
(positive)



13 Sites

STEP 4

Indicators:-

Negative	Positive
Anagallis tenella (0%+)	Cirsium arvense (20%+)
Carex panicea (0%+)	Cirsium vulgare (20%+)
Daucus carota (0%+)	
Glaux maritima (0%+)	
Leontodon autumnalis (40%+)	
Lychnis flos-cuculi (0%+)	
Molinia caerulea (0%+)	
Trifolium pratense (20%+)	

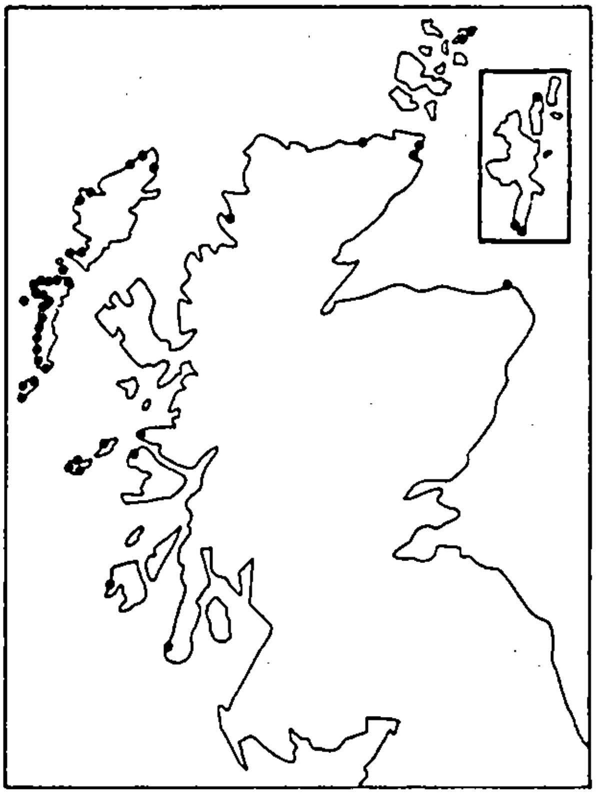
SCORE -3 or less -------- 8

SCORE -2 or more -------- 9

DISTRIBUTION OF SITES INVOLVED

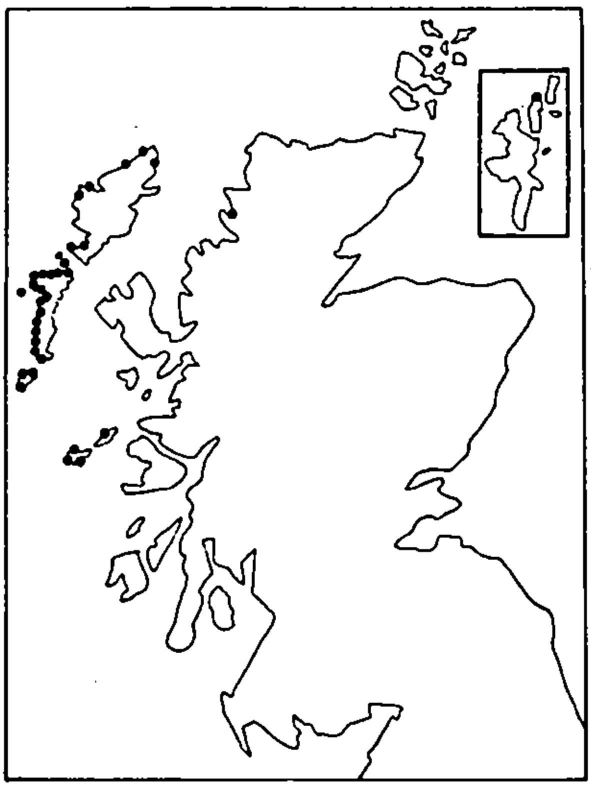
IN DIVISION 3/1

4



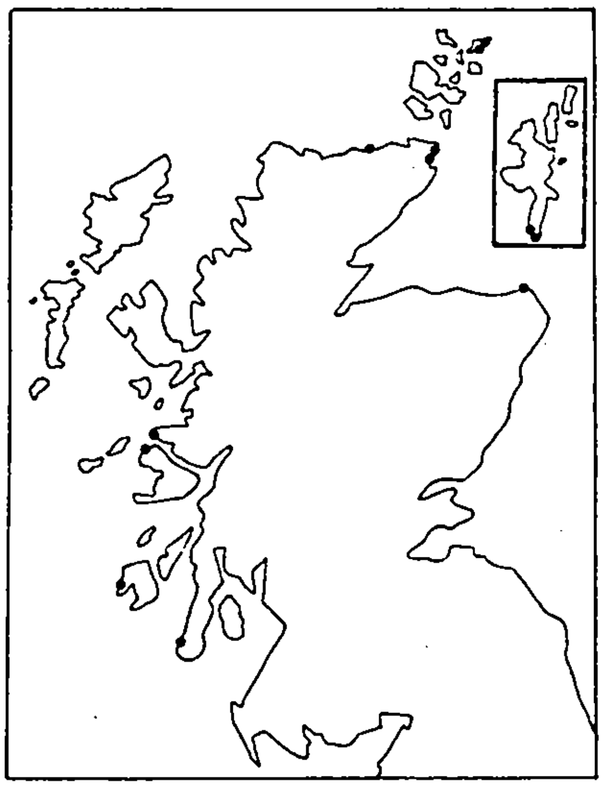
45 Sites

8
(negative)



33 Sites

9
(positive)



12 Sites

STEP 5

Indicators:-

Negative	Positive
Anagallis tenella (0%+)	Carex capillaris (0%+)
Cynosurus cristatus (20%+)	Gentianella amarella (20%+)
Iris pseudacorus (0%+)	Succisa pratensis (40%+)
Lolium perenne (20%+)	
Plantago major (0%+)	
Poa annua (0%+)	
Sagina procumbens (0%+)	

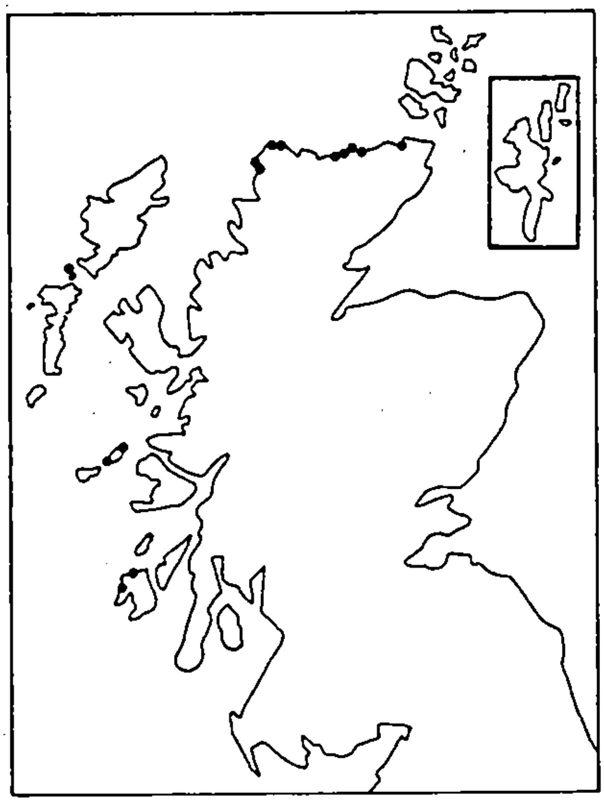
SCORE 0 or less -------- 10

SCORE 1 or more -------- 11

DISTRIBUTION OF SITES INVOLVED

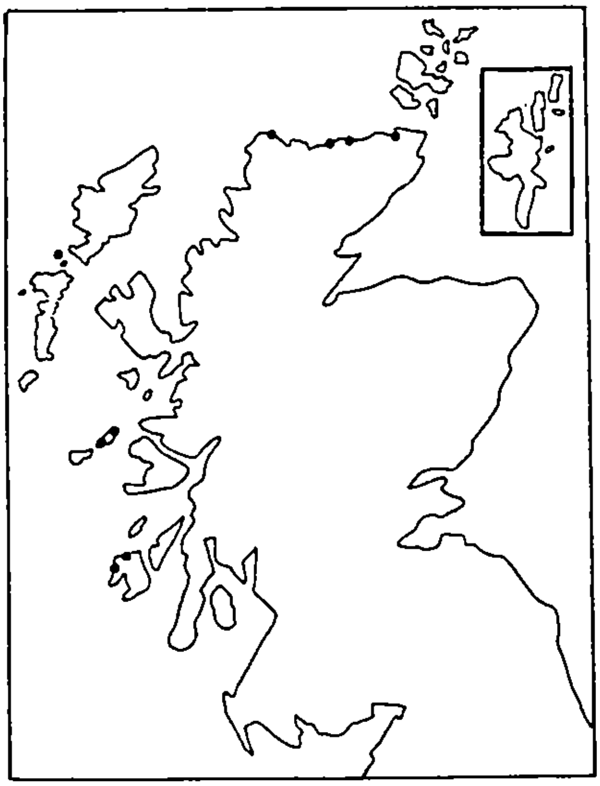
IN DIVISION 3/2

5



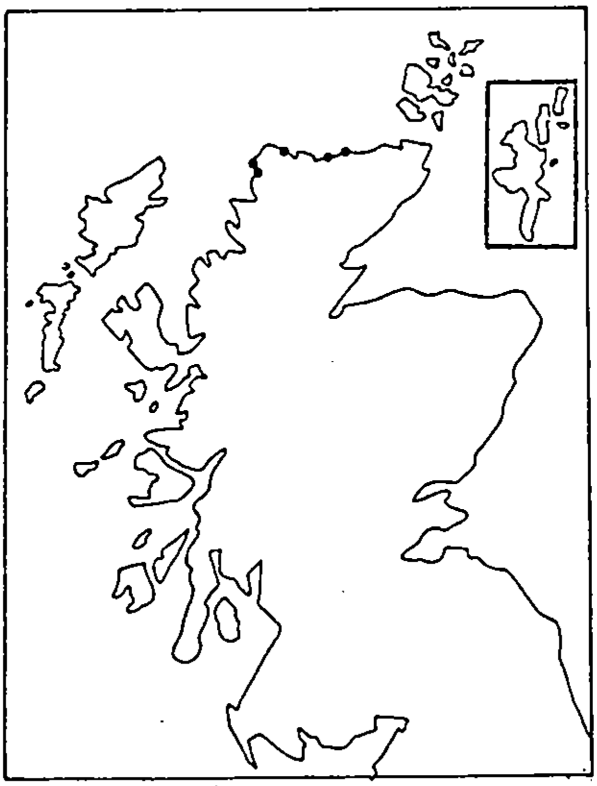
14 Sites

10
(negative)



9 Sites

11
(positive)



5 Sites

STEP 6

Indicators:-

Negative	Positive
	Armeria maritima (20%+)
	Aster tripolium (20%+)
	Carex distans (0%+)
	Cochlearia officinalis (20%+)
	Glaux maritima (20%+)
	Juncus gerardii (20%+)
	Leontodon autumnalis (40%+)
	Plantago maritima (60%+)
	Puccinellia maritima (20%+)
	Spergularia media (20%+)

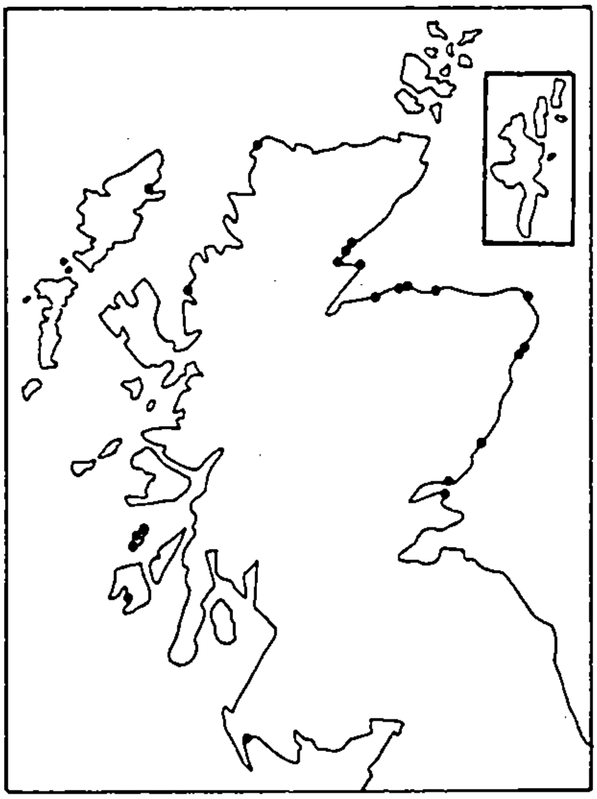
SCORE 4 or less -------- 12

SCORE 5 or more -------- SITE TYPE 11

DISTRIBUTION OF SITES INVOLVED

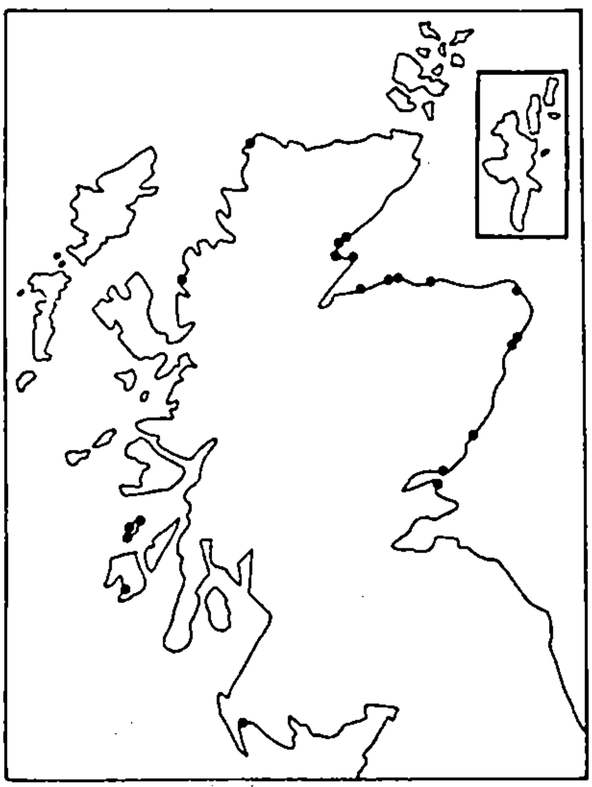
IN DIVISION 3/3

6



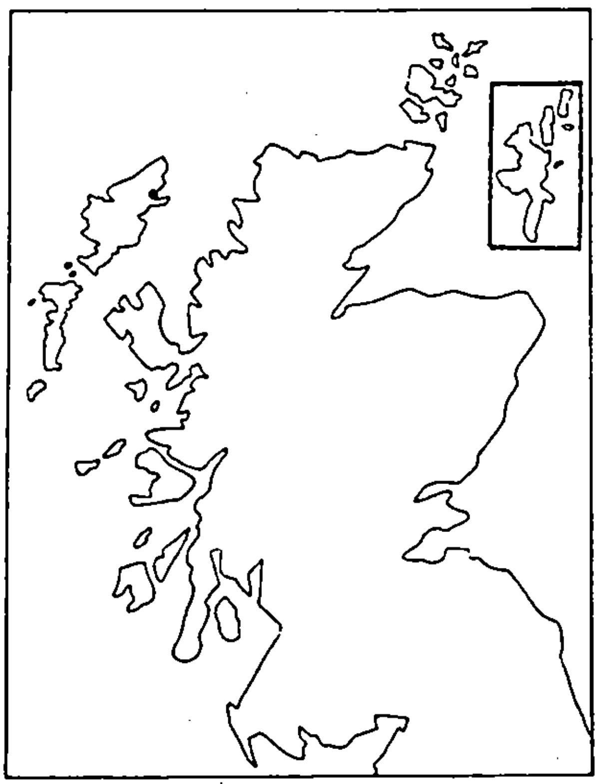
22 Sites

12
(negative)



21 Sites

Site Type 11
(positive)



1 Site

STEP 7

Indicators:-

Negative	Positive
—	Alchemilla vulgaris (0%+) Alliaria petiolata (0%+) Alnus glutinosa (0%+) Anthriscus sylvestris (0%+) Calystegia sepium (0%+) Cardamine flexuosa (0%+) Carex remota (0%+) Deschampsia cespitosa (20%+) Festuca arundinacea (20%+) Galium aparine (20%+)

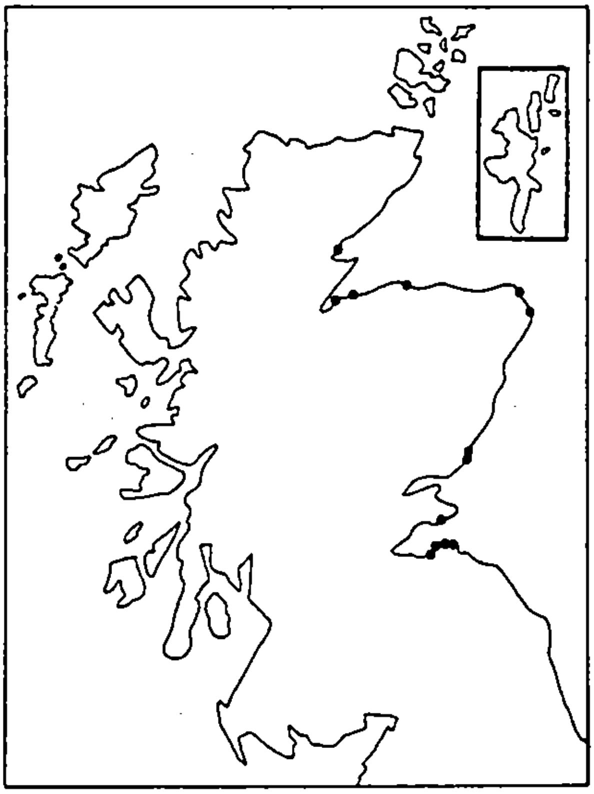
SCORE 4 or less -------- 13

SCORE 5 or more -------- SITE TYPE 14

DISTRIBUTION OF SITES INVOLVED

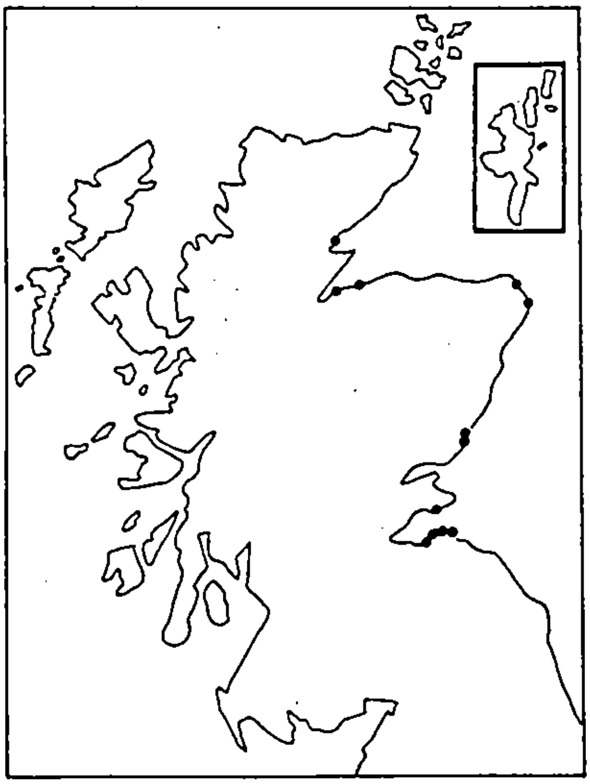
IN DIVISION 3/4

7



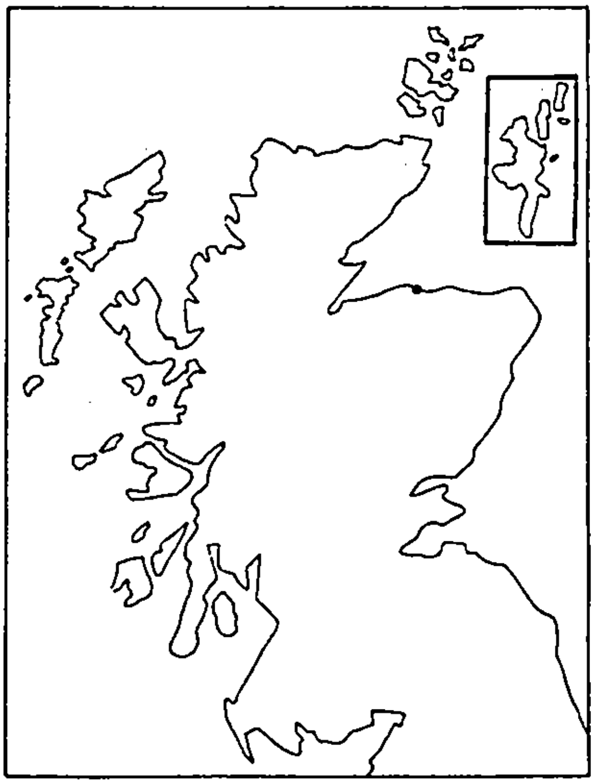
13 Sites

13
(negative)



12 Sites

Site Type 14
(positive)



1 Site

STEP 8

Indicators:-

Negative	Positive
Agrostis stolonifera (60%+)	Lotus corniculatus (60%+)
Atriplex hastata (0%+)	Thymus drucei (20%+)
Eleocharis uniglumis (0%+)	
Erodium cicutarium (0%+)	
Potentilla anserina (20%+)	
Ranunculus repens (20%+)	
Saxifraga tridactylites (0%+)	
Viola tricolor (20%+)	

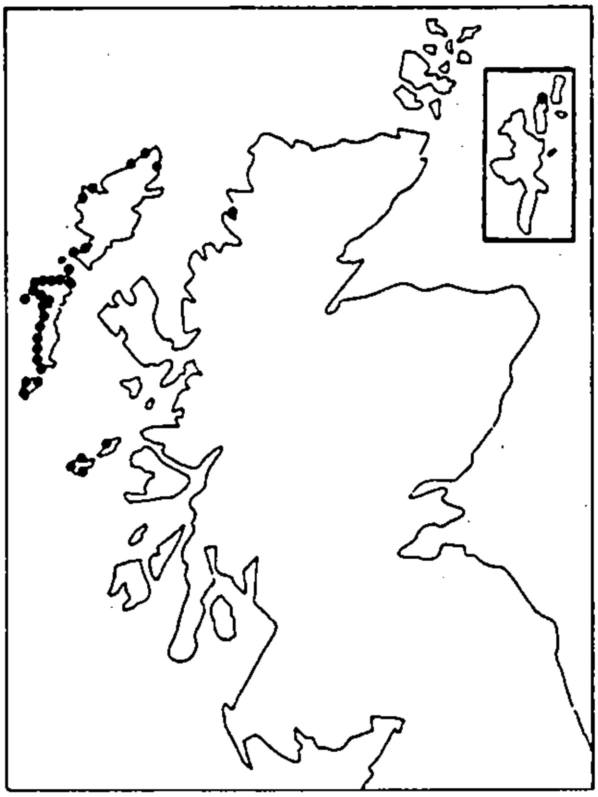
SCORE -3 or less -------- SITE TYPE 1

SCORE -2 or more -------- SITE TYPE 2

DISTRIBUTION OF SITES INVOLVED

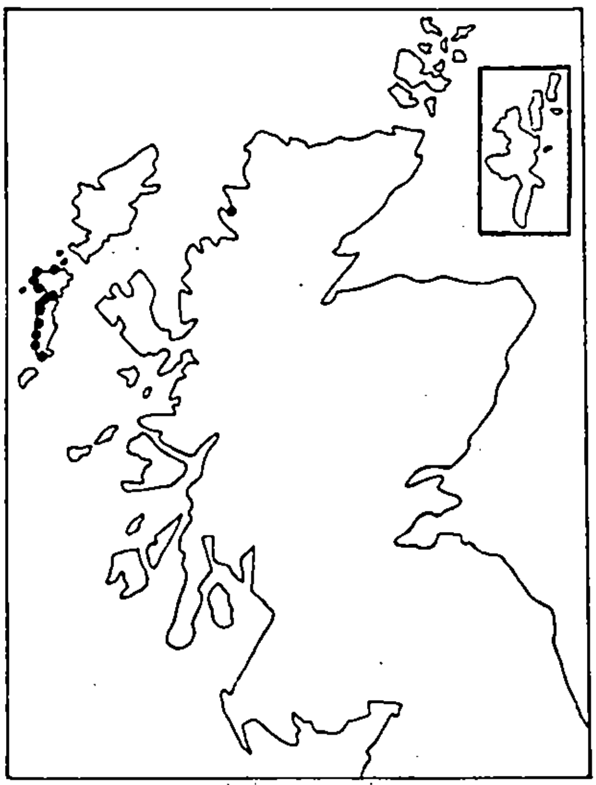
IN DIVISION 4/1

8



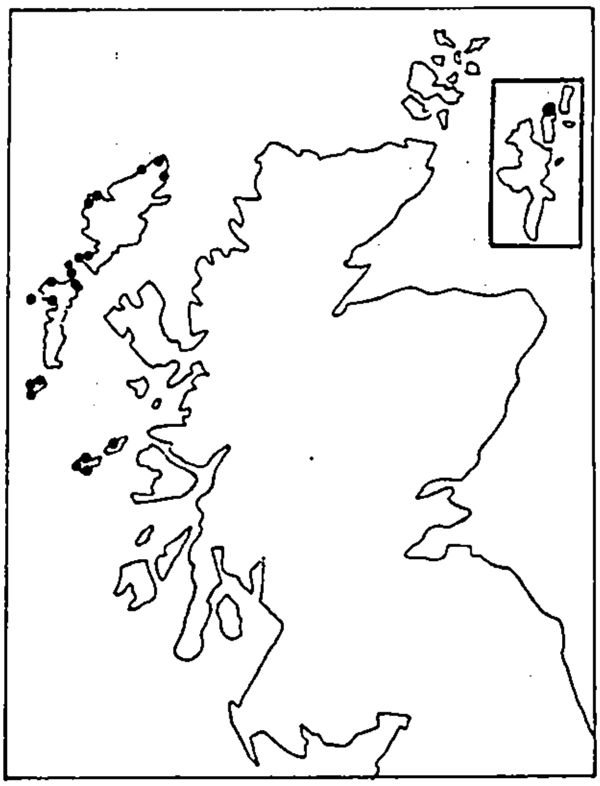
33 Sites

Site Type 1
(negative)



13 Sites

Site Type 2
(positive)



20 Sites

STEP 9

Indicators:-

Negative	Positive
Arenaria serpyllifolia (0%+)	Cerastium holosteoides (60%+)
Campanula rotundifolia (0%+)	Coeloglossum viride (0%+)
Geranium molle (0%+)	
Hypochoeris radicata (0%+)	
Ranunculus bulbosus (0%+)	
Taraxacum spp. (20%+)	
Thalictrum minus (0%+)	
Veronica chamaedrys (0%+)	

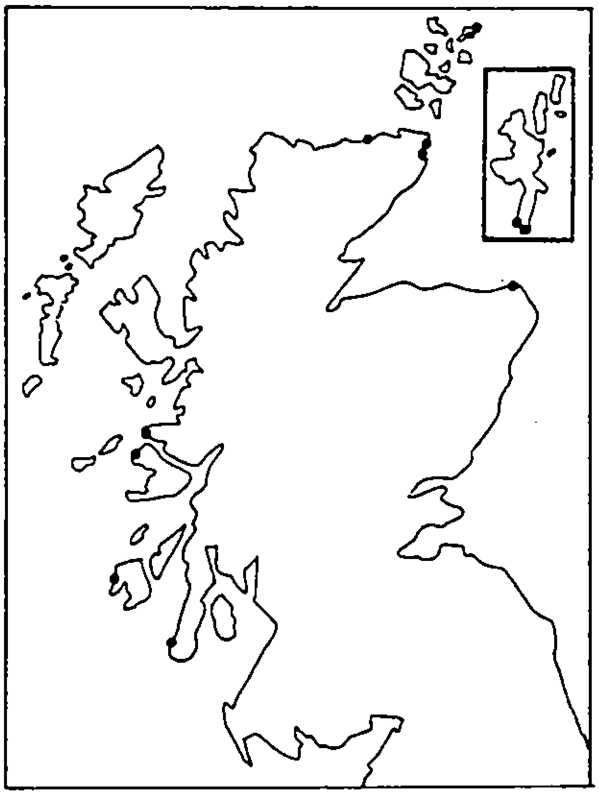
SCORE -2 or less -------- SITE TYPE 3

SCORE -1 or more -------- SITE TYPE 4

DISTRIBUTION OF SITES INVOLVED

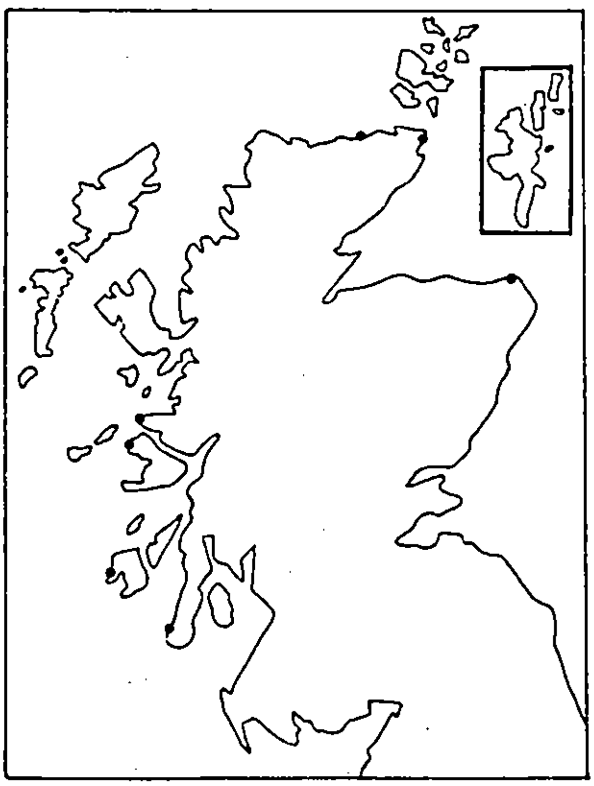
IN DIVISION 4/2

9



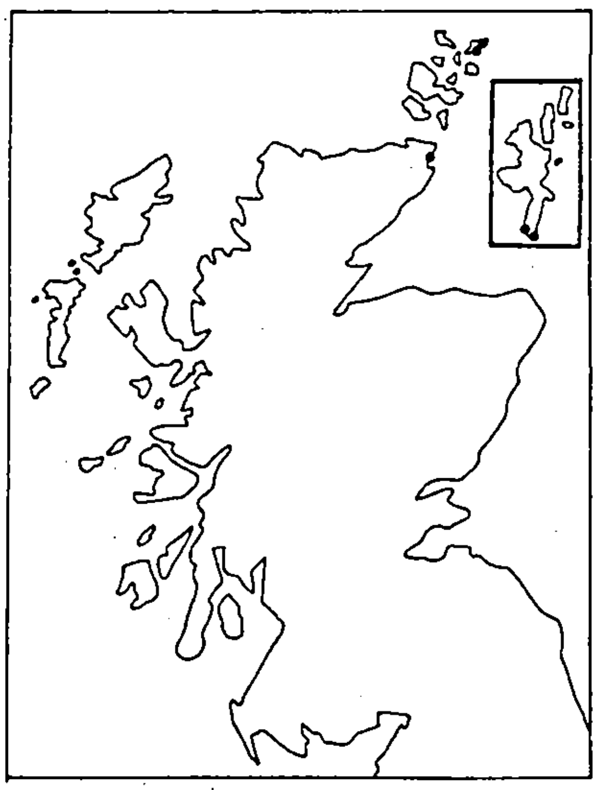
12 Sites

Site Type 3
(negative)



7 Sites

Site Type 4
(positive)



5 Sites

STEP 10

Indicators:-

Negative	Positive
Carex panicea (0%+)	Achillea millefolium (60%+)
Carex pulicaris (0%+)	Anthyllis vulneraria (0%+)
Erica tetralix (0%+)	Euphorbia helioscopia (0%+)
	Heracleum sphondylium (20%+)
	Oxytropis halleri (0%+)
	Primula veris (0%+)
	Trollius europaeus (0%+)

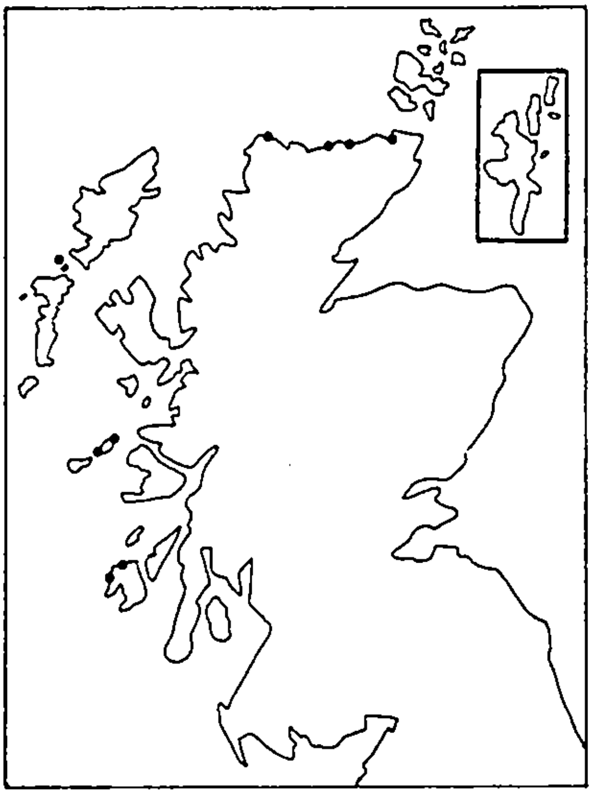
SCORE 1 or less -------- SITE TYPE 5

SCORE 2 or more -------- SITE TYPE 6

DISTRIBUTION OF SITES INVOLVED

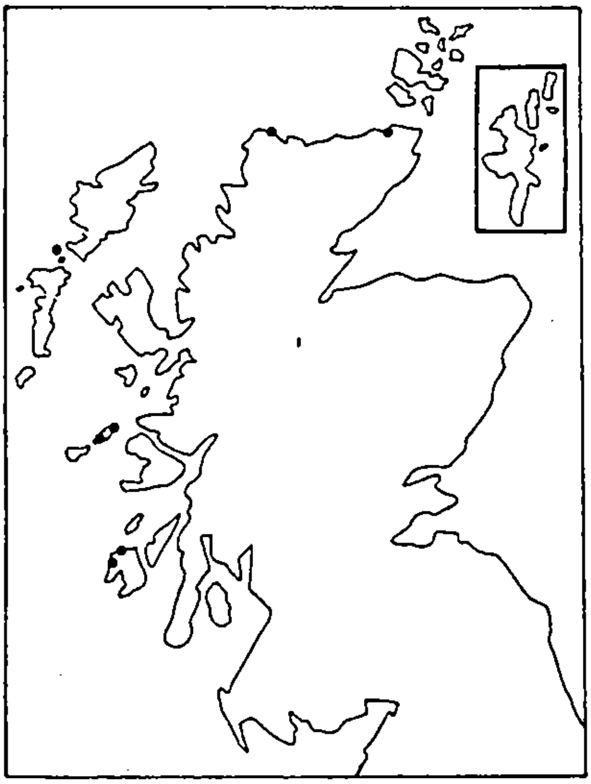
IN DIVISION 4/3

10



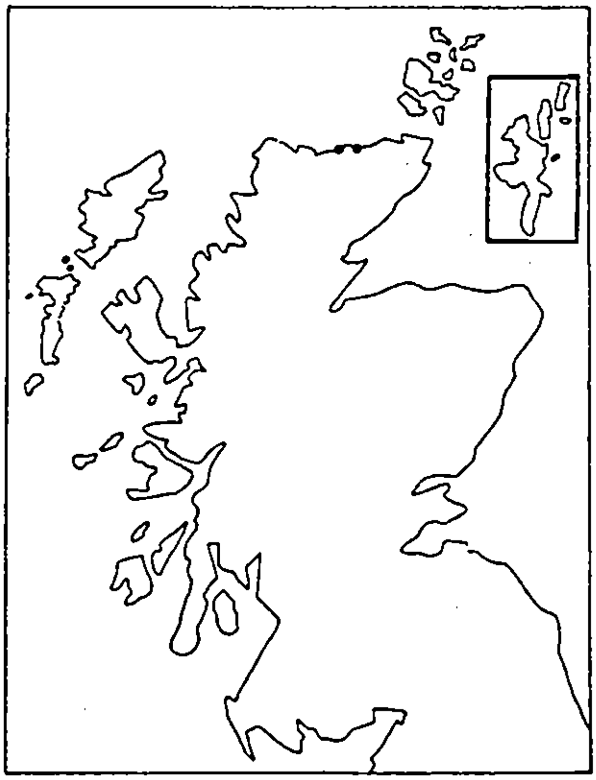
9 Sites

Site Type 5
(negative)



7 Sites

Site Type 6
(positive)



2 Sites

STEP 11

Indicators:-

Negative	Positive
Angelica sylvestris (0%+)	Ammophila arenaria (40%+)
Caltha palustris (0%+)	Dryas octopetala (0%+)
Cardamine pratensis (0%+)	
Centaurea nigra (40%+)	
Daucus carota (0%+)	
Eleocharis palustris (0%+)	
Epilobium palustre (0%+)	
Filipendula ulmaria (0%+)	

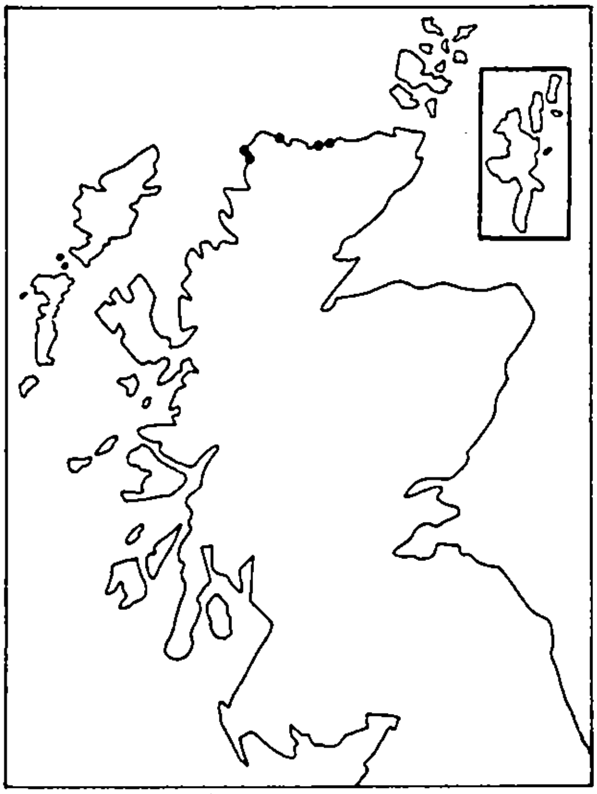
SCORE -4 or less -------- SITE TYPE 7

SCORE -3 or more -------- SITE TYPE 8

DISTRIBUTION OF SITES INVOLVED

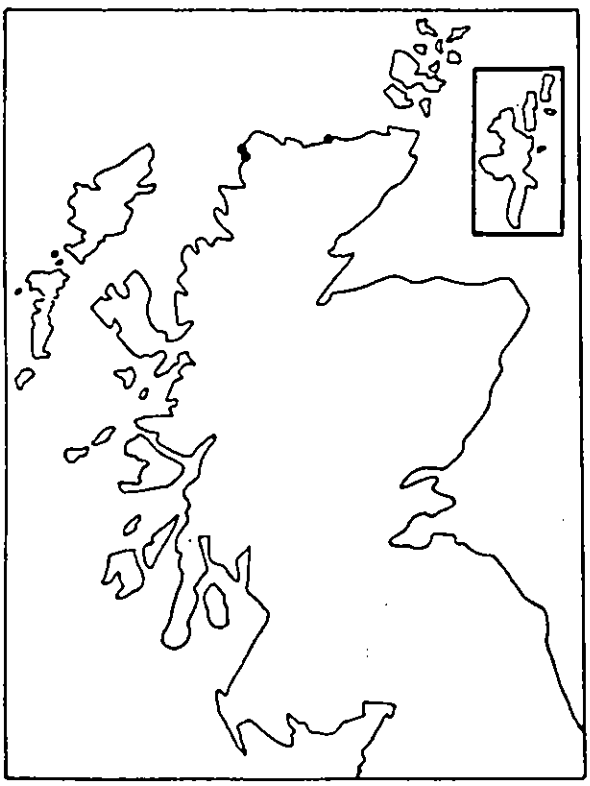
IN DIVISION 4/4

11



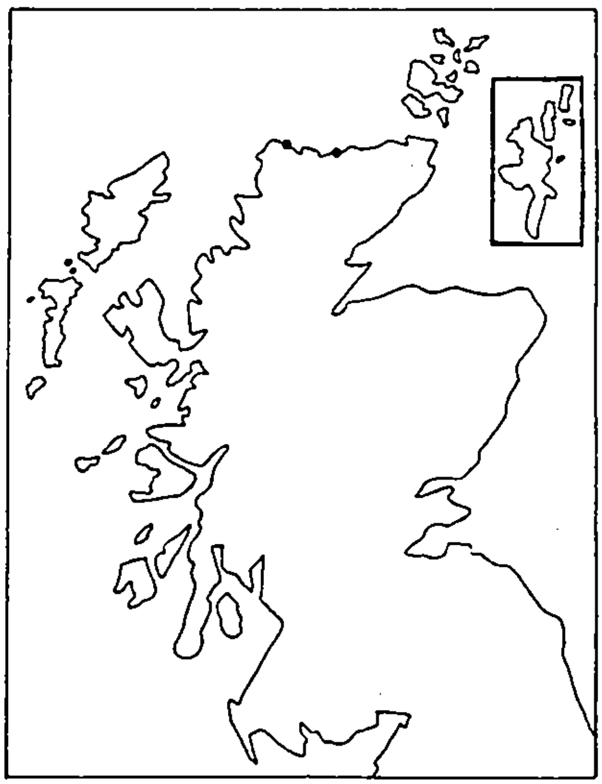
5 Sites

Site Type 7
(negative)



3 Sites

Site Type 8
(positive)



2 Sites

STEP 12

Indicators:-

Negative	Positive
Agrostis tenuis (40%+)	Bellis perennis (20%+)
Chamaenerion angustifolium (0%+)	Carex panicea (20%+)
	Carex pulicaris (0%+)
	Drosera rotundifolia (0%+)
	Erica tetralix (20%+)
	Molinia caerulea (20%+)
	Narthecium ossifragum (0%+)
	Trichophorum cespitosum (0%+)

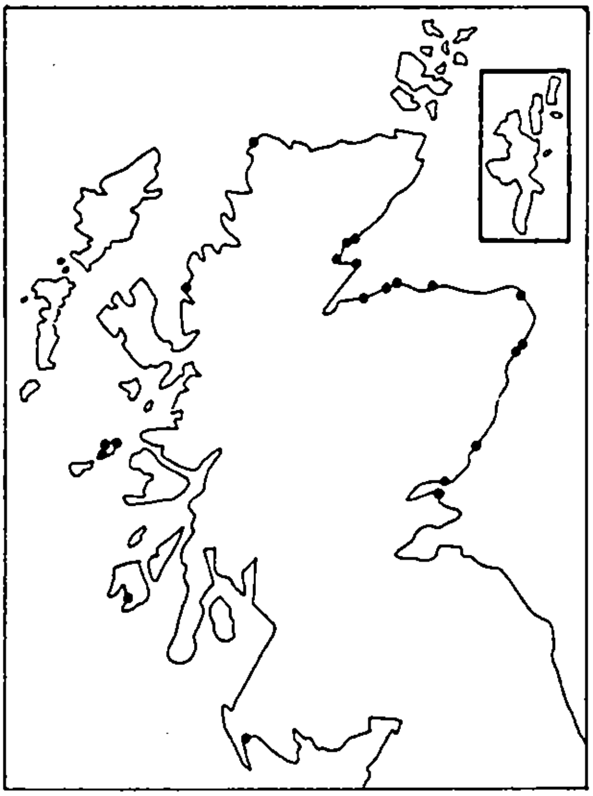
SCORE 1 or less -------- SITE TYPE 9

SCORE 2 or more -------- SITE TYPE 10

DISTRIBUTION OF SITES INVOLVED

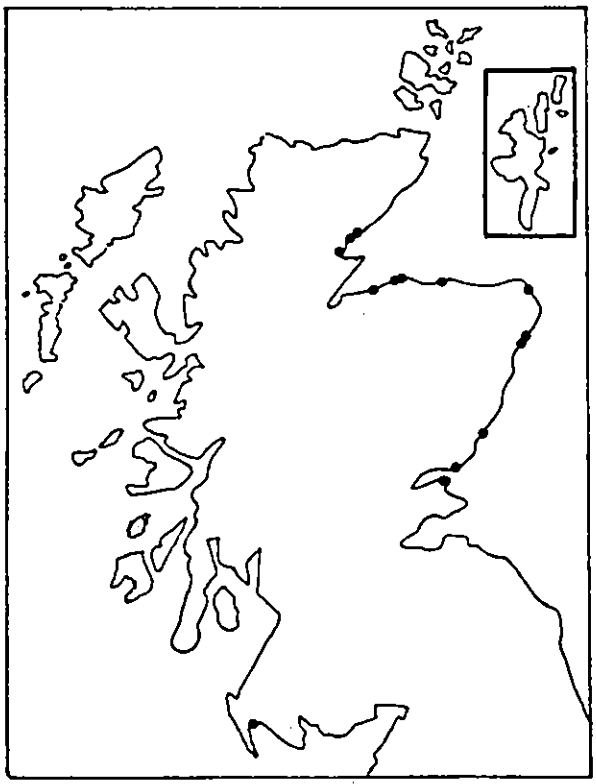
IN DIVISION 4/5

12



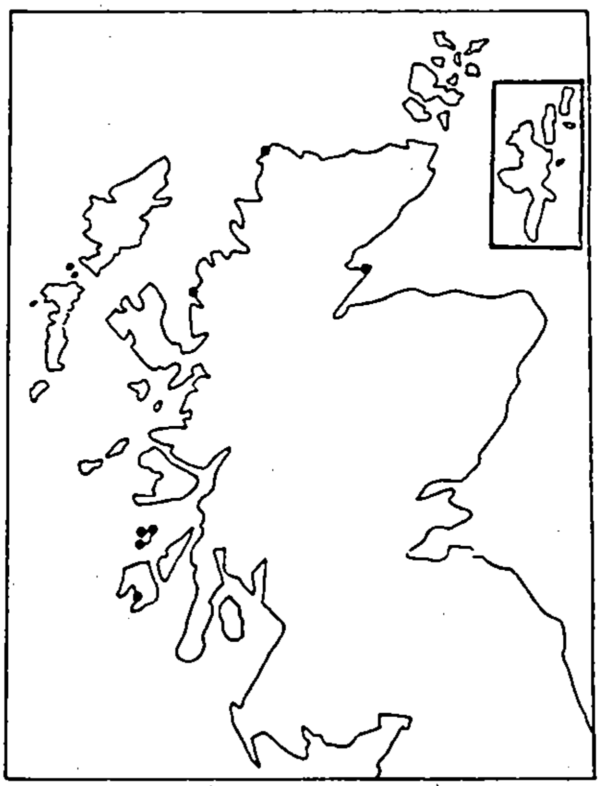
21 Sites

Site Type 9
(negative)



14 Sites

Site Type 10
(positive)



7 Sites

STEP 13

Indicators:-

Negative	Positive
Achillea millefolium (20%+)	Armeria maritima (0%+)
Campanula rotundifolia (20%+)	Glaux maritima (0%+)
Rumex obtusifolius (0%+)	Plantago maritima (20%+)
Thalictrum minus (0%+)	Puccinellia maritima (0%+)
	Salicornia agg. (0%+)
	Suaeda maritima (0%+)

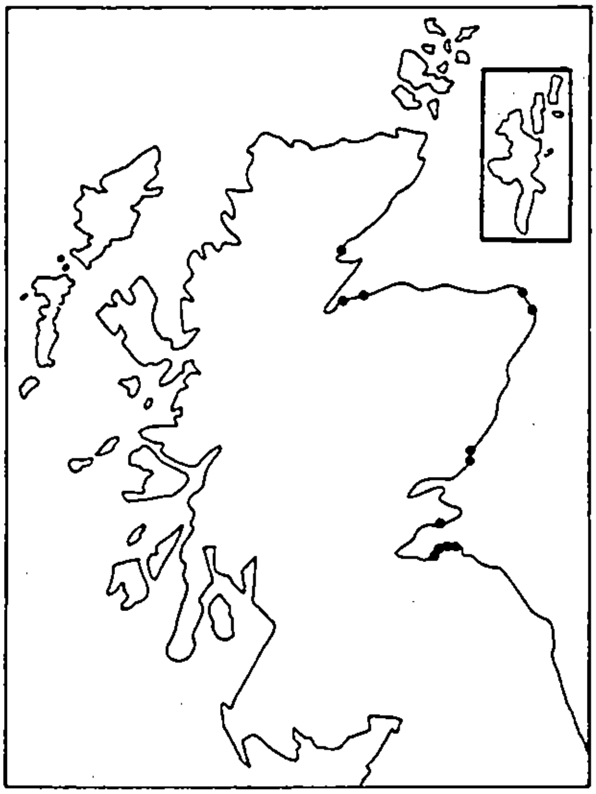
SCORE 1 or less -------- SITE TYPE 12

SCORE 2 or more -------- SITE TYPE 13

DISTRIBUTION OF SITES INVOLVED

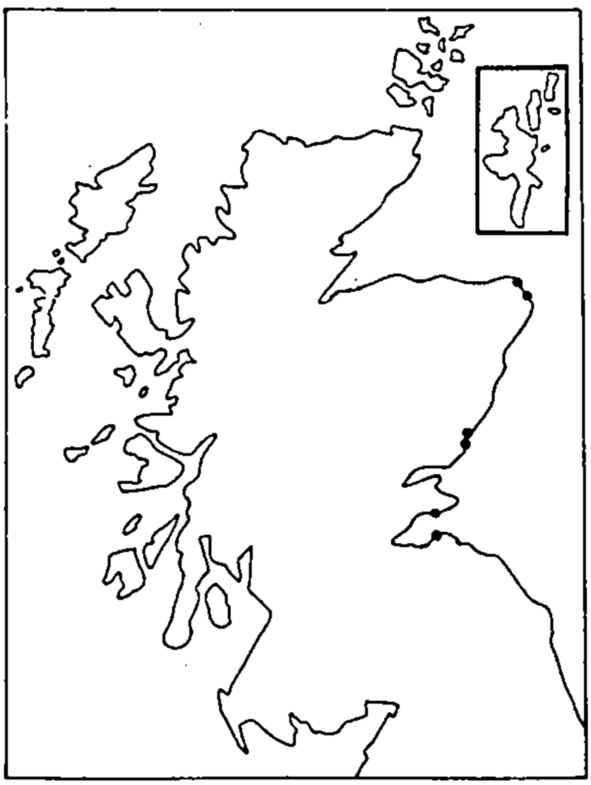
IN DIVISION 4/7

13



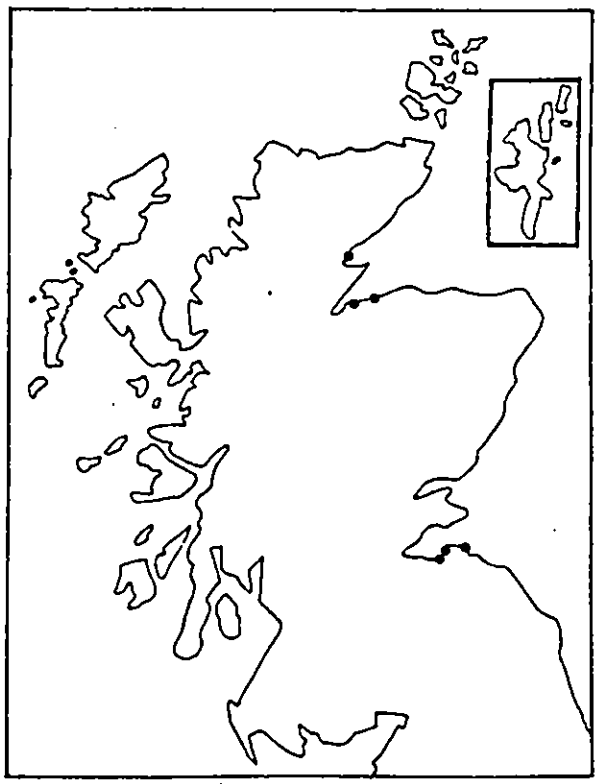
12 Sites

Site Type 12
(negative)



6 Sites

Site Type 13
(positive)



6 Sites

9 SOIL CLASSIFICATION

9.1 Aims of the Soil Classification

The main aim of the soil classification is to assist in producing a comprehensive and useful interpretation of the vegetation types (see Section 7) and also to account for some of the differences between sites and site types (see Section 8). The traditional descriptions of sand dune vegetation types are strongly influenced by successional trends in which the progressive stabilization of sand and the development of a soil profile plays a central role. The accepted explanation for the development of vegetation on sand dunes is based largely on general observation and the subjective selection of a series of examples to illustrate the hypotheses thus generated. The Scottish Coastal Survey, with its large number of objectively chosen samples, provides an excellent opportunity to test the validity of these hypotheses.

9.2 The Method of Soil Recording

Compared with the conventional methods of profile description employed by experienced soil surveyors, the procedure used in the Scottish Coastal Survey is rather crude and possibly insensitive. The reasons for the method used are threefold.

(a) Experienced soil surveyors were not available and the method employed had to be within the capability of people who had to do the work.

(b) Even with experienced soil surveyors, it can be quite difficult to achieve a reasonable degree of reproducibility, so the method used was designed to give as much standardization as possible.

(c) It was hoped to produce a soil classification by methods analogous to those used for the vegetation and sites, i.e. by numerical classification, and it is difficult to transform conventional soil data into a form suitable for this type of procedure.

The method of soil recording that was developed to meet these requirements is described in detail, with instructions on how to implement it, in Appendix 1 - Handbook of Field Methods (pages 13 and 24-25). Basically, the method avoids the prior division of the soil profile into pedologically identifiable horizons and, instead, uses a purely arbitrary division into 10cm thick layers. Because most rooting by plants occurs in the top 40cm of soil, this was the maximum depth to which the profile descriptions were taken. In consequence, the characteristics of the soil were recorded in four layers - at 0-10cm, 10-20cm, 20-30cm and 30-40cm depth. In conventional pedological terms, each of these layers might comprise one or more distinct horizons. Thus the penalty of this method of recording is to blur the detail of both horizon characteristics and the depth at which they occur. Where two or more fairly distinctive horizons occurred in the same 10cm layer, all the characteristics present were recorded but with no numerical information as to amount or order, i.e. recording all the characteristics present as though the layer were a uniform mixture. The accompanying soil profile diagram and soil smears (see Handbook of Field Methods - opposite page 25) were used to interpret this sort of situation for individual profiles but there is no easy way that this type of information can be incorporated into the numerical data on which the soil classification used in this report is based.

Only four types of soil characteristics are really suitable for visual and tactile (feeling between the fingers) recording.

(a) Organic material - the presence of organic (as opposed to inorganic) material in the soil. This was divided into four categories or attributes: litter (undecomposed plant remains), roots, peat and incorporated humus, the latter being assessed by differential colouration and feel.

(b) Substrate type - the inorganic components of the soil. This makes use of the standard particle size fractions recognized in soils - clay, silt, sand, gravel, cobbles, angular stone, boulders and solid rock. The last two size categories (boulders and solid rock) were taken to signify the termination of the soil profile because they preclude further digging (but not necessarily root growth). The smaller particle sizes were assessed by feel and the larger by visual means.

(c) Colour - this is a very important characteristic in the interpretation of soil profiles because it carries information on the prevailing chemical process, i.e. reduction or oxidation, and on the distribution of humus. More particularly, it is change in colour, one horizon relative to another, that is important and at least some of this information is successfully incorporated into the numerical data. Only six basic colours were recognized - black, grey, dark brown, light brown, yellow and white. The recording of multiple colours for a layer was permitted.

(d) Moisture status - quite simply the moisture present in the soil at the time of sampling divided into three categories, dry, damp and wet.

9.3 Characteristics and Limitations of the Soil Data

Much has already been said above to indicate the types of data that were collected and their possible limitations. Obviously this is a relatively crude way to describe such a complex and variable entity as a soil but, as an approach to the problem, it does have its strengths. The main advantages of the method are simplicity and standardization. It was not the intention of the survey to describe each and every profile down to the very last detail but merely to establish the nature of the relationships between quite widely varying vegetation types and the soils on which they grow. If the overall trends can be determined by the use of such apparently crude data, then it will lay a firm foundation for more detailed studies of the plant/soil or vegetation/soil relationship at some time in the future.

Particular note should be taken of the use above of the phrase "relatively crude", because there are grounds for supposing that these types of soil data are really a good deal better than they might appear to be at first sight. Hopefully, this will become apparent when the results of the classification are discussed.

A number of other limitations of the data should also be borne in mind. The first of these limitations is that a single soil pit in the middle of the 25 sq m (5 x 5m) quadrat is being used to represent conditions throughout the quadrat. In most cases this is justified by the degree of uniformity within the quadrat; a large proportion of the 25 sq m quadrats are substantially uniform with respect to both vegetation and soil, i.e. 75-80% perhaps. Others are less uniform and some are so complex as to defy adequate representation by even a large number of soil pits (and it would not be easy to mean the data from a number of pits anyway). Non-uniformity in the soil is not necessarily such a severe problem as might be expected. For example, one of the soil types derived by analysis, and described later, is defined by solid rock or boulders being exposed at the ground surface, i.e. this is the condition observed at the centre of the quadrat. Nevertheless, this "soil type" has associations with quite a narrow range of vegetation types. This rather unexpected association is possible because the circumstances under which solid rock and boulders occur at the surface obviously dictate quite a narrow range of alternatives for the soil proper. In this particular case, the soil surrounding rock and boulders tends to be peat or peat/sand mixtures. What is also significant, is that soils developed in these circumstances vary in depth and moisture relationships over quite small distances on the ground. Thus, where the rock is close to the surface, quite shallow well drained soils have developed whilst further away, but still within the confines of the quadrat, deep, wet peat may be found. Not surprisingly, this combination of habitats tends to produce a characteristic vegetation type. Obviously it does not work in every single case, a few rocks stick out of pure, blown sand, but, on average, superficial rock at the quadrat centre does define a particular set of edaphic conditions over the quadrat as a whole. There are several other examples of this type of "concealed association" and, indeed, it would seem that the soil data have at least some of the robustness found in vegetation (species list) data.

In practice, the soil data were quite well recorded but, despite the definitions and advice given on the recognition of various features in the Handbook of Field Methods, some features gave difficulty. The distinction between peat and peat/soil mixtures was a difficult one but humus incorporated and the colour black or dark brown seemed to be a rough equivalent when it came to numerical classification. In the less mature soils, the decision as to whether humus was incorporated or not, and to what depth, proved to be a minor problem. Here again, colour seemed to provide a good substitute. Light brown colour usually means that humus is present, whereas yellow and white generally indicate pure mineral sand. The detection of silt when present in appreciable quantities, also seemed to present some problems. Hence the more highly organic saltmarsh soils tend to be classified along with peats, which is not an unreasonable result on the basis of their visual features (and their water relationships, except that it is saline and not freshwater).

Overall, colour proved to be quite an important factor, particularly in the lower levels of the soil classification, i.e. after the main types had been sorted out on the basis of substrate material and depth. What influence moisture content had on the assessment of colour is not known but the effect is thought to be fairly minimal. This conclusion is based on a comparison between the colour recorded in the field and that of the dried soil smears on the field sheets. The differentiation of colours was also so coarse, i.e. six colours only, that there was less chance of moisture content having an influence (cf. the use of Munsell Colour charts).

Rather surprisingly, the moisture status of the soil proved to be quite an important distinguishing feature in the lower levels of the soil classification. First reaction to this feature was that it was likely to be a meaningless distinction, based largely on the weather conditions immediately before or at the time of sampling. However, a closer examination of the matter reveals that such fears are largely unfounded. First of all, it is usually the moisture content below 10cm that is important. At this depth there should be greater stability of moisture content and less effect of recent rainfall. There are also some sites where the soils within them have been separated almost solely on the basis of moisture content. As whole sites rarely took more than a few days to survey, the different moisture contents are unlikely to have been an artefact of the weather. Finally, when it comes to examining the association between soils and vegetation types, there are almost invariably quite marked differences between soil types that have been separated purely on moisture content. These matters are discussed further in the context of describing the individual soil types

At the same time that the soil profiles were recorded in the field, three soil samples were also taken - from 5cm, 15cm and 30cm depths. Apart from a few loss-on-ignition (LOI) determinations, which are not discussed in this report, no other work has been done on them. The samples provide a potential source of information from which specific hypotheses concerning the soil and its relationship with the vegetation and other ecological factors might be investigated at some time in the future.

More recently, some samples (two from each site) have been analysed to determine their free calcium carbonate content. However, as all of these samples were taken from quadrats located as near to the sea as possible, with the additional requirement that they should contain little or no incorporated humus, the results shed little light on the soil classification. All they do is to show that some sites do have high levels of calcium carbonate in their beach (or near beach) sand whilst others do not. To what degree this influence extends inland is not known for most sites. Some of these results have been reported on in Section 8 (the Site Classification) and a supplement to the Main Report, giving further details, will be produced at a later date.

9.4 Derivation of the Soil Classification

The soils were classified by the same method as that employed for the vegetation classification, using ISA directly on the attribute data described above. The only information additional to that recorded on the field sheet (see Handbook of Field Methods) was where the profile was effectively terminated by the presence of a water table. This was coded according to depth in the same four layers as the other features (codes 90-93 were in fact used).

One minor complicating factor was that it was not possible to record any soil profiles at Morrich More and also on part of Barry Links. Both sites have been used in the past as firing ranges and there is a consequent danger from unexploded missiles. This means that a total of 94 out of 3,847 quadrats were not sampled for soil. One further quadrat contained a soil composed only of ashes and domestic debris (a rubbish dump) which could not be accommodated on the soil recording sheet. It was, therefore, considered as unclassifiable. This leaves 3,752 quadrats for which it was possible to allocate a soil type. All statistics and significance levels have been calculated to this base.

The ISA was taken down to seven levels (see Figure 8), at which stage there were 35 classes. In general, it divided rather unequally, with several terminations on the positive side. Four of these classes were amalgamated, one pair because they involved such a small number of quadrats and were still extremely heterogeneous (see CS7) and the other because the classes were essentially the same, i.e. boulders at the surface and solid rock at the surface (see TS10). The result was 33 soil types which, after further examination of their internal properties in conjunction with an ordination of the types, were divided into five series. These series are named as follows.

1. Deep Sandy Soils (DS1-DS8)
2. Peaty Soils (PS1-PS5)
3. Sandy Cobble Soils (CS1-CS7)
4. Thin Soils (TS1-TS10)
5. Beach Deposits (BD1-BD3)

9.5 Soil Type Descriptions

9.5.1 Deep Sandy Soils (DS)

There are eight types of Deep Sandy Soil which account for 2,741 out of the 3,753 quadrats (73%) for which soil profile data were obtained. Because of their numerical superiority, these are is obviously the most important series of soil types for understanding the relationship with vegetation. If there there are strong associations between soil and vegetation, then the common soil types should be closely related to the common vegetation types. The Deep Sandy Soil series ranges from what is virtually "raw" mineral sand, with little or no organic matter present, to quite well developed (mature) profiles in which there is a good deal of humus incorporated down to 40cm depth (maximum soil recording depth in this survey). The different types almost certainly represent a developmental series which progress with time and in the absence of further disturbance by sand movement. Both removal and deposition of sand tend to keep the profile immature. Different types of sand, i.e. siliceous as opposed to shell sand, different particle sizes and the inclusion of weatherable minerals, are also involved but, to what extent, it is difficult to determine without detailed physical and chemical analysis of the sand fraction itself. As already noted, the samples are available but have not been worked on yet.

Obviously both the data and the soil classification derived from it represent a gross simplification of what really exists. Many of the sandy soils are quite mobile now, or have been in the past. Some profiles contain buried soils, more recent material having been deposited on the top, whilst others have been truncated and old surfaces exposed. The type of soil classification produced inevitably looks at generalities and there are often quite a number of exceptions to the rule. These exceptions may be caused by a variety of events that affect the soil and its relationship with the vegetation but are no longer readily observable.

The Deep Sandy Soil series (DS1-DS8) is now described in putative developmental order.

DS1 (49 quadrats)
Brief description - Immature (no humus), yellow sand, dry.

This relatively uncommon soil type is composed of almost pure yellow sand with little or no humus present (only 16% of examples had humus recorded in the top 10cm). Other size fractions, e.g. clay, silt, gravel and cobbles, are virtually absent. All the profiles of this type were recorded as dry down to 20cm but most had become damp at 40cm. Apart from Sanna in the south-west, this is an exclusively north and east coast soil type. Sand colouration, i.e. iron staining of the sand grains, and relatively low rainfall are probably the basis of the type.

DS2 (158 quadrats).
Brief description - Immature (no humus), yellow sand, damp.

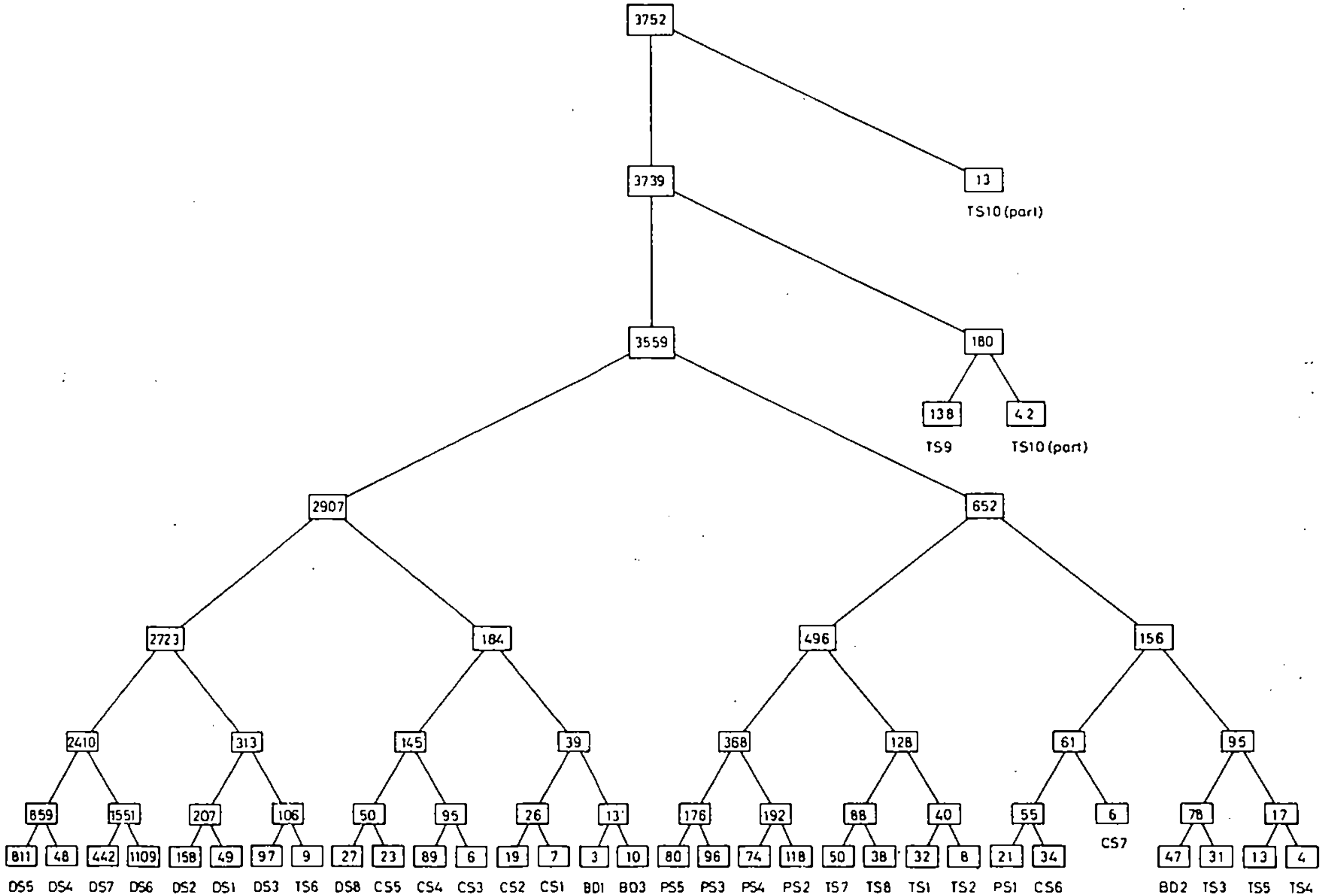
The only obvious distinction between DS1 and DS2 is that the latter is a good deal damper, even near the surface (65% of the quadrats in DS2 were recorded as being damp in the 10-20cm zone). Below 20cm, all the profiles in both types were recorded as being damp and this is continued down to 40cm with only one incidence of wet being recorded. Whether this distinction is real or merely an effect of the weather immediately prior to sampling, i.e. it had rained in the last few days, is not immediately obvious (see also DS5 and DS6). The geographical distribution of DS2 is very similar to that of DS1, on the north coast and northern half of the east coast but also in a group of sites in south-west Scotland. However, as some of the recording involving the two types types was done in the exceptionally hot, dry summer of 1976 and, on a number of sites recorded at this time there were both dry (DS1) and damp (DS2) types, the distinction would appear to be a genuine one. The fact that there are no parallel distinguishing features for DS1 and DS2 is only to be expected with this degree of immaturity, i.e. all pure sand looks much the same. In terms of subsequent development, it would be postulated that the two types would diverge with time. An examination of the associated vegetation types (see Table 6) tends to confirm the distinction between DS1 and DS2, i.e. the types are different as far as the plants are concerned.

DS3 (97 quadrats).
Brief description - Immature (no humus), white/yellow sand, damp.

This type is similar to DS2, with very little humus incorporated even in the top 10cm (7% of profiles in the type) but with a much higher content of comminuted shell which often masks the basically yellow colour of the sand. DS3 is very characteristic of the northern half of the Outer Hebrides (Harris and Lewis) but does occur to some extent in other parts of Scotland with the exception of the southern half of the east coast.

Figure 8

Soil Type Classification



DS4 (48 quadrats).
Brief description - Semi-mature (some humus), light brown/white shell sand, dry.

The type has a moderate degree of humus incorporation in the upper layers of the profile. There is probably quite a high shell content in most examples of the type but this is more reliably indicated by the white colour than by direct recording of shell fragments. This apparent anomaly may be the result of fine comminution of the shell, so that laminar fragments are no longer evident. Humus staining may also tend to conceal the presence of shell without microscopic examination. Only analysis of the soil samples would confirm or refute these suggestions. The type is characteristic of the southern half of the Outer Hebrides (Bara and South and North Uist). However, unlike DS3, it also occurs sporadically on other parts of the Scottish coast.

DS5 (811 quadrats)
Brief description - Semi-mature (some humus), light/dark brown sand, dry.

This common soil type (22% of quadrats) exhibits a good deal of humus incorporated in the top 10cm, where the colour is usually light or dark brown due to masking of the mineral colour of the sand by organic matter. With increasing depth, the colour pales to light brown or, in some cases, to yellow as the amount of humus diminishes. In contrast to the following type (DS6), DS5 was recorded as being fairly dry at the surface and even quite dry at 40cm depth (55% of the profiles are dry and 45% damp at this depth). As with types DS1 and DS2, the question arises as to whether a distinction based on moisture at the time of sampling is real. This is discussed in connection with DS6 (below). DS5 is a common soil type, well distributed round the Scottish coast but it is significantly less abundant in Harris and Lewis (northern Outer Hebrides) and on the north coast.

DS6 (1,109 quadrats).
Brief description - Semi-mature (some humus), light/dark brown sand, damp.

This is the most common soil type recorded in the survey, occupying nearly 30% of the quadrats. DS5 and DS6 together account for 51% of the soils. Superficially, DS6 is very similar to DS5, the main difference being that the former is damp as opposed to dry. Despite the fact that the upper horizon (0-10cm) tends to be darker in colour than DS5, it pales more quickly with depth, light brown being the dominant colour below 10cm. There is also a slight tendency towards the initiation of a peat layer at the surface. The other feature which distinguishes DS6 from DS5 is a sharp increase in the amount of shell recorded in the profile. In terms of geographical distribution, DS6 shows a distinctive western tendency as compared with DS5, which is more abundant in the east of Scotland.

Because DS5 and DS6 are by far the most common soil types recorded in the survey, the reality of their distinction (or otherwise) is important. The degree of dryness or dampness in the profile is the most clear-cut distinguishing feature and this gives some grounds for doubt. However, when it comes to the main purpose of the exercise, which is to account for the different vegetation types in relation to edaphic factors, there are very marked differences between DS5 and DS6 (see Table 6). These contrasting associations go a long way towards confirming the apparently frail distinction based on visual attributes alone. In particular, the behaviour of the Duneland vegetation types

D2, D3 and D4 in relation to these two soil types provides good evidence of their difference as far as the plants are concerned. The ecological interpretation of this difference is that water relations are the key factor. This will be discussed in greater detail later in this section.

DS7 (442 quadrats).
Brief description - Mature (humus rich), dark brown sand, damp.

This is the most mature type in the Deep Sandy Soil series, with a considerable amount of humus incorporated in the profile, often to a depth of 40cm or more. DS7 is a common soil type, accounting for nearly 12% of quadrats. The dominant soil colour is dark brown, paling gradually to light brown with depth but nearly 50% of the examples are still dark brown at 40cm. The profile is usually uniformly damp from 0-40cm, with little tendency towards wetness, i.e. the water table is considerably deeper than 40cm in summer and is not the cause of dampness. Soil type DS7 is well distributed round the Scottish coast, being rather more abundant on sites in the west and north of Scotland than in the east.

DS8 (27 quadrats).
Brief description - Mature (much humus), dark brown sand, with some gravel and cobbles, damp.

This type is really transitional with the Sandy Cobbles (CS) series (see below). The top few centimetres of the profile are dark brown and sandy, like those for DS7, but there are increasing amounts of cobbles, and to a lesser extent gravel, with depth. These larger size fractions are, however, always set in a sandy matrix, which is the basic difference from the CS series of soils, where the amount of sand is often much reduced, or even absent, in some layers. The type has a very characteristic geographical distribution, being most common in the Moray Firth sites but also occurs in three sites on the north coast and on Islay and Colonsay in the south-west.

9.5.2 Peaty Soils (PS)

In practice, the Peaty Soil series are mostly mixtures of peat and sand, as it is only in areas which blown sand never reaches that uncontaminated development of peat can occur. To what extent the sand affects the peat and the plants that grow on it is an open question but the amount of calcium carbonate (in the form of shell fragments) thus incorporated is probably the most important factor.

There are five types of Peaty Soil. The series comprises 389 examples or just over 10% of the quadrats sampled. The most extreme type, PS5, is a deep, wet peat with little sand present. At the other extreme, PS1 is a peat/sand mixture that is transitional with the more mature, Deep Sandy Soils, e.g. DS7, and possibly with some of the sand/cobble mixtures. It is not clear to what extent the Peaty Soils are a developmental series, like the Deep Sandy series above. There is no doubt that some of the peats have developed over blown sand which at some time in the past was the soil surface but, as a result of a high water table, peat has developed on top of it. There are various possible causes of a high water table: the quadrat may at the edge of a loch or stream, in a deep slack or there may be flushing in the profile. In other cases, the peat is not underlain by sand but has developed on top of some other substrate type such as drift, boulders or solid rock. Peat formation may be the result of convergent processes. In some places it may be initiated by high water table, i.e. the hydrology of the site, whilst elsewhere the combination of high rainfall and low evapotranspiration may be sufficient to set the process into motion. The Peaty Soils series is now described, starting with peaty sands and finishing with the more pure peats.

PS1 (21 quadrats).
Brief description - Peat, sand (clay, silt) mixture, with gravel, cobbles and angular stone embedded, damp.

The finer constituents of this type are mainly peat and sand but clay and silt were also recorded in some profiles. Peat decreases with depth, whilst sand increases along with cobbles, gravel and angular stone, in that order of importance. The dominant colour throughout the profile is dark brown or black, with some examples paling to light brown with depth. All examples of this type are at least 40cm in depth. In terms of its geographical distribution, PS1 is most common on the Moray Firth sites and on Coll, Tiree, Colonsay and Islay in the south-west (see also DS8) and may be in some way related to raised beach deposits.

PS2 (118 quadrats).
Brief description - Peat, sand (clay, silt) mixture, damp.

This type differs from PS1 by having less cobbles and gravel in the profile and more silt. On average, the profile is also shallower, 43% being only 20cm deep and another 20% only 30cm deep. The main underlying material for these shallower examples is solid rock (56% of the 63% which are less than 40cm deep). The profile was recorded as predominantly damp. The main colour is dark brown or black but with more light brown than PS1 and this feature increases with depth. In terms of geographical distribution, PS2 is mainly a northern and western type (the result of an oceanic climate?). About 10% of this type are saltmarsh soils.

PS3 (96 quadrats).
Brief description - Peat, sand (silt) mixture, wet.

In general, this seems to be a wetter counterpart of PS2. It differs from it by containing much less clay, slightly less silt and only very small amounts of gravel (no cobbles or angular stone). Like PS2, not all examples of this type have profiles deeper than 40cm; 10% terminate at 20cm and 21% at 30cm. The main underlying material for shallower soils is the water table (27% out of 31%). Again, the dominant colour in the upper part of the profile is dark brown or black but this tends to pale to light brown with depth. In terms of its geographical distribution, PS3 is very similar to PS2, probably for the same reason of oceanic climate. It should be noted that about 20% of this type are saltmarsh soils for reasons that are explained in Section 9.3.

PS4 - (74 quadrats).
Brief description - Peat (sand) mixture, damp.

This is a very much more peaty type than the preceding members of the series (PS1-PS3). Sand increases slightly with depth, a little clay and silt were recorded but the larger constituents, gravel, cobbles and angular stone, are comparatively unimportant. Not all the examples of this type are as deep at 40cm, 1% terminate at 10cm, 3% at 20cm and 12% at 30cm. Underlying material for the shallower soils is varied and includes examples with boulders, solid rock and water table. Profile colour is dark brown or black throughout, with a small proportion being light brown at 40cm. Again, in terms of geographical distribution, PS4 is largely a northern and western type, with only Spey Bay (Central) and Strathbeg in the east containing examples. Both these site have a strong freshwater influence, with a large river and a loch respectively.

PS5 - (80 quadrats)
Brief description - Peat (sand, silt), mixture, wet.

This is the most peaty type of all, being fairly uniform peat throughout. Silt and sand are the most common non-organic constituents. The silt, and a small amount of clay, are largely associated with highly organic saltmarsh soils which form nearly 30% of the type. Cobbles and gravel are largely absent at all levels in the profile. Only 5% of the soils terminate at 20cm and 6% at 30cm, solid rock and water table being responsible in roughly equal proportions. In terms of geographical distribution, PS5 is fairly widespread but is more abundant in the west and north and has no occurrences on the southern half of the east coast. One site, Tong on Lewis, is largely responsible for the saltmarsh element in PS5, containing 17 quadrats (57% of the site) of this type.

9.5.3 Sandy Cobble Soils (CS)

There are seven types of Sandy Cobble soils in the series, ranging from virtually unaltered substrate, i.e. mostly beach deposits, to sand and cobbles with a thin layer of peat on the top. In the context of the whole survey they are not particularly important, with a total of only 184 quadrats out of the 3,752 for which soil data were obtained, i.e. just under 5%. Like the Deep Sandy Soils, the Sandy Cobble Soils form a reasonably coherent developmental series. Their presence within a site appears to be related to the occurrence of beach deposits and, hence, the concentration of the series in the Moray Firth region and on the north-east coast. The various types within the series are probably related to the age of the deposit, i.e. to the length of time that the profile has had to develop.

The types in the Sandy Cobble series are now described in putative developmental order.

CS1 (7 quadrats).
Brief description - Sand and cobbles mixture, immature (no humus), yellow or light brown.

The profile of this uncommon type consists of a mixture of sand, gravel and cobbles down to 40cm. Sand decreases slightly with depth whilst cobbles increase. There is no humus in the top 10cm of the profile and even roots were absent in the seven examples recorded. The sand colour is yellow or light brown, with occasional white grains or bands. With such a small number of examples no conclusions can be drawn about the geographical distribution of CS1.

CS2 (19 quadrats).
Brief description - Sand and cobbles mixture, immature (no humus), white.

This type is very similar to CS1 but the predominant colour of the sand is white, or, in a few instances, light brown, but never yellow. Again, there is no humus or roots in the top 10cm of the profile. This type is most abundant in sites on the Moray Firth and on the north-eastern coast.

CS3 (6 quadrats).
Brief description - Sand and cobbles mixture, semi-mature (some humus).

This rather uncommon type is probably equivalent to one of the semi-mature, Deep, Sandy types, e.g. DS2, except for the gravel and cobbles which it contains. The profile is composed primarily of sand and cobbles with a little gravel or angular stone. There is quite good humus incorporation in the top 10cm but this decreases rapidly with depth and none is recorded below 20cm. Cobbles increase with depth and there is a good deal of silt throughout the profile. The predominant colour is dark brown at the top and light brown at the bottom. With only six examples of the type, few conclusions can be drawn about the geographical distribution of CS3.

CS4 (89 quadrats).
Brief description - Deep sand with gravel and cobbles, semi-mature (some humus), dry.

This is the most common type in the Sandy Cobble series. The profile is generally more sandy than the preceding types in the series. CS4 is very similar in terms of profile development to the semi-mature, Deep Sandy types DS4 and DS5, the only real difference being the presence of gravel and cobbles, which increase rapidly with depth. There is a good deal of incorporated humus in the top layer (0-10cm) and there is still some as deep as 40cm in a few more mature examples of this type. The predominant colour is light or dark brown near the surface and light brown or yellow at depth. In terms of its geographical distribution, CS4 is very much an east coast type with its highest concentration in sites on the Moray Firth.

CS5 (23 quadrats).
Brief description - Deep sand with gravel and cobbles, semi-mature (some humus), damp.

This type is very similar to CS4, the only obvious difference being that it is usually damper. It is difficult to find direct evidence that this is a real difference but characteristic associations with the vegetation types seem to confirm the distinction. As with CS4, the main concentration of the type is in the Moray Firth region.

CS6 (34 quadrats).
Brief description - Peaty, high organic sand and cobbles overlying cobbles, boulders or solid rock.

This type probably has some affinities with some of the more mature Deep Sandy Soils, e.g. DS7 or, more particularly, DS8. There is also some similarity with the Peaty types PS1 and PS2. The soil is quite sandy down to about 20cm where cobbles tend to take over, along with some gravel or angular stone. The top 20cm is also quite high in organic matter, either as incorporated humus or peat or both. Some of the profiles terminate at 20cm (12%) and others at 30cm (24%), the main cause being solid rock or boulders. Those that continue to 40cm are almost pure cobbles with some gravel, but no sand, in the 30-40cm layer. CS6 is quite widespread but is somewhat less common on the southern half of the east coast.

CS7 (6 quadrats).
Brief description - Varied mixtures of sand, gravel and cobbles with some clay and silt.

There is very little to be said about this type, except that it does appear to be associated with some vegetation types. The type is really a hotch-potch of very disturbed profiles with a strong maritime influence.

9.5.4 Thin Soils (TS)

Little can be said in general about the Thin Soil series. The only real feature that the members have in common is their thinness, usually less than 20cm and many less than 10cm, right down to the most extreme forms of the type in which there is no soil at all. There are ten types in the series and numerically they are of moderate importance, with 378 quadrats (just over 10% of those recorded). As was emphasized in the introduction to the section on soils, a single soil sample from the middle of a 25 sq m quadrat does not necessarily represent the quadrat as a whole. Nowhere is this more obvious than with the more extreme types of the Thin Soil series, some of which represent a very localized condition that is atypical of the rest of the quadrat. However, as will be seen later, this does not necessarily conceal the overall relationship between vegetation and soil, although this may not be evident from looking at individual quadrats. The Thin Soil series is now described in approximate inverse order of depth, i.e. starting with the deepest.

TS1 (32 quadrats).
Brief description - Peat or high organic sand with water table at 20-40cm.

This type is transitional with some of the Peaty Soil types, in particular PS2 and PS3. It does not resemble the Sandy Cobble types, because TS1 contains no gravel, cobbles or angular stone at any level in the profile. The top 20cm is mainly sand, with some peat and silt mixed in. There is a good deal of humus incorporated in the upper part of the profile, hence the dominant colour of dark brown or black in the 0-10cm layer. There is also a tendency for the profile to show rapid colour transitions, either because of the way in which the substrate was laid down, i.e. different materials at different times sometimes with intervening phases of erosion, or through the presence zones of chemical eluviation or deposition. The soil pales quickly to light brown, yellow or white in the 10-20cm layer. The water table is reached at a depth of 20cm in 56% of the type and 30cm in a further 28%, i.e. 84% have the water table in the top 30cm. The remaining 16% are up to 40cm deep and do not, therefore, strictly warrant the description of a "thin soil". These deeper examples are composed of pure sand with a little silt and are universally wet. It is assumed that they are subject to a high water table for part of the year even though it was not found in the top 40cm at the time of recording. In terms of its geographical distribution, TS1 is quite widespread but with a definite concentration in the north-west and north.

TS2 (8 quadrats).
Brief description - Peat or high organic sand, with some clay, with water table or solid rock at 20cm.

This type is very similar indeed to TS1. It is distinguished by the presence of more clay, less silt and the fact that some profiles contain a little gravel. All the examples of the type terminate at 20cm, with water table and solid rock equally responsible. The geographical distribution is very similar to that for TS1 as far as can be judged from a sample of eight.

TS3 (31 quadrats)
Brief description - Thin sand overlying cobbles.

This type shows close affinities with the Beach Deposit series and, in particular, BD1 and BD2 (see below). As the brief description indicates, the profile consists of little more than sand with organic matter or a thin layer of peat over virtually pure cobbles with some gravel also present. Some examples have clay or silt near the surface and these are associated with the saltmarsh habitat. In terms of geographical distribution, this type is more concentrated in sites on the Moray Firth than elsewhere.

TS4 (4 quadrats).
Brief description - none.

A very rare type that defies simple description. The profile is very shallow, 10-20cm, terminating in boulders, solid rock or water table. The only common feature found in the top 10cm is the presence of shell, along with sand, silt, clay, cobbles and angular stone in varying amounts. No conclusions can be drawn about its geographical distribution.

TS5 (13 quadrats).
Brief description - Thin sand with organic matter, gravel, cobbles and angular stone on top of boulders, solid rock or water table.

All examples of the type terminate at 10cm, most commonly on boulders or solid rock but a few on water table. The top 10cm which makes up the soil, such as it is, is composed of sand with organic matter incorporated or a thin layer of peat, with gravel, cobbles and angular stone mixed in. This type is widely but sparsely distributed round the Scottish coast.

TS6 (9 quadrats)
Brief description - Thin shell sand on solid rock.

This is a very simple type, being composed primarily of shell sand, with a little organic matter, possibly some gravel, cobbles or angular stone, on top of solid rock at or before 10cm depth. The type shows no distinctive geographical distribution.

TS7 (50 quadrats).
Brief description - Peat or sandy peat overlying boulders, solid rock or water table at 10cm.

Surprisingly, this is a relatively common type. The real emphasis is on the peaty element, the majority of profiles consisting of sandy peat or peaty sand over solid rock. Water table is a comparatively unimportant feature (4%) and most profiles are merely damp, rarely wet. In terms of geographical distribution, TS7 is a western and, to a lesser extent, a northern type. It occurs on sites that include fringes of rock where peat has developed under high rainfall conditions.

TS8 (38 quadrats).
Brief description - Peaty or organic sand, with some silt, overlying water table or solid rock at 10cm.

This is a much wetter type than TS7, both by direct assessment and the fact that in 92% of quadrats there is a the water table at no more than 10cm depth. As with TS7, the emphasis is on the peaty nature of the soil, except for a minority of quadrats which are of saltmarsh origin. In terms of geographical distribution, the type is largely north-western, with an outlier group in sites on the Moray Firth.

TS9 (138 quadrats).
Brief description - Water table at or near the surface.

This type represents some rather varied situations, from marshes, stream beds and loch edges to saltmarsh. In general, it does not constitute a very coherent type, as the only real common factor is that at the time of sampling there was so much free water present that it was impossible to dig and record a profile without it filling with water. At some other time of the year the water table might have been lower so at least the upper layer could have been recorded and the soil assigned to a more definitive type. Nevertheless, Table 6 does show that TS9 has several significant associations with vegetation types, particularly marsh and saltmarsh types. It should be noted that TS9 includes few "peaty" profiles because these are normally too well drained in summer to carry standing water. In terms of its geographical distribution, TS9 is mostly a western type, being particularly abundant in the southern Outer Hebrides and on the Inner Hebrides.

TS10 (55 quadrats).
Brief description - Solid rock or boulders at the surface.

This is quite a common type which, despite its apparently inhospitable features, has some associations with the vegetation types. It is obvious that rock can occur at the centre of a quadrat in almost any substrate type, e.g. in sand, drift or peat. However, quite a high proportion of the examples of this type recorded in the survey are associated with peaty soils. TS10 is widely distributed around the Scottish coast but with a heavy concentration in the southern half of the Outer Hebrides (south and north Uist in particular).

9.5.5 Beach Deposits (BD)

This series is so extreme that it hardly qualifies for the title of "soil". There are three types within the series. They total 60 quadrats or just under 2% of the soils recorded and are, therefore, not very important. Their common feature is the total absence of organic matter, or even roots, in the profile. To all intents and purposes they are unmodified, undifferentiated, mineral soils. Most are beach deposits but others may be riverine in origin.

BD1 (3 quadrats)
Brief description - Thin layer of sand and shell mixed with or overlying gravel and cobbles (no organic matter).

A very uncommon type and the brief description above can not be elaborated. All examples of this type occur on one site, Spey Bay (West), on the Moray Firth.

BD2 (47 quadrats)
Brief description - Pure cobbles down to 40cm, with occasional sand and gravel (no organic matter).

Again, there is little more to be added to the brief description. Nearly all examples of this type (39 out of 47) occur in sites on the Moray Firth, Whiteness having no less than 10 quadrats (22% of the site) of this type.

BD3 (10 quadrats)
Brief description - Sand with gravel and cobbles overlying solid rock or boulders at 10-20cm or cobbles down to 40cm.

Again, a very simple description. Nearly half this type terminate at 10cm on solid rock or boulder, the rest are just pure cobbles from 20-40cm. The type has no distinctive distribution round the Scottish coast.

9.6 Association Between Soil and Vegetation Types

As has already been noted, the primary purpose of producing a soil classification was to assist in the interpretation of the vegetation and site types. The relationships between the soils and particular vegetation and site types has been discussed in context in Sections 7 and 8 of this report.

Table 6 shows the overall relationship of the 33 soil types (the rows) and the 28 vegetation types (the columns). The table entries take the form of a dot (.) where no coincidence of soil and vegetation type occurs, NS (not significant) where there is coincidence, but where the number of quadrats in question does not differ significantly from what might be expected by chance, and plus (+) or minus (-) where the number of coincidences is significantly more or less, respectively, than might be expected by chance. The particular test used here is Fisher's Exact Test (direct calculation of factorials) because many of the expected values, i.e. those for the less common soil types, are less than 5 and a straightforward chi-square test is not applicable. One + or - means 95% probability, two (++ or --) means 99% and three (+++ or ---) means 99.9%.

Ordering of the rows and columns in the table is the simple, unmodified first axis order for a reciprocal averaging ordination of the soil and vegetation data respectively. As will be noted, there is a strong top right to bottom left diagonal trend in the table. However, the same problems of ordering exist as in Tables 2 and 3 (see Section 7.6), i.e. because of multi-dimensionality, no single ordering can be completely satisfactory. No attempt has been made here to produce such a sophisticated solution as in Tables 2 and 3. It is sufficient to appreciate that Table 6 confirms the general conclusion that there is a good relationship between soil and vegetation types. This relationship could undoubtedly be be clarified if more detailed soil analyses were available, e.g. calcium carbonate determinations and loss-on-ignition. Figures for proportions of various soil types in the different vegetation types are given in context in Section 7 and similar information for sites in Section 8 (see also Table 5 in Section 8.3.8).

TABLE 6. - ASSOCIATION BETWEEN TWENTY-EIGHT VEGETATION TYPES AND THIRTY-THREE SOIL TYPES USING FISHERS EXACT TEST

SOIL TYPES	VEGETATION TYPES																										
	P2	P3	P1	G4	G7	M3	G3	G6	M4	G2	M2	G1	D5	D6	H4	C1	D2	M1	D3	G5	C	S5	F2	S4	S3	F1	S2	S1
BD1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	NS	.	.	.	.	.	.	.	.	.
BD2	.	.	.	.	.	.	NS	.	.	.	.	.	.	.	.	---	NS	.	NS	+	NS	.	.	.	+	NS	.	.
BD3	.	.	.	.	.	.	.	.	.	.	.	NS	.	.	.	.	.	++	NS	.	NS	.	.	.	.	++	.	.
CS1	.	.	.	.	.	.	NS	.	.	.	.	.	.	.	.	.	.	.	+	.	NS	.	.	.	.	.	.	.
CS2	.	.	.	.	.	.	NS	.	.	.	.	.	.	.	.	-	NS	NS	NS	.	NS	.	+	NS	.	NS	.	.
DS1	.	.	.	.	.	.	NS	.	.	.	.	.	NS	.	.	-	NS	.	++	.	+++	.	.	.	.	.	.	.
DS4	.	.	.	.	.	.	NS	.	.	.	.	.	.	.	NS	NS	NS	.	+++	.	++	.	.	.	.	.	.	.
DS3	.	.	.	.	.	.	NS	.	.	.	NS	.	.	.	NS	---	NS	.	NS	.	+++	.	.	NS	NS	+++	NS	NS
DS2	.	.	.	.	.	.	--	.	.	NS	NS	--	.	.	.	---	NS	NS	+++	.	+++	NS	.	NS	NS	+++	.	.
TS6	.	.	.	.	.	.	.	.	.	NS	.	.	.	.	.	NS	.	.	NS	.	+	.	.	.	.	++	.	.
CS4	.	.	.	.	NS	NS	+++	.	.	NS	.	-	NS	+++	.	---	NS	NS	+	.	.	NS	.	.	.	.	+	.
CS3	.	.	.	.	.	++	.	.	.	.	.	.	.	.	.	NS	NS	.	.	.	.	.	.	.	.	.	.	.
TS3	.	.	NS	.	.	.	+	.	.	.	.	NS	NS	.	.	-	NS	+	NS	.	.	.	.	NS	NS	NS	NS	NS
CS5	.	.	.	.	.	.	NS	.	.	NS	NS	NS	.	+	.	NS	NS	.	NS	.	.	NS	.	.	.	.	NS	.
DS5	.	.	---	NS	-	.	+++	---	.	--	---	---	NS	.	---	+++	+++	NS	+++	.	NS	NS	.	---	NS	-	.	.
TS4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	NS	.	.	.	.	.	NS	.	.	.	+	.	.	.
DS6	---	NS	---	NS	NS	NS	---	---	.	---	--	NS	--	NS	+++	+++	NS	-	---	.	NS	-	NS	--	NS	NS	NS	NS
TS5	.	.	++	.	.	.	NS	NS	.	.	NS	NS	+	.	NS	NS	.	.	NS	.	.	.	.	.	.	.	.	.
DS8	.	.	.	.	.	.	+++	.	.	NS	.	NS	NS	.	.	NS	NS	NS	NS	.	.	.	.	.	.	.	.	.
CS6	NS	.	NS	.	.	.	NS	NS	.	NS	.	NS	NS	NS	NS	NS	.	.	NS	.	.	.	.	.	.	.	.	.
DS7	NS	NS	NS	+	NS	.	NS	NS	.	++	NS	++	NS	.	+++	+++	NS	+	---	.	---	NS	.	NS	NS	.	NS	NS
TS7	++	.	+++	.	.	.	NS	.	.	+++	.	++	NS	.	NS	-	NS	.	NS	.	.	.	.	.	.	.	.	.
CS7	.	.	.	.	.	.	.	.	.	++	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	++
PS1	NS	.	+++	.	NS	+	NS	NS	.	+	.	NS	NS	+	.	-	.	.	NS	.	NS	.	.	NS	.	.	.	.
TS1	.	.	.	.	+	.	.	NS	.	.	.	+++	.	.	++	--	.	.	.	.	.	NS	.	NS	.	.	.	+++
TS2	.	.	.	.	.	.	.	.	.	.	.	+	NS	.	NS	.	.	NS	.	.	.	.	.	+	.	.	.	.
PS2	NS	.	+++	NS	NS	.	---	NS	.	+++	NS	+++	+++	.	NS	---	NS	.	-	.	-	NS	.	NS	.	.	NS	++
PS4	+++	.	+++	.	NS	.	-	NS	.	+	+	++	NS	.	NS	---	.	.	-	.	.	.	.	NS	.	.	.	.
PS3	NS	NS	+	NS	NS	.	.	+++	.	NS	+++	+++	NS	.	++	---	.	NS	.	.	.	NS	.	+++	.	.	.	+++
TS8	NS	+++	NS	.	+	.	.	+	+	.	+++	NS	.	.	NS	.	.	.	NS	.	NS	.	.	NS	NS	NS	.	NS
PS5	+++	.	+++	NS	NS	.	-	++	.	NS	+++	NS	NS	.	.	.	.	.	--	.	.	NS	.	+++	.	.	+	NS
TS9	NS	NS	NS	.	NS	+	---	+++	+++	NS	+++	+	+++	.	NS	---	.	+	-	.	-	.	NS	NS	.	NS	.	+++
TS10	NS	.	NS	.	.	.	NS	.	.	NS	.	NS	NS	.	NS	NS	.	.	NS	+	NS	+	.	NS	NS	.	.	++

NS = not significant
+, ++ AND +++ = positively significant at 95%, 99% and 99.9% levels of probability, respectively
-, -- and --- = negatively significant at 95%, 99% and 99.9% levels of probability, respectively

10 ACKNOWLEDGEMENTS

We would like to thank all the landowners, crofters and farmers upon whose land on the coasts of Scotland we entered to complete the field survey. It is a pleasure to record the friendliness with which we were received in these remoter parts of Great Britain, with many people going out of their way to help us with our work.

In a survey of this magnitude, it is inevitable that many people assisted with the work. Their names are listed below in alphabetical order with a record of the part they played.

Institute of Terrestrial Ecology

A E Bailey-Watts	Field team leader
M E Bindloss	Field team leader
R H Britton	Field team leader
D L Cheyne	Assistance with survey map preparation
S M Coles	Field team leader
R Cox	Assistance with data handling
J Dale	Field team leader
L Farrell	Field team leader
E M Field	Field team leader and responsible for all bryophyte work
R M Fuller	Field team leader
A J P Gore	Nominated Officer, ITE
L Harrison	Clerical assistance on supplementary survey
J A Hays	Field assistant and assistance with data handling
D G Hewett	Field team leader, assistance with survey design, responsible for herbarium, vascular plant referee, map boundaries and overlays, assistance with map and report preparation
M D Hooper	Nominated Officer ITE (successor to A.J.P. Gore)
S Knees	Field team leader
I D Leith	Field assitant
G R Miller	Field team leader
R C Munro	Field assistant
T D Murray	Field team leader
A Nelson	Assistance with data handling
A Owen	Assistance with maps
R J Parsell	Field team leader
N J Pearce	Field team leader, assistance with data handling and analysis
J M Pizzey	Field team leader, responsible for logistics of survey and maps, assistance with design of survey, herbarium, lichen identification, data handling and report preparation
J Proctor	Field team leader
D S Ranwell	Responsible for supplementary survey and lichen reports
P Rothery	Biometrical advice
S M C Robertson	Field team leader and assistance with data handling
R Scott	Field team leader

M W Shaw	Field team leader, responsible for survey design, data handling, analysis and report preparation

Natural Environment Research Council

J Killick	Field team leader

Contract labour

J Blanchflower	Field assistant
M Brewin	Field assistant
C Brown	Clerical assistance with supplementary survey
J Brown	Field assistant
P Curry	Field assistant and assistance with bryophyte identification
P Fry	Field assistant
D Harris	Field assistant
J Healey	Field assistant
R E Jones	Field assistant
D Kay	Survey map preparation (1975)
P Lambley	Lichen identification
C Leon	Field assistant
J K Linfoot	Field assistant
A Macey	Field assistant
M Main	Preparation of bryophyte and lichen samples and assistance with bryophyte identification
A Ogilvie	Field assistant
S Raper	Field assistant
C M Seidel	Field assistant
L Shaw	Field assistant
C Shennan	Field team leader and assistant
A Smith	Field assistant
R Stimpson	Lichen identification

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