Sand Dune Vegetation Survey of Great Britain:

A national inventory

Part 2: Scotland

T.C.D. Dargie
Ecological Consultant

Loch Fleet View
Skelbo Street
Dornoch
Sutherland
Scotland
IV25 3QQ

January 1993

ISBN 1 873701 31 4 Set of three parts
ISBN 1 873701 19 5 Part 1 - England
ISBN 1 873701 20 9 Part 2 - Scotland
ISBN 1 873701 21 7 Part 3 - Wales

Contents

	Contents		1
	Acknowledgements		4
	Summary		5
1.	Introduction		
	1.1	Coastal dunes	6
	1.2	Coastal ecology research by the Nature Conservancy Council and the Joint Nature Conservation Committee	6
	1.3	The Sand Dune Survey of Great Britain	6
	1.4	The dune vegetation survey of Scotland	6
2.	Methods		
	2.1	Scope of the survey	10
	2.2	National Vegetation Classification and mapping units	10
	2.3	Locating the sites to survey	11
	2.4	Review of existing sources of information	11
	2.5	Field survey	11
	2.6	Vegetation analysis	12
	2.7	Preparation of vegetation maps	13
	2.8	Collation of other information	13
	2.9	Organisation of survey work	13
	2.10	Area calculation	14
	2.11	Presentation of survey results	14
3.	Physical nature of the dune resource		
	3.1	Dune system classification	15
	3.2	Retreat and progradation at the beach/dune interface	18
4.	The impact of human activities		
	4.1	Interpretation and limitations of the data	19
	4.2	Agriculture	19
	4.3	Recreation	20
	4.4	Urban and industrial development	20
	4.5	Quarrying and other sand/shingle extraction	20
	4.6	Sea defence and dune stabilisation	21
	4.7	Forestry	21
	4.8	Waste disposal	21
	4.9	Military usage	21
	4.10	Conservation	21
	4.11	An overall assessment of human impact	21
5.	General characteristics of Scottish dune vegetation and rare dune species		
	5.1	Introduction	23
	5.2	Dune vegetation in the National Vegetation Classification	24
	5.3	Nationally rare and scarce plants on Scottish dunes	33

6. Strandline and foredune communities, transitions to saltmarsh
- 6.1 NVC communities and rare species 36
- 6.2 SD2 *Honkenya peploides - Cakile maritima* strandline community 36
- 6.3 SD3 *Matricaria maritima - Galium aparine* strandline community 36
- 6.4 SD4 *Elymus farctus* foredune community 36
- 6.5 Transitions to saltmarsh 36

7. Mobile dune communities
- 7.1 NVC communities and rare species 39
- 7.2 SD5 *Leymus arenarius* mobile dune community 39
- 7.3 SD6 *Ammophila arenaria* mobile dune community 42

8. Semi-fixed (SD7) and fixed (SD8) dune grasslands
- 8.1 NVC communities and rare communities 46
- 8.2 Harmonisation problems 46
- 8.3 Approach to harmonisation 46
- 8.4 SD7 *Ammophila arenaria - Festuca rubra* semi-fixed dune community 47
- 8.5 SD8 *Festuca rubra - Galium verum* fixed dune grassland community 54

9. Other dry grassland and bracken communities on dunes
- 9.1 NVC communities and rare species 59
- 9.2 Dune grasslands featuring *Arrhenatherum elatius* (SD9, MG1) 59
- 9.3 Calcifugous dune grasslands (SD12) 59
- 9.4 Other calcifugous grasslands (U1, U2, U4, U5, U13) 64
- 9.5 Other dry mesotrophic grasslands (MG5, MG6, MG7) 64
- 9.6 Calcicolous grasslands (CG2, CG6, CG10) 64
- 9.7 Dunes dominated by *Carex arenaria* and lichens (SD10, SD11) 69
- 9.8 Bracken communities on dunes (U20, W25) 69

10. Dry heath and wet heath
- 10.1 NVC communities 74
- 10.2 H11 *Calluna vulgaris - Carex arenaria* dune heath 74
- 10.3 M16 *Erica tetralix - Sphagnum compactum* wet heath 74

11. Dune wetlands
- 11.1 NVC communities and rare species 79
- 11.2 Dune slack communities (SD13-SD17) and wet mesotrophic grassland 79
- 11.3 Mire (M) communities on sand dunes 79
- 11.4 Swamps and tall-herb fens (S) on Scottish dunes 79
- 11.5 Aquatic communities 80

12. Dune scrub and woodland
12.1 NVC communities and rare species 87
12.2 Dune woodland 87
12.3 Dune scrub 87

13. Ruderal vegetation on sand dunes
13.1 Background 92
13.2 Western Isles land use 92
13.3 Vegetation patterns in old-field successions 92
13.4 Significance 93

14. The nature conservation value of Scottish dunes
14.1 Assessing nature conservation value 94
14.2 Size and diversity 94
14.3 Naturalness 103
14.4 Rarity 103
14.5 Fragility 103
14.6 Typicalness and position in an ecological/geographical unit 103
14.7 Recorded history and educational value 106
14.8 Potential value 106
14.9 Intrinsic appeal 106

15. Conclusions and recommendations
15.1 Conclusions 107
15.2 Recommendations 107

16. Bibliography 108

Annex 1 111

Acknowledgements

Sincere thanks are due to several persons for their invaluable assistance with parts of this project. Other authors of site reports (Imogen Crawford, Clive Doarks, Stuart Hedley, Claire Holder, Geoffrey Radley, Jim Robertson, Anne Waite, Sarah Woolven) contributed the essential raw material. Scottish Natural Heritage (ex-NCC Scotland and ex-NCCS) staff in headquarters, regional and sub-regional offices provided much logistic back-up to survey and advice on their dunes. Claire Holder (JNCC), as Nominated Officer for this Scottish component, provided support throughout the production of this account and detailed comments on a draft. Martin Wigginton (Scottish Natural Heritage) and Dr Andrew Malloch (University of Lancaster) reviewed the final draft. Geoffrey Radley (English Nature) directed most of the Sand Dune Survey of Great Britain and his overall perspectives on NVC communities and sand dune ecology have been most useful throughout. He also kindly allowed a draft of his English report to be adapted for use in the early part of this account for Scotland. Dr Pat Doody (JNCC) commissioned the national survey and deserves credit for obtaining the support to see it to completion and publication.

Financial support was provided by Scottish Natural Heritage for surveys undertaken in 1991 and the production of this national report.

Summary

This report describes the compilation of a sample inventory of Scottish coastal dunes and their vegetation between 1987 and 1991. The vegetation of 34 dune sites was described and mapped using the National Vegetation Classification. Information on the geomorphology, land use and management of each site was also collected. The sample set comprises about 30% of Scottish vegetated dune area, but only about 5% of all Scottish dune sites.

The results highlight the enormous diversity of coastal dune vegetation in Scotland, with 110 distinct types recorded from across the full spectrum of the National Vegetation Classification, plus further transitional types. Several possible new sub-community types to the National Vegetation Classification are identified. The area of each vegetation type in each site is measured and presented in tables, allowing sites to be compared and placed in sample context. Dune habitats in Scotland are shown to have relatively few rare and scarce plant species.

The locations of vegetation types are mapped and these results are used to seek geographical patterns. Seven dune communities each have a western/northern hyperoceanic distribution which extends from Islay to Shetland/Caithness. Twelve dune communities have a southwestern/ eastern distribution which is more continental in character and probably grade into dune communities characteristic of much of the remainder of England and Wales, though at least one type of Scottish dune heath is probably not found elsewhere in Britain.

Scotland is shown to be poor in types of dune slack vegetation but this is compensated for by large numbers of mire and swamp types which come to dominate dune wetlands in the Scottish climate.

The close relationship between dune vegetation and geomorphological processes is emphasised, as is the influence of land use. Extensive grazing methods are still widespread in Scotland and probably determine the very large extent of fixed dune grassland found in sample sites. The importance of ruderal vegetation associated with non-intensive fallows in Western Isles machair is discussed. Other forms of land use are shown to be less important but more intensive forms of stock grazing, management as golf course and forestry plantation are locally important in reducing the nature conservation quality of sites. The nature conservation value of Scottish sampled dunes is reviewed in terms of normal criteria.

The limitations of using only a sample set of sites for producing a national synthesis of Scottish dunes are emphasised repeatedly in the report. The major disadvantage is that it is not possible to present categories of dune type which which are characteristic of a particular geographical area type, preventing a summary of site typicalness and site individuality for Scotland.

1. Introduction

1.1 Coastal dunes

Sand dunes are one of a series of terrestrial habitats that in Britain are almost entirely restricted to the coast. The others are saltmarshes, maritime cliffs and grasslands, vegetated shingle and strandlines.

Sand dunes can form along the coast wherever there is a sufficient supply of sand in the intertidal zone to form a beach plain whose surface dries out between tides. The dry sand can then be blown landward and deposited above the high tide mark. In temperate areas such as Britain this blowing sand can be trapped by specialised grasses. These grow up through successive layers of sand to form characteristically steep, vegetated dunes. Such dunes differ markedly in shape from those formed where vegetation is not important as a stabilising force.

Sand dunes support specialised plant species and plant communities which are confined to this habitat. They also contain a large number of species and communities with a wider distribution. The diversity of plant life reflects the range of soil chemistry, aspect, water regime and other physical conditions found on dune systems in Britain. To an ecologist, dune vegetation illustrates the ecological principles of zonation and succession with great clarity, and dunes are invaluable for ecological teaching and research.

1.2 Coastal ecology research by the Nature Conservancy Council and the Joint Nature Conservation Committee

This survey is one of a series of co-ordinated botanical surveys of major British coastal habitats. These have been planned and executed up to 1991 by the coastal section of the Nature Conservancy Council (NCC) Chief Scientist's Directorate (CSD) as part of an integrated programme of research and survey (Galvin 1990). The work has been continued since April 1991 by the Joint Nature Conservation Committee (JNCC). The other surveys in this series to date are the Saltmarsh Survey (Burd 1989) and the Vegetated Shingle Survey (Sneddon & Randall in press). The overall aims of this research programme are:

- to establish the size, location and quality of the main terrestrial coastal habitats in Great Britain;

- to allow the impact of development proposals to be assessed on sites of national importance, and on the resource as a whole;

- to provide guidance on the management of major coastal habitats;

- to investigate the role of physical and biological processes in the maintenance of natural and semi-natural coastal habitats.

1.3 The Sand Dune Survey of Great Britain

The specific objectives of the sand dune survey are:
- to review existing knowledge of British dune vegetation;
- to compile an inventory of the range and extent of dune vegetation throughout Britain;
- to allow the national and regional importance of each individual site to be assessed;
- to provide vegetation maps and descriptions for each site in sufficient detail to support site-specific casework and conservation management planning, and to act as a baseline for future monitoring.

The end products from this survey consist of:

- a bibliography of literature relating to British dunes and their vegetation;
- site reports and vegetation maps for each of the sites visited;
- national reports for each of the three countries, summarising the resource of each country;
- a computer database to hold the results of the survey.

1.4 The dune vegetation survey of Scotland

This report is the Scottish component of three national reports comprising the Great Britain survey. It is based upon 34 site reports listed in Annex 1. The location of sites is shown in Figure 1 and site details are listed in Table 1.1. All site surveys use the National Vegetation Classification (NVC - see Chapter 2) and the site set is made up of 27 NCC CSD surveys conducted between 1987 and 1990, five sites surveyed in 1991 with JNCC support, and a further two independent surveys of Barry Links and Tentsmuir.

The total dune area surveyed is 9,641.2 ha (Table 1.1). This represents 30.7% of the dune and machair/links area in Scotland (31,436 ha - Ritchie & Mather 1984). This is a reasonable sample of the total dune resource of Scotland using area as the basis for calculating sample size. However, it is more restricted if the total of Scottish dune systems is used as an alternative measure of representation. A total of 647 dunes was surveyed by Ritchie & Mather (1984), though this involved division of very large beaches to make work manageable. Maps giving the locations of Scottish dune sites, plus an appendix with names and grid references, are given in Ritchie & Mather (1984). The NVC survey total of 34 sites is thus only 5.25% of the Scottish site total. The sample nature of the Scottish NVC survey places restrictions on interpretation of the complete resource (i.e. the national context), but hopefully it is large enough to cover the bulk of variation in Scottish dune vegetation.

The report is structured to present survey methods (Chapter 2), a summary of site physical characteristics (Chapter 3), human impacts (Chapter 4), and a detailed account of vegetation types which places each site in the national context (Chapters 5 - 13). The nature conservation value of Scottish dune vegetation is reviewed in Chapter 14, followed by conclusions in Chapter 15.

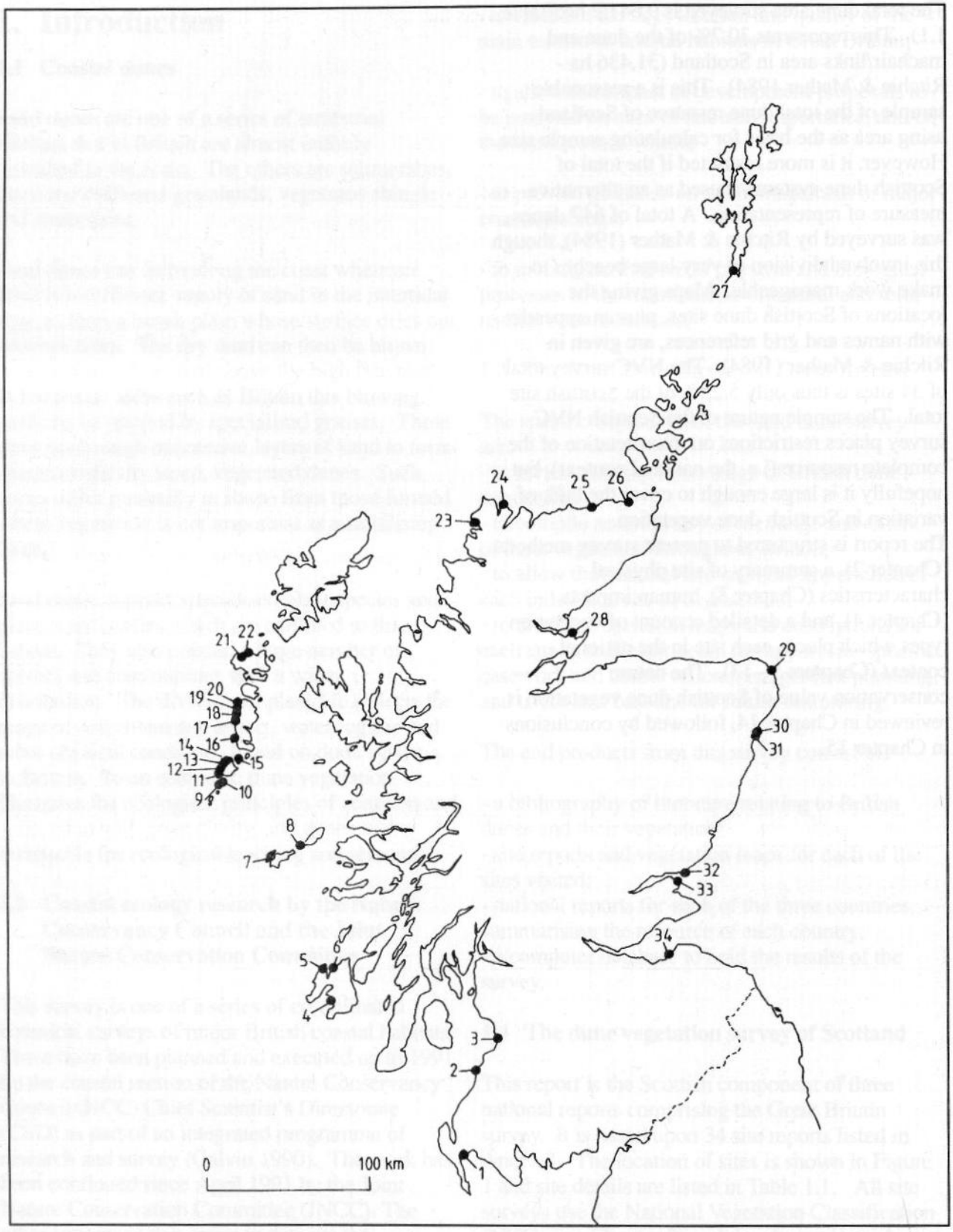


Figure 1.1 Location of dune survey sites in Scotland. Site names, district, coordinates and survey area are given in Table 1.1.

Table 1.1 Dune sites surveyed in Scotland. Site areas include transitions to saltmarsh but not saltmarsh itself.

	SITE	DISTRICT	GRID REFERENCES OF SITE LIMITS	AREA (hectares)
1	TORRS WARREN	Dumfries and Galloway	NX 101507 NX 172556	846.9
2	TURNBERRY	Ayrshire	NS 195070 NS 200047	16.0
3	TROON	Ayrshire	NS 330290 NS 342280	84.0
4	LAGGAN BAY, ISLAY	Argyll and Bute	NR 295558 NR 322487	202.8
5	ARDNAVE, ISLAY	Argyll and Bute	NR 278737 NR 289727	256.0
6	KILLINALLAN, ISLAY	Argyll and Bute	NR 299704 NR 331737	262.2
7	HOUGH BAY & BALEVULLIN, TIREE	Argyll and Bute	NL 927485 NL 985481	505.3
8	CROSSAPOL & GUNNA, COLL	Argyll and Bute	NM 101513 NM 152540	579.1
9	VATERSAY	Western Isles	NL 630954 NL 637939	120.5
10	UIDH, VATERSAY	Western Isles	NL 659959 NL 661959	5.5
11	TANGUSDALE, BARRA	Western Isles	NF 650010 NF 640006	82.8
12	BORVE, BARRA	Western Isles	NF 650020 NF 650010	64.0
13	ALLASDALE, BARRA	Western Isles	NF 658040 NF 657028	92.7
14	CLEAT, BARRA	Western Isles	NF 673048 NF 666048	18.8
15	FUDAY	Western Isles	NF 725082 NF 743085	228.0
16	KILPHEDER, SOUTH UIST	Western Isles	NF 731189 NF 732205	114.2
17	HOWBEG, SOUTH UIST	Western Isles	NF 748360 NF 751363	20.7
18	HOWMORE, SOUTH UIST	Western Isles	NF 754363 NF 750370	64.5
19	DRIMSDALE, SOUTH UIST	Western Isles	NF 750370 NF 752383	192.7
20	STILLIGARY, SOUTH UIST	Western Isles	NF 752383 NF 754390	52.0
21	MIDDLEQUARTER, NORTH UIST	Western Isles	NF 798750 NF 802761	64.1
22	SOLLAS, NORTH UIST	Western Isles	NF 802761 NF 815767	153.0
23	SHEIGRA TO OLDSHOREMORE	Sutherland	NC 183599 NC 181600	116.0
24	AN FHARAID	Sutherland	NC 392688 NC 402692	166.2
25	SANDSIDE BAY	Caithness	NC 957657 NC 968659	79.6
26	DUNNET LINKS	Caithness	ND 218705 ND 205683	690.3
27	BAY OF QUENDALE	Shetland	HU 369128 HU 389140	221.0
28	MORRICH MORE	Ross and Cromarty	NH 798831 NH 899835	1,267.8
29	LOCH OF STRATHBEG	Banff and Buchan	NK 062628 NK 106570	450.2
30	SANDS OF FORVIE	Gordon	NK 008247 NK 033289	762.5
31	FOVERAN	Gordon	NK 004245 NJ 993208	140.4
32	BARRY LINKS	Angus	NO 503323 NO 560338	788.7
33	TENTSMUIR	Fife	NO 473277 NO 483202	507.2
34	ABERLADY BAY	East Lothian	NT 459818 NT 483827	425.5
				Total 9,641.2

2. Methods

2.1 Scope of the survey

A complete dune survey of Scotland was intended at project inception but that objective had to be changed as progress was slower than anticipated. It was then decided the project should attempt to cover a representative selection of the extensive Scottish dune coast. A clear working definition of a vegetated dune system was adopted : all areas of natural and semi-natural vegetation on blown sand of geologically recent marine origin.

2.2 National Vegetation Classification (NVC) and mapping units

In 1975 the Nature Conservancy Council commissioned Lancaster University to develop a National Vegetation Classification (NVC), with the principal objective of providing a common language for the description of British vegetation. The resulting system appeared ideally suited to the needs of a nationwide dune survey, and the communities and sub-communities of the NVC were adopted as mapping units. At the start of the survey only a preliminary conspectus was available for the sand dune chapter of the NVC. This was used for the first two years of the survey. Field data were fed back to the NVC unit at Lancaster University, who then compiled a revised classification. The new classification was used for all sites surveyed after 1st September 1988. Data from sites surveyed before that date required harmonisation to convert them to the revised system.

The NVC is a systematic and comprehensive classification of British plant assemblages (Rodwell 1991a, 1991b, in prep.). It aims to provide broad-based descriptions of plant communities from all natural, semi-natural and major artificial habitats throughout Britain. It is intended to be a means of classifying vegetation into types that can be identified in the field and mapped on the ground. It can, in this way, provide the language, the measure and the means with which to assess vegetation across the country. By setting a national standard the NVC enables each dune site to be put into a wider Scotland and Great Britain context.

Vegetation data from over 80% of Britain's 10 x 10 km grid squares, including islands and remote mainland areas, have been collected and analysed in a standard fashion. The resulting 300 British plant communities are described in eleven chapters, each dealing with a recognised habitat. Each chapter provides descriptions of the communities' floristics and structure, together with their habitat, zonations and successions and the major factors influencing their variation and range.

Each NVC community is defined by a small number of characteristic species called 'constants' which are diagnostic of that community, though not necessarily dominant. These communities can be divided into sub-communities, each with the suite of species characteristic of the community but also exhibiting a number of plants that make the assemblage distinct as a variation within the overall community. These species are termed sub-community 'preferentials'. Within each community there will also be a range of species which have been recorded alongside the constants and preferentials and which are associated with the community but are not indicative of it. Such 'associates' rarely occur in great abundance.

Vegetation samples gathered in the field according to NVC methodology can usually be allocated to a community type and a sub-community. The NVC communities and sub-communities are abbreviated as a code (e.g. SD18b) consisting of three elements:
- NVC chapter code (SD for the sand dune and shingle chapter);
- community number (18);
- sub-community letter (b).

Accompanying the NVC code is the full title of the community and sub-community as stated in the NVC. This is intended to provide an outline of the vegetation assemblage present but the relevant NVC chapter should be consulted for a full description of the community, its distribution and affinities.

The following volumes were all required to classify the vegetation in this national survey of Scottish dunes:

SD	Shingle, strandline and sand dune communities
H	Heaths
M	Mires
MG	Mesotrophic grasslands

CG Calcicolous grasslands
S Swamps and tall herb fens
A Aquatics
SM Saltmarsh communities
MC Maritime cliff communities
U Calcifugous grasslands and upland communities
W Woodlands and scrubs

2.3 Locating the sites to survey

Sand dune systems were located principally by identification on a series of 1:50,000 Ordnance Survey maps held by the coastal section of the Chief Scientist Directorate of the NCC. From these maps a list of dune sites was compiled with the site name and the approximate grid reference. This list was then checked with regional staff of the NCC and with a list of dune sites afforded statutory protection supplied from the NCC's COREDATA system. A selection of Scottish sites was surveyed before NCC re-organisation in 1991. There were gaps in geographical coverage and five further sites were added to the survey in 1991 in consultation between JNCC and the Nature Conservancy Council for Scotland (NCCS). In addition, two further sites in south-east Scotland (Barry Links and Tentsmuir) were included because independent NVC surveys existed to fill in a further geographical gap.

2.4 Review of existing sources of information

Prior to this survey there has been a detailed systematic vegetation survey of the dunes of Scotland by the Institute of Terrestrial Ecology on behalf of the NCC (Shaw, Hewett & Pizzey 1983). The classification system resulting from that survey is not clearly related to the NVC, though there are some areas of broad similarity (Dargie in prep.). Dunes are also covered in a preliminary phytosociological treatment of Scotland along continental lines (Birse 1980, 1984). In addition there has been a very thorough geomorphological survey of all Scottish dunes produced by the University of Aberdeen for the Countryside Commission for Scotland (summarized in Ritchie & Mather 1984), plus a number of published and unpublished descriptive works on particular sites. All these sources were consulted, plus unpublished information from site files held by NCC/NCCS regional offices.

2.5 Field survey

Vegetation recording
After an initial inspection of the site to assess the overall range and pattern of variation, the vegetation was divided by the surveyor into homogeneous stands. Within each stand type, typical sample areas were chosen and the vegetation recorded from inside 2 m x 2 m quadrats.

The NVC manual recommends that a minimum of five quadrats should be recorded from each stand type at each site. The time constraints of a wide ranging national survey did not allow this recommendation to be followed in all sites, but care was taken to ensure that at least one full quadrat was taken from each major stand type at each dune system surveyed.

Within the quadrats all vascular plants, bryophytes and macrolichens were identified and recorded using the Domin cover/abundance scale. In the majority of surveys this information was supplemented with data on aspect, soil pH, slope, bare ground, litter layer, vegetation height and grazing.

For most sites information on grazing was collected using the 'impact' scale devised by Dr L. Boorman for a survey of grazing management on sand dunes (Boorman 1986). The five points on this scale are:

0 no signs of grazing;
1 some plants eaten;
2 sward grazed short;
3 sward grazed short and up to 25% of the area grazed bare;
4 sward grazed short and more than 25% of the area grazed bare.

A brief written description was also made of the quadrats and any other relevant features were noted.

Extensive use was made of target notes. These were used for two distinct purposes:
- to note particular features or to comment on land use;
- to supplement quadrat records particularly in areas subject to local disturbance or modification, in the more localised or restricted plant

communities and in vegetation mosaics and transitions which are difficult to describe purely by means of quadrats.

The target notes consisted of a written description of the feature or vegetation type(s), with or without a list of species found. In a few cases approximate Domin scores were given to the species recorded.

Vegetation mapping

The larger sand dune systems posed special problems for vegetation mapping because of their complex terrain and absence of artificial, mapped features. Many Ordnance Survey maps show only the inland boundary and the high water mark. Under these circumstances vegetation boundaries sketched directly onto an Ordnance Survey base map would have been wildly inaccurate. Conventional topographic surveying techniques could produce very accurate results, but would have been too costly and time-consuming. In one case (Site 1, Torrs Warren) a very accurate topographic map existed and was made available by the Ministry of Defence. This was used in mapping.

An approach using aerial photographs was devised which allowed vegetation boundaries on large dune systems to be drawn in the field quickly, and with reasonable accuracy. The prints were taken into the field and vegetation boundaries drawn upon drafting film overlays using the features and changes in texture on the photographs as landmarks. Experience showed that satisfactory results could be obtained from colour or black and white prints at scales of between 1:10,000 and 1:5,000. An effort was made to obtain the most recent coverage that met these criteria. In no case was photography more than 15 years old used for mapping.

For many of the smaller dune sites no detailed topographic maps or aerial photographs were available. In these cases (notably in the Western Isles) enlarged copies of 1:10,000 or 1:10,560 Ordnance Survey maps were used as the base for mapping. Provided the site was not too broad, and provided there were sufficient identifiable features on or adjacent to the site, vegetation boundaries could be drawn without unacceptable loss of accuracy.
Whatever the base used, the techniques of field mapping were similar. The boundaries of each apparently uniform stand were sketched on to the map or photograph, taking advantage of viewpoints such as high dunes and adjacent hills wherever possible. The locations of all quadrats were marked and the stands or features to which target notes referred were clearly labelled. Where overlays were used, artificial boundaries and prominent landmarks were drawn in. Map overlays were marked with grid line intersections and air photograph overlays with the fiducial marks to ensure exact re-alignment. All overlays and field maps were labelled with the site name, date, recorder and, where applicable, the aerial photograph print number.

2.6 Vegetation analysis

Quadrat data for each site were entered into a microcomputer database using the VESPAN II suite of programs devised by Andrew Malloch of Lancaster University (Malloch 1988). The TABLE program was used to produce quadrat tables, whilst the keys, tables and written descriptions provided in the various chapters of the National Vegetation Classification (NVC) (Rodwell 1991 a&b; Rodwell in prep.), were used to allocate each quadrat to an NVC group. However, in several cases non-NVC terms were used to describe the vegetation.

For the larger and more complex sites a TWINSPAN (Hill 1979) analysis was performed on this data as an aid to the classification of the quadrats. The end groups resulting from this analysis were compared with the keys, tables and written descriptions provided in the various chapters of the NVC. In most cases these end groups did correspond to an NVC group. Occasionally the TWINSPAN analysis split to a different level and some re-interpretation of the end groups was necessary to place all the quadrats in their correct NVC categories. It should be emphasised that the TWINSPAN analysis was performed primarily as a means of grouping like quadrats together to aid their manual classification, though the relationship between the end groups did sometimes give insights into the classification of intermediate stands.

Towards the end of the project the MATCH programme became available (Malloch 1990). This calculates coefficients of similarity between

sample data and the vegetation tables used to define each of the NVC types. This programme was used to check some of the manual classifications and to help with the conversion of the data from those sites originally classified using the preliminary version of the sand dune NVC chapter.

Finally, as part of the preparation of the national report, quadrats from all sites except Barry Links and Tentsmuir were assembled into a master data set (1,769 samples) for use in quadrat and species selection exercises.

2.7 Preparation of vegetation maps

Where aerial photographs are used as the base for mapping there is always some distortion of the image due to tilt and relief displacement. Accurate transfer of information to a map base therefore requires the use of specialised optical equipment. High accuracy can be obtained using stereoplotters but these are slow and require trained operators. In practice sufficient accuracy can be obtained using simpler instruments (Grant Enlarger, Bausch and Lomb stereo zoom transferscope, Zeiss Sketchmaster). The latter two machines can compensate for differences in scale and for distortions due to tilting. The Grant Enlarger can compensate only for differences in scale. In both cases the procedure was similar: the images of the field overlay and the print to which it relates were super-imposed on the map base and adjusted to fit it using identifiable fixed points. The vegetation boundaries and other features drawn on the field overlay were then transferred on to the map base. A final map was then prepared using the results of the vegetation analysis to determine the mapping units. A very large photomosaic was involved in survey of the Morrich More and map production involved an intermediate stage, constructing a slotted template to provide ground control for linking overlays from separate aerial photographs (Dargie 1989). Occasionally the distortions on the aerial photographs could not be entirely compensated for. In these cases the boundaries were transferred a piece at a time using local scaling to match sections of the photograph image to sections of the base map.

Where a base map had been used in the field the production of the final map was considerably simplified. Here the information on the map overlays drawn in the field were used directly to produce the final map, in conjunction with the results of the vegetation analysis.

2.8 Collation of other information

Additional information on the sites was obtained from the files of the regional offices of the Nature Conservancy Council, from field observation and from people with local knowledge. For most sites a standard summary form was completed with a series of fields giving details of the type of dune system, land use, management, use by the public and dynamic state.

In the sections where grazing was recorded, the form provided a series of options. The surveyor could select either moderate, light or heavy grazing and grazing in spring, summer, autumn or winter. If an option was selected then a 'Y' was entered; otherwise it was left blank. A similar system was used to record erosion and vehicle damage with the difference that selected options could be recorded as either localised 'L' or widespread 'W'.

In a few cases such as the fields dealing with fires, forestry and golf courses, the surveyors were asked to estimate the area affected. If the feature did not occur then a zero value was recorded. In these fields a blank meant that the information was not recorded.

A distinction was drawn on the form between marine erosion, the term used to describe the removal of dune by the sea, and erosion damage. This second term was used to describe instability within a dune system, normally resulting from human or animal activity, but including the removal of sand by wind.

2.9 Organisation of survey work

The field survey work was carried out over five field seasons, 1987 to 1991. In each of these seasons a team of three surveyors carried out field surveys between late April and the end of September. In addition, external contracts were let for Western Isles sites in 1988 (to I. Crawford), the Morrich More in 1988 and supplementary sites in 1991 (to T.C.D. Dargie). Supervision ensured that information was collected in a consistent manner,

with one individual (G.P. Radley) remaining in overall control of the Great Britain project for most of its duration. Supervision of the final survey stages of work for this Scottish report was the responsibility of C. Holder (JNCC).

Quality control was ensured by the following means:

Training in survey methodology
At the start of each field season a field training course was run for the directly employed surveyors. The survey methodology was also demonstrated to the external contractors. Both contractors and directly employed staff were visited in the field at intervals to ensure that their methods remained consistent. Particular attention was paid to the definition of uniform stands and the drawing of boundaries, to the estimation of Domin scores and to the identification of NVC types.

Species identification
Species identification was a major part of the training courses. During the survey samples were taken of any vascular plants that could not be confidently identified in the field, to allow them to be fully keyed out. In cases where uncertainty remained, specimens were pressed and taken back to base for checking. Only the most unmistakable lichens and bryophytes were identified in the field. In all other cases specimens were collected and identified later in the laboratory or by lower plant specialists.

Maintaining consistency
In the early part of the survey some problems arose as a result of relatively inexperienced field surveyors tackling large sites on their own. It was therefore decided to adopt a procedure where, for most sites, at least two people worked on each site. The surveys were moreover arranged so that the surveyors worked towards each other. This meant that any inconsistency in the boundaries they had drawn became immediately apparent when they joined up and could be sorted out whilst still in the field.

2.10 Area calculation

Before the national inventory of dune vegetation could be compiled it was necessary to measure the area occupied at each site by each of the vegetation types. Funds were not available to digitize maps and thus obtain areas from vector coordinate data. An alternative approach was therefore used. Most site maps were sampled by intense line intercept grids (lines spaced at 100 m intervals parallel with national grid lines) and the percent cover of large vegetation types estimated as a proportion of total line length (Nature Conservancy Council 1990a). These values were then converted to hectares by estimating total map area from an accurate count of 0.25 cm squares superimposed upon the vegetation map. The line intercept approach should produce area estimates within 5% of the precise value for large vegetation types (Canfield 1941). Very small vegetation types were measured individually using a 1 mm grid on a transparent overlay. Morrich More (Site 28) areas were calculated by weighing vegetation types cut from a copy of the vegetation map (Dargie 1989).

2.11 Presentation of survey results

In order to ensure that the results of the site surveys were available to NCC regional staff as soon as possible after the work was done, the results of each site survey were published separately in either the Contract Surveys or CSD Reports series of NCC, or in JNCC publications. These reports each contain a summary of the methodology, a list of vegetation types, a description of the site, a vegetation map and the field data. A full list of these reports is given in Annex 1.

3. Physical nature of the dune resource

3.1 Dune system classification

During the field survey the geomorphological structure of each dune system was recorded using the classification system of Ranwell & Boar (1986). This recognises five main types of coastal dune system: offshore island; prograding dune, ness or cuspate foreland; spit; bay; and hindshore. In addition, an extreme form of hindshore dune, hindshore machair, was recognised due to its importance on the western and northern coasts of Scotland, plus two other features of geomorphological interest: the presence of climbing dunes and tombolos.

Classic offshore island dunes tend to develop as linear features in the direction of longshore drift, based on sand or shingle. These are only found in surveyed sites as barrier islands developed on offshore bars at Morrich More (Ross and Cromarty). Dunes are also found on small rocky offshore islands (e.g. Gunna, to the west of Coll) but such cases are considered here as a type of low climbing dune developed inland and above short bay dunes determined by low rock promontories.

Prograding dunes, nesses and cuspate forelands build out (prograde) from the coast due to abundant sand supply either from longshore drift in two directions (cuspate foreland, most notably at Barry Links in Angus), or from a very shallow and extensive sandy shore to seaward. Offshore island dunes at Morrich More provide shelter for lines of rapidly developing, low prograding dunes (and extensive saltmarsh) to landward, producing a massive strandplain which is possibly unique in Great Britain.

Large spit dunes are only well-developed at Sands of Forvie (Gordon), upon shingle deposited by storm waves in the mouth of the Ythan estuary. In addition, dunes at Loch of Strathbeg developed as a spit system until they linked with the opposing coast to function now as a bay dune. Elsewhere spits are very small, again developing at the mouths of streams or small rivers flowing through dunes.

Bay dunes are developed upon sand trapped within the shelter of rock headlands, forming a half-moon shape in the beach and outer dune zones. These are very frequent on irregular, rocky coasts with an offshore sand supply (e.g. the bay dunes of Traigh Bailamhuilinn and Traig Chornaig, part of Hough Bay and Balevullin Machair on Tiree). A common feature is open water or slack developed inland from the bay dune ridge (e.g. Loch of Strathbeg), forming a machair or winter loch.

Hindshore systems usually develop initially as bay types but abundant sand supply and onshore prevailing winds drive the sand inland for considerable distances as a series of dune ridges or mobile parabolic dunes, often leaving depressions to windward which develop into slacks. Bay of Quendale, Shetland, has an extensive area of hindshore dune inland from an outer bay dune ridge. Hindshore machair is an extreme form in which exceptionally strong winds limit vertical dune development to form a sand plain ('machair') over and around rock and peatland inland from the beach (e.g. Allasdale, Barra).

Climbing dunes represent sand areas blown up on to terrain inland of the main dune system (e.g. Gullane Hill at Aberlady Bay). Tombolo dunes are developed on sand or shingle necks which link a rock island with the mainland, generally between two close and opposing bay dunes (e.g. Crossapol dunes, western Coll).

The dune types encountered are recorded on a site basis in Table 3.1. Most sites are composite systems, made up of more than one dune type, though the majority of these have one form predominant. Bay dunes and hindshore machair are by far the most frequent types. Climbing dunes are moderately common. Spits, prograding systems, normal hindshore dunes, offshore islands and tombolos are relatively uncommon, though the first three of these types are generally very large (see Table 1.1). Hindshore machair has a western and northern distribution, with dune spits confined to east coast systems. Other types show no clear geographical restriction. Surveyed sites are only a small sample of Scottish dunes and the relative frequencies observed may not be a correct reflection of the balance in the total population.

Table 3.1 Distribution of dune types in surveyed Scottish dune systems. P = present. T = trace (small feature).

	SITE	OFFSHORE ISLAND	PROGRADING DUNE, NESS OR CUSPATE FORELAND	SPIT DUNE	BAY DUNE	HINDSHORE DUNE	HINDSHORE MACHAIR	CLIMBING DUNE	TOMBOLO
1	TORRS WARREN	-	-	-	P	P	-	-	-
2	TURNBERRY	-	-	-	P	-	-	-	-
3	TROON	-	-	-	P	-	-	-	-
4	LAGGAN BAY	-	-	-	P	P	-	-	-
5	ARDNAVE	-	-	-	-	-	-	P	-
6	KILLINALLAN	-	P	-	-	-	-	P	-
7	HOUGH BAY & BALEVULLIN	-	-	-	P	-	P	P	P
8	CROSSAPOL & GUNNA	-	-	-	P	-	P	P	P
9	VATERSAY	-	-	-	-	-	P	-	-
10	UIDH	-	-	-	P	-	P	P	-
11	TANGUSDALE	-	-	-	P	-	P	-	-
12	BORVE	-	-	-	P	-	P	-	-
13	ALLASDALE	-	-	-	P	-	P	-	-
14	CLEAT	-	-	-	P	-	P	P	-
15	FUDAY	-	-	-	P	-	-	P	-
16	KILPHEDER	-	-	-	-	-	P	-	-
16	HOWBEG	-	-	-	-	-	P	-	-
18	HOWMORE	-	-	-	-	-	P	-	-
19	DRIMSDALE	-	-	-	-	-	P	-	-
20	STILLIGARY	-	-	-	-	-	P	-	-
21	MIDDLEQUARTER	-	P	-	-	-	P	-	-
22	SOLLAS	-	-	-	P	-	P	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	-	P	-	P	-	-
24	AN FHARAID	-	-	-	P	-	P	P	-
25	SANDSIDE BAY	-	-	-	P	-	P	-	-
26	DUNNET LINKS	-	-	-	P	-	P	-	-
27	BAY OF QUENDALE	-	-	-	P	-	P	-	-
28	MORRICH MORE	P	P	T	-	-	-	-	-
29	LOCH OF STATHBEG	-	-	P	P	-	-	-	-
30	SANDS OF FORVIE	-	-	P	P	-	-	P	-
31	FOVERAN	-	-	T	P	-	-	-	-
32	BARRY LINKS	-	P	T	-	-	-	-	-
33	TENTSMUIR	-	P	T	-	-	-	-	-
34	ABERLADY BAY	-	P	T	P	-	-	P	-
	Totals	1	6	2 (7)	22	2	20	10	2

3.2 Retreat and progradation at the beach/dune interface

The accurate measurement of marine erosion and of dune progradation is complex and requires repeated visits to monitor changes. In its most sophisticated form it involves construction of a beach sediment budget and such work is restricted to only the Morrich More in surveyed sites (Hansom & Leafe 1990). However an attempt was made during this survey to obtain a rough idea of the processes at work at the time the sites were visited. The surveyors were asked to record signs of current marine erosion or progradation and to estimate the percentage of the active shoreline that was affected.

The main feature used to indicate marine erosion was a steep cliff at the front of the dunes, combined with an absence of embryo dunes. Additional confirmation was sought from signs such as the exposure of marram *Ammophila arenaria* roots in the cliff face or the presence on it of slumped sections of previously stable dune turf.

Signs used to indicate progradation included series of parallel dune ridges supporting vegetation that became progressively younger towards the sea and the presence at the top of the beach of well developed embryo dune vegetation, often dominated by sand couch-grass *Elymus farctus*.

Aerial photographs used for vegetation mapping, compared with older photography, could sometimes be used to check these interpretations by looking for changes in the position of the shoreline relative to the fixed structures between the date of the photographs and that of the survey.

The results of this survey have been summarised by recording the proportion of beach eroding and prograding, dividing the survey sites into four categories (Table 3.2):

- Sites with net marine erosion: those where the percentage of the shoreline recorded as actively eroding was >10% greater than the percentage recorded as prograding;

- Sites with net progradation: those where the percentage of the shoreline recorded as prograding was >10% greater than that recorded as eroding;

- Sites in approximate equilibrium: those where the percentage of the shoreline in the two categories defined above differed by 10% or less ;

- Sites of uncertain status: survey data not available (an estimate made based on map patterns).

A total of nineteen sites show net erosion, nine suggest approximate equilibrium, and only two show progradation. Four sites are of uncertain status. This summary of erosion and accretion is based on very crude data and considerably simplifies the complexities occuring within individual sites. Despite such complexities (which can involve seasonal and short-to-long term cycles in erosion/progradation balance), the overall conclusion is that there are considerably more sites that are retreating than are advancing. This is consistent with the findings of other authors in Scotland (Ritchie & Mather 1984).

Table 3.2 Erosion and progradation status of surveyed Scottish dune systems. Percentage data refer only to sand beach length at interface zone with vegetated dunes, not to complete site coastline.

	SITE	PERCENTAGE BEACH LENGTH ERODING	PERCENTAGE BEACH LENGTH PROGRADING	SITE STATUS
1	TORRS WARREN	10	0	APPROXIMATE EQUILIBRIUM
2	TURNBERRY	20	30	APPROXIMATE EQUILIBRIUM
3	TROON	0	15	NET PROGRADATION
4	LAGGAN BAY	20	15	APPROXIMATE EQUILIBRIUM
5	ARDNAVE	20	6	NET EROSION
6	KILLINALLAN	30	13	NET EROSION
7	HOUGH BAY & BALEVULLIN	85	2	NET EROSION
8	CROSSAPOL & GUNNA	70	1	NET EROSION
9	VATERSAY	30	0	NET EROSION
10	UIDH	60	0	NET EROSION
11	TANGUSDALE	70	0	NET EROSION
12	BORVE	10	0	APPROXIMATE EQUILIBRIUM
13	ALLASDALE	10	0	APPROXIMATE EQUILIBRIUM
14	CLEAT	20	0	NET EROSION
15	FUDAY	10	0	APPROXIMATE EQUILIBRIUM
16	KILPHEDER	25	1	NET EROSION
17	HOWBEG	20	3	NET EROSION
18	HOWMORE	20	0	NET EROSION
19	DRIMSDALE	20	0	NET EROSION
20	STILLIGARY	20	0	NET EROSION
21	MIDDLEQUARTER	60	2	NET EROSI ON
22	SOLLAS	40	0	NET EROSION
23	SHEIGRA TO OLDSHOREMORE	?	?	UNCERTAIN - ERODING?
24	AN FHARAID	50	0	NET EROSION
25	SANDSIDE BAY	70	30	NET EROSION
26	DUNNET LINKS	?	?	UNCERTAIN - ERODING?
27	BAY OF QUENDALE	100	0	NET EROSION
28	MORRICH MORE	20	70	NET PROGRADATION
29	LOCH OF STRATHBEG	25	10	NET EROSION
30	SANDS OF FORVIE	5	5	APPROXIMATE EQUILIBRIUM
31	FOVERAN	0	10	APPROXIMATE EQUILIBRIUM
32	BARRY LINKS	?	?	UNCERTAIN - EQUILIBRIUM?
33	TENTSMUIR	?	?	UNCERTAIN - PROGRADING?
34	ABERLADY BAY	40	30	APPROXIMATE EQUILIBRIUM

4. The impact of human activities

4.1 Interpretation and limitations of the data

Information on the impact of human activities on dunes was collected in site survey (see Chapter 2). The most serious limitation of such data is that it is heavily dependent on information collected during a single visit to each site, generally during the summer months. Although other sources of information were sought to supplement the field recording it is inevitable that some forms of activity, especially seasonal ones, will have been under-recorded.

Another limitation that should be borne in mind when considering this data is that for most activities the information was collected in a qualitative rather than a quantitative fashion. For example, a dune where there is small-scale sand removal for agriculture would have been recorded as having mineral extraction in the same way as one with a large commercial quarry. There is also some imprecision in those cases where the surveyor was asked to subjectively estimate the level of an activity. This was the case for grazing, erosion and vehicle damage.

Despite these limitations the information collected on human activities does have the advantage of having been collected from all sites in Scotland within the period 1987 to 1991. It is moreover based largely on direct observation. As such it provides a useful summary of the current state of human activity on dunes that is only available from more dated sources (e.g. Ritchie & Mather 1984).

4.2 Agriculture

The dunes of Scotland have probably been shaped and moulded by agriculture for most of their existence. The characteristic semi-natural vegetation of most stable dunes is grasslands or heathlands which have developed as a result of grazing of the indigenous vegetation by sheep, rabbits and cattle. In the absence of such grazing some areas of stable dune, apart from very exposed systems, would probably have developed into scrub or woodland - the former is present in quantity at Morrich More. Dune woodlands are common elsewhere abroad, notably in the Netherlands where the tradition of pastoral management of dunes is much less widespread.

During this survey grazing by domestic stock was recorded from 30 sites, with no stock at two sites (Sands of Forvie, Aberlady Bay) and two sites uncertain (Barry Links, Tentsmuir). Sands of Forvie (a National Nature Reserve) and Aberlady Bay (a Local Nature Reserve) are operated for conservation, with no stock grazing as management objectives. In addition, part of Aberlady Bay is used intensively for golf courses. Elsewhere stock grazing (by sheep and cattle, by pigs in addition at Loch of Strathbeg, occasionally by horses and geese) is the norm on surveyed sites. Heavy grazing is found in all or part of eleven sites: Torrs Warren, Turnberry, Laggan Bay, Ardnave, Hough Bay and Balevullin (Tiree), Crossapol and Gunna (Coll), Sheigra to Oldshoremore, An Fharaid, Dunnet Links, Bay of Quendale, and Loch of Strathbeg. Elsewhere stock grazing is light to moderate in the remaining 21 sites with information. Stock grazing is managed as large private enterprises, as crofter grazing, and as common grazing in crofting areas. Intensive management is restricted to Ardnave and Loch of Strathbeg. Elsewhere methods are generally extensive in character and impacts are less severe, though conversion to semi-improved mesotrophic grassland is not uncommon.

Rabbits are widespread in Scotland and are probably only absent from Hough Bay and Balevullin (Tiree), where brown hares are abundant. In all surveyed sites there was little evidence of heavy rabbit grazing except around major burrow concentrations. There was no evidence of the effects of rabbit population flux, especially the impact of myxamotosis, apart from moderate densities of individual shrubs at Aberlady Bay. Roe deer occur in a few systems, with light impact on grazing but a more important role in checking scrub development.

Moderate to heavy grazing by the above herbivores maintains a low grass sward and allows high species diversities to develop in the absence of re-seeding and fertiliser treatment (rare occurrences in surveyed sites). It thus has major conservation benefits to offer, with even semi-improved pastures having long species lists in western and northern sites.

Arable cultivation of dunes for potatoes, oats and other cereals is still common in the Western Isles. Until recently it was also practised on the mainland at Sheigra to Oldshoremore. It was formerly widespread elsewhere - re-vegetated rigg and furrow systems are extensive within the dunes of Hough Bay and Balevullin (Tiree), Crossapol and Gunna (Coll), and even Sands of Forvie which is rated as one of the most natural of Scottish dune systems. Most Western Isles arable land is operated on a fallow system and a species-rich succession is present, of interest as the major last vestige of a former extensive landuse system (Crawford 1989).

4.3 Recreation

The extent to which sand dunes are used for recreation is not an easy thing to quantify. In this survey no attempt was made to record actual numbers of people, instead indirect indicators of the level of recreational activity were used: footpath extent and associated dune erosion, modification and 'improvement' of dunes upon golf courses.

Very little evidence of erosion damage due to recreational use was found in surveyed sites, mainly due to an absence of fixed facilities which tend to concentrate wear and tear effects, such as caravan sites, beach huts, and car parks. Likewise, there was very little evidence of recreational off-road vehicle damage. The major exception was at Aberlady Bay where footpaths were extensive and path erosion was present in several places, usually close to one large car park on the edge of Gullane. This shows the impact of walking by people upon a dune system close to a large urban area (in this case Edinburgh). Most dunes surveyed were distant from population centres and large tourist developments, explaining the low general level of walking and recreational vehicle impacts. The situation in Scottish dunes as a whole is probably not so favourable, judged by trampling damage and litter statistics published by Ritchie & Mather (1984). Medium and high levels of trampling damage were found on 23% of all Scottish dunes, and on 41% of mainland beaches. Medium and high litter levels were found on 18% of all Scottish dunes, and on 32% of mainland beaches.

One particular aspect of the leisure industry that warrants special attention is the use of dunes as golf courses. The game of golf is believed to have originated on the dune grasslands or 'links' of eastern Scotland (Nature Conservancy Council 1990b) and many features of modern golf courses have their origin in the natural topography of links grassland. Golf courses were recorded on three survey sites (Troon, Sandside Bay, Aberlady Bay, total extent c. 500 ha) and are present on adjacent unsurveyed dune land at Turnberry, Sheigra to Oldshoremore, Morrich More and Foveran. Golf courses only rarely result in the total destruction of semi-natural vegetation but the modern game does require greens and tees to be converted to a completely artificial sward, though Scottish fairways are normally only mown and hence are slightly altered (producing a floristic composition similar to grazed turf). The least modified dune vegetation is usually found in areas of rough, though exclusion of grazing is usual on golf courses and tall grass growth can greatly reduce species diversity (e.g. at Aberlady Bay).

4.4 Urban and industrial development

Most Scottish dunes are remote from urban and industrial development and hence show little impact from these land uses. The only exceptions among surveyed dunes were the use of part of the Morrich More as a corridor for storing and launching flowbundles for the oil industry (mainly over saltmarsh, with only short sectors through dune) and the loss of climbing dune at Aberlady Bay to long-term residential development at Gullane. Industrial land use is confined to around 4% of Scottish beaches, largely on the Clyde and Forth coasts, and at Aberdeen (Ritchie & Mather 1984).

4.5 Quarrying and other sand/shingle extraction

The extraction of sand and shingle from dunes and from intertidal areas has been a source of concern for many years, both in terms of coastal protection and nature conservation. Despite this, the practice continues and active mineral extraction was recorded from eight sites (Torrs Warren, Troon, Laggan Bay, Hough Bay and Balevullin, Crossapol and Gunna, Middlequarter, Bay of Quendale, Aberlady Bay). It is only large in scale at Bay of Quendale where there have been poor

attempts at restoration. Extraction of sand or aggregate was recorded at approximately 20% of Scottish dunes (more commonly on island dune systems) by Ritchie & Mather (1984), though no data are given on relative proportions from beach and dune workings.

4.6 Sea defence and dune stabilisation

The presence of sea defences can profoundly affect the dynamic processes that create and maintain dune systems. This in turn can have major implications for the vegetation. Very few surveyed Scottish dunes had evidence of sea defences (old cars are used at Middlequarter) and dune stabilisation has only been employed at Hough Bay, Sheigra to Oldshoremore, and Dunnet Links (as marram planting and other grass seeding to combat marine erosion and to stabilise blowouts). It is possible that some 'soft' defence works were under-recorded as they may not have been obvious to casual inspection. The overall extent of protection and stabilisation measures is small in Scotland (Davidson et al. 1991).

4.7 Forestry

Large scale, state-financed afforestation with conifers has been carried out on several of the larger dune systems in Scotland, notably Tentsmuir and Culbin Sands. Plantations were recorded at eight surveyed sites (Torrs Warren, Laggan Bay, Dunnet Links, Morrich More, Loch of Strathbeg, Barry Links, Tentsmuir, Aberlady Bay), though the total extent (c. 269 ha) is a great underestimate since the very extensive woodlands at Tentsmuir lie outside the survey area. The plantings at Culbin and Morrich More were designed to stabilise mobile dunes. Recreational facilities are provided by the Forestry Commission at large sites (notably Tentsmuir, outside the survey area).

4.8 Waste Disposal

The disposal of industrial waste on dunes is probably rare in Scotland and was only recorded at Torrs Warren. The dumping of agricultural and domestic refuse, plus fly tipping, was recorded at ten locations, all on a small scale (Torrs Warren, Turnberry, Troon, Ardnave, Hough Bay and Balevullin, Middlequarter, Sollas, Loch of Strathbeg, Sands of Forvie, Aberlady Bay).

4.9 Military usage

The coastal zone has long been of military importance. This form of land use reached a peak during the second world war when many British dune systems had some form of defence installation and larger sites were intensively used for battle training. Defence installations were recorded in about half of surveyed Scottish sites, with three sites (Torrs Warren, Morrich More, Barry Links) being used at present for intensive training. The total extent of land take and modified vegetation in these sites is estimated at c. 38 ha and is thus small. Off-road vehicle damage is noted as widespread and severe in surveys of Torrs Warren and Morrich More. This is also probably the case at Barry Links.

4.10 Conservation

The management of land for nature conservation is a comparatively recent phenomenon. Nature conservation was recorded as a land use from most surveyed sites. Twenty-four sites were recorded as SSSIs, four as National Nature Reserves (Drimsdale, Dunnet Links, Sands of Forvie, Tentsmuir), one as a Local Nature Reserve (western part of Aberlady Bay site), one as an RSPB reserve (Loch of Strathbeg) and one further RSPB site pending (Coll). Most of the Western Isles sites fall within the Machair of the Uists and Benbecula, Barra and Vatersay Environmentally Sensitive Area declared in April 1988. Designated site area was generally smaller than survey area, though designated extent is generally large. Conservation is rarely the sole use of land over the whole survey area, though conservation management has reduced the impact of some other activities. Apart from stabilisation of eroding dunes (by grass planting and seeding), active management for conservation is rare in survey sites and programmes directly affecting the course of natural succession (scrub clearance, re-introduction of grazing on ungrazed sites) were not recorded.

4.11 An overall assessment of human impact

An attempt to summarize the scale of human impact is given in Table 4.1. Loss of or change from natural and semi-natural habitat can be quantified for the recorded categories, allowing a quantitative comparison of different impacts.

Stock grazing is most important by far in sites surveyed, though golf courses, forestry plantation and arable cultivation are also significant. Military use, miscellaneous land take and quarrying/excavation are very small in scale. These data should be treated cautiously due to the sample nature of this exercise. In most cases they represent the minimum scale of impact because survey area normally excluded land take from dune vegetation outside of mapped areas. In several cases very large extra areas are involved (agriculture at Morrich More, unsurveyed golf course at Turnberry, plantations at Tentsmuir). Even within survey area of 9,641 ha it is sobering to find that 12.2% of land has been grossly changed from a natural or semi-natural state, given that Scottish dunes are probably the least disturbed in Britain.

Table 4.1 Extent of semi-natural and natural dune vegetation lost to or greatly modified by human impact in surveyed sample of Scottish dune systems.

TYPE OF HUMAN IMPACT	AREA LOST OR CHANGED (hectares)
GOLF Greens, tees, fairways, rank rough vegetation (NVC MG1)	296.30
STOCK GRAZING Semi-improved and improved grassland plus NVC MG5	513.86
FORESTRY PLANTATION	268.85
QUARRIES AND SAND EXCAVATION	5.86
MILITARY USE Target areas, turf damage, buildings	37.65
OTHER LAND TAKE Houses, gardens, cemeteries, tracks, roads, car parks, campsites,silage clamps	49.60
TOTAL (hectares)	1172.12

5. General characteristics of Scottish dune vegetation and rare dune species

5.1 Introduction

The vegetation of sand dunes is shaped by a combination of physical, biotic and human factors. Within even a small dune system there can be marked gradients of instability, soil pH, moisture content, grazing pressure and trampling. This wide range of conditions is reflected in the diversity of dune vegetation.

In north west Europe coastal sand dunes are created and maintained by vegetation. The crucial factor in the initiation of dune formation is the ability of certain plant species to withstand burial by wind blown sand and to grow up through it. In Scotland there are three main species, all grasses, which do this; sand couch-grass (*Elymus farctus*), sea lyme-grass (*Leymus arenarius*) and marram grass (*Ammophila arenaria*). Sea couch-grass has only a modest ability to withstand burial, but its comparative tolerance of saltwater (Gimingham 1964) means that it often initiates dune formation in the form of an embryo dune close to the strand line. Sea lyme-grass is a bigger plant, with a greater ability to grow up through fresh sand. It is a predominantly northern species but in surveyed Scottish dunes it is perhaps less important than might be expected. Marram remains the main dune building species. It can keep pace with up to 1 m of fresh sand deposition per annum, as well as producing far-spreading horizontal rhizomes (Gemmell et al. 1953, Ranwell 1972). By binding the dune together, and by maintaining the aerodynamic roughness of the surface, marram allows dunes to build up to a considerable height. Only in extremely exposed dune systems such as the hindshore machairs of the western and northern coasts of Scotland is its performance in dune building restricted by coastal erosion, restricted sand supply and very high average wind speeds.

Actively growing dunes are an extremely hostile environment for most plants. Not only is there constant burial by fresh sand, but the loose sand is also very free draining and therefore subject to severe drought. Dunes are also poor in nitrogen and phosphorus. Consequently the vegetation is normally composed of only a few, highly specialised species. However, as the rate of sand deposition declines, conditions start to ameliorate. Smaller grasses, annual and perennial herbs start to appear in greater number and these are then joined by sand-binding acrocarpous mosses capable of growing up through a few millimetres of accumulating sand (e.g. *Ceratodon purpureus* and *Tortula ruralis ruraliformis*) (Birse et al. 1957), followed by various pleurocarpous mosses which are intolerant of sand deposition, and then by lichens. The cool and humid conditions of most Scottish dunes promote very rapid moss colonisation, helping to stabilise the dune surface and to speed up the process of soil formation. Simultaneously the vigour of the marram declines as the rate of burial decreases (Willis et al. 1959, Hope-Simpson & Jefferies 1966).

The subsequent course of the succession depends on several factors. In Britain as a whole most dunes have been grazed until relatively recently. Under the influence of grazing some form of dune grassland is likely to develop. The nature and species-richness of this grassland is greatly influenced by the type of sand on which it has developed. Where the sand contains a substantial proportion of calcium, generally in excess of 3% weight, grazing appears to have been able to maintain dune grassland for long periods. Where the initial calcium content is lower leaching will, in time, reduce the pH (Wilson 1960) and under these circumstances dune heath can develop.

Very different vegetation develops where the sand is within reach of the freshwater table. This can happen either because the deflation floor of a blowout is close to the water table (e.g. Sands of Forvie), or where the water table rises up towards an existing surface as the dune system extends. Under both these conditions dune slacks can develop, often characterised by a marked annual fluctuation in water level. In prograding dune systems the hollows between low dune ridges also develop into slacks, passing through saltmarsh and swamp phases in the process (e.g. Morrich More, Tentsmuir). Water levels in slacks normally reach a peak in early spring, when many are flooded for periods of several months. They then fall sharply through the summer, reaching up to 2 m below ground level before starting to rise again in autumn (Ranwell 1959). The vegetation of these areas has had to adapt to these unusual conditions

and is largely unique to sand dunes. Not all wet areas on dunes can be described as slacks. Some systems also contain areas of more consistently wet ground, especially where the sand overlies an impermeable substrate. The vegetation of these areas is likely to consist of mire, fen or swamp vegetation, with strong similarities to vegetation of equivalent habitats inland (e.g. Hough Bay and Balevullin, Crossapol and Gunna).

Under continued grazing the vegetation of the older parts of dune systems will continue to develop and on some sites it can be seen to grade into grassland and heath communities that are very similar to inland types. This resemblance can be increased further by agricultural or recreational management, promoting the growth of productive or wear-resistant grasses.

If grazing is relaxed (a rarity in Scotland, though the case in sites largely devoted to nature conservation, e.g. Sands of Forvie) then the succession enters a new phase. Existing dune grassland swards can change their composition and appearance, becoming rank and less species rich. Simultaneously woody species start to invade and scrub starts to develop. In time this scrub will develop into woodland. One scrub species, sea buckthorn (*Hippophae rhamnoides*), is especially associated with British sand dunes, though it is not widely distributed on Scottish systems (recorded at Aberlady Bay and Tentsmuir). A wide range of other shrub and tree species can also grow on dunes, at least in the more stable areas. Semi-natural dune woodland is virtually absent in Scotland but it is found in dunes of the Dutch coast and appears to be developing in older stands of scrub at some English and Welsh sites.

In practice vegetation very seldom entirely follows the orderly succession outlined above. Areas of dune frequently become destabilised and then gradually revegetate by secondary succession. Sometimes the original sequence is repeated, at other times a distinctly different succession occurs. Sand sedge *Carex arenaria* and colonising mosses, especially *Tortula ruralis ruraliformis*, play key roles in such secondary successions.

5.2 Dune vegetation in the National Vegetation Classification.

The National Vegetation Classification (NVC) was commissioned by the Nature Conservancy Council in order to provide a common language of vegetation description for use by all those involved in the conservation of nature in Britain. Although it has linkages with continental phytosociological classifications, it recognises that vegetation varies along a whole series of continua and it aims to provide a series of recognisable reference points along those continua.

The NVC is divided into a series of chapters, each one dealing with a major type of habitat. Then, within each chapter, the vegetation is divided into communities, some of which are again divided into sub-communities. The chapter on sand dunes contains only that vegetation that is exclusively or mainly found on dunes. It does not attempt to include all vegetation that occurs on dunes.

Table 5.1 lists the communities and sub-communities covered by the sand dune chapter, plus those communites from other chapters that are most frequently encountered on dunes. Information is included on the distribution of dune communities and sub-communities in and outwith Scotland, plus other non-dune NVC types which occur on Scottish dunes. Almost 80 NVC communities are found on Scottish dunes. The dune chapter encompasses strandline, mobile dunes, semi-fixed dunes, dune grasslands, slacks and dune scrub - a sequence which closely approximates a simple dune succession. The mobile dunes are divided into three communities SD4, SD5 and SD6, according to which of the major sand binding grasses is dominant. The marram-dominated community (SD6) is further subdivided into a series of sub-communities that represent different degrees of mobility, with some regional differences also overlaid. None of the mobile dune types possess more than a fragmentary bryophyte layer. Most of the semi-fixed dune types are grouped together in one community, SD7. Here again the sub-communities define regional variants and differing degrees of fixation.

Dune grasslands are divided into two communities that reflect the major division between the grasslands of calcareous sands (SD8) and those of

acidic sands (SD12). The sub-communities here reflect variations in base status and soil moisture, along with regional differences. A third community, SD9, is found mainly on neutral to calcareous sand but contains the taller and possibly somewhat eutrophic grasslands in which false oat grass (*Arrhenatherum elatius*) is dominant.

Slacks are represented by 5 communities: SD13, SD14, SD15, SD16 and SD17. Each of these is in turn divided into sub-communities. All of these types represent different combinations of physical factors such as soil pH, water regime and successional change. The SD13 and SD14 communities represent the earlier stages of successional development.

The only scrub community included within the dune chapter (SD18) is that dominated by sea buckthorn *Hippophae rhamnoides*. This is divided into two sub-communities according to the stage in the succession that has been reached.

Vegetation in which sand sedge *Carex arenaria* is dominant is recognised as a distinct community, SD10. It is also a component of a rather specialised 'grey dune' SD11 community in which lichens dominate the sward.
Outside the sand dune chapter, only the heathlands section includes a community (H11) that is more or less confined to dunes. This is again characterised by sand sedge and it is divided into a series of regional sub-communities in which Scottish types are very important. Several other heath communities can also occur within dune systems. Wet heaths, which are found in dune slacks at several acidic sites, are to be found in the mires chapter. There are examples of a number of different calcicolous, mesotrophic and acidic grassland communities. Some of these fit well with the existing sub-communities, others appear to represent slight variations not fully described in the NVC. Bracken-dominated vegetation is found not infrequently on sand dunes. Most Scottish samples can be referred to the uplands and acidic grasslands chapter (U20).

The scrub on dry dunes, apart from that dominated by sea buckthorn, can mostly be referred to the scrubs section of the woodlands chapter (W21 to W24). That which develops in dune slacks is normally dominated by species of willow (*Salix spp.*) and/or birch (*Betula spp.*) and can be found in communities W1 to W4.

The more permanently damp areas on dunes mostly fall either into the mires (on base-poor sites) or into the swamp and tall herb fen chapters. Permanent open water is less common. It does occur but was not tackled in any detail during this survey.

Transitions to other coastal habitats are commonly encountered. Saltmarshes frequently abut dunes, especially in association with prograding types or sectors. There are some communities (SM16, SM18, SM24, SM28) that are particularly characteristic of the transition zone. Where sand has been blown up over nearby cliffs there can also be transitions to maritime cliff grassland communities.

Despite the very broad range of the NVC there do appear to be a few consistent types of Scottish dune vegetation that fall outside current descriptions. These are described in detail in this report. A full vegetation description is not given here for standard NVC communities and sub-communities and readers are referred to NVC chapters for such detail if it is required. This report concentrates more on extent and distribution patterns within surveyed Scottish dunes, plus anomalies to the NVC.

Table 5.1 List of National Vegetation Classification types commonly found on sand dunes, grouped by habitat. * = present in Scotland. ** = provisional new dune NVC type, possibly restricted to dunes in Scotland. + = NVC dune vegetation type absent from surveyed Scottish dunes but characteristic of dunes elsewhere in Britain. xx = non-dune NVC vegetation type which, on dunes, is possibly restricted to dunes in Scotland. **T** = trace or uncertain status in Scotland (single site, single quadrat record).

Strandline

SD2	*	*Honkenya peploides-Cakile maritima* strandline community.
SD3	*	*Matricaria maritima-Galium aparine* strandline community.

Mobile dunes

SD4	*	*Elymus farctus* ssp. *borealis-atlanticus* foredune community.
SD5a	*	*Leymus arenarius* mobile dune, species poor sub-community.
SD5b	*	*Leymus arenarius* mobile dune, *Elymus farctus* sub-community.
SD5c	*	*Leymus arenarius* mobile dune, *Festuca rubra* sub-community.
SD6a	*	*Ammophila arenaria* mobile dune, *Elymus farctus* sub-community.
SD6b	*	*Ammophila arenaria* mobile dune, *Elymus farctus-Leymus arenarius* sub-community.
SD6c	*	*Ammophila arenaria* mobile dune, *Leymus arenarius* sub-community.
SD6d	*	*Ammophila arenaria* mobile dune, typical sub-community.
SD6e	*	*Ammophila arenaria* mobile dune, *Festuca rubra* sub-community.
SD6f	*	*Ammophila arenaria* mobile dune, *Poa pratensis* sub-community.
SD6g	*	*Ammophila arenaria* mobile dune, *Carex arenaria* sub-community.

Semi-fixed dunes

SD7a	*	*Ammophila arenaria-Festuca rubra* semi-fixed dune, typical sub-community.
SD7b	*	*Ammophila arenaria-Festuca rubra* semi fixed dune, *Hypnum cupressiforme* sub-community.
SD7c	*	*Ammophila arenaria-Festuca rubra* semi-fixed dune, *Ononis repens* sub-community.
SD7d	*	*Ammophila arenaria-Festuca rubra* semi-fixed dune, *Tortula ruralis* ssp. *ruraliformis* sub-community.
SD7e	+	*Ammophila arenaria-Festuca rubra* semi fixed dune, *Elymus pycnanthus* sub-community.
SD7?f	**	*Ammophila arenaria - Festuca rubra* semi-fixed dune, provisional *Galium verum* sub-community.
SD7?g	**	*Ammophila arenaria - Festuca rubra* semi-fixed dune, provisional *Heracleum sphondylium* sub-community.

Table 5.1 (continued) List of National Vegetation Classification types commonly found on sand dunes, grouped by habitat. * = present in Scotland. ** = provisional new dune NVC type, possibly restricted to dunes in Scotland. + = NVC dune vegetation type absent from surveyed Scottish dunes but characteristic of dunes elsewhere in Britain. **xx** = non-dune NVC vegetation type which, on dunes, is possibly restricted to dunes in Scotland. **T** = trace or uncertain status in Scotland (single site, single quadrat record).

Dune grasslands

SD8a	*	*Festuca rubra-Galium verum* fixed dune grassland, typical sub-community.
SD8b	*	*Festuca rubra-Galium verum* fixed dune grassland, *Luzula campestris* sub-community.
SD8c	*	*Festuca rubra-Galium verum* fixed dune grassland, *Tortula ruralis* ssp. *ruraliformis* sub-community.
SD8d	*	*Festuca rubra-Galium verum* fixed dune grassland, *Bellis perennis-Ranunculus acris* sub-community.
SD8e	*	*Festuca rubra-Galium verum* fixed dune grassland, *Prunella vulgaris* sub-community.
SD9a	*	*Ammophila arenaria-Arrhenatherum elatius* dune grassland, typical sub-community.
SD9b	+	*Ammophila arenaria-Arrhenatherum elatius* dune grassland, *Geranium sanguineum* sub-community.
SD12a	*	*Carex arenaria-Festuca ovina-Agrostis capillaris* grassland, *Anthoxanthum odoratum* sub-community.
SD12b	*	*Carex arenaria-Festuca ovina-Agrostis capillaris* dune grassland, *Holcus lanatus* sub-community.

Neutral grassland

MG1a	*	*Arrhenatherum elatius* coarse grassland, *Festuca rubra* sub-community.
MG1e	*	*Arrhenatherum elatius* coarse grassland, *Centaurea nigra* sub-community.
MG5a	*	*Centaurea nigra-Cynosurus cristatus* meadow, *Lathyrus pratensis* sub-community.
MG5b	*	*Centaurea nigra-Cynosurus cristatus* meadow, *Galium verum* sub-community.
MG6a	*	*Lolium perenne-Cynosurus cristatus* pasture, typical sub-community.
MG6b	*	*Lolium perenne-Cynosurus cristatus* pasture, *Anthoxanthum odoratum* sub-community.
MG7a	*	*Lolium perenne* leys, *Lolium perenne-Trifolium repens* leys.
MG7e	*	*Lolium perenne* leys, *Plantago lanceolata* sub-community.
MG8	xx	*Cynosurus cristatus - Caltha palustris* flood pasture.
MG9	xx	*Holcus lanatus - Deschampsia cespitosa* coarse grassland.
MG10a	*	*Holcus lanatus-Juncus effusus* rush pasture, typical sub-community.

Table 5.1 (continued) List of National Vegetation Classification types commonly found on sand dunes, grouped by habitat. * = present in Scotland. ** = provisional new dune NVC type, possibly restricted to dunes in Scotland. + = NVC dune vegetation type absent from surveyed Scottish dunes but characteristic of dunes elsewhere in Britain. **xx** = non-dune NVC vegetation type which, on dunes, is possibly restricted to dunes in Scotland. **T** = trace or uncertain status in Scotland (single site, single quadrat record).

Neutral grassland (continued)

MG11a	*	*Festuca rubra-Agrostis stolonifera-Potentilla anserina* inundation grassland, *Lolium perenne* sub-community.
MG12	**xx**	*Festuca arundinacea* coarse grassland.
MG13	**xx**	*Agrostis stolonifera - Alopecurus geniculatus* inundation grassland.

Calcicolous grassland

CG2	**xx**	*Festuca ovina - Avenula pratensis* grassland.
CG6a	*	*Avenula pubescens* grassland, *Dactylis glomerata-Briza media* sub-community.
CG10	**xx**	*Festuca ovina - Agrostis capillaris - Thymus praecox* grassland.

Acidic grassland

U1	*	*Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland, undifferentiated .
U2a	*	*Deschampsia flexuosa* grassland, *Festuca ovina - Agrostis capillaris* sub-community.
U4	**xx**	*Festuca ovina - Agrostis capillaris - Galium saxatile* grassland.
U5	**xx**	*Nardus stricta - Galium saxatile* grassland.
U13	**xx**	*Deschampsia cespitosa - Galium saxatile* grassland.
U20	*	*Pteridium aquilinum-Galium saxatile* community, undifferentiated.

Sand sedge and 'grey' dunes

SD10a	*	*Carex arenaria* dune, *Festuca rubra* sub-community.
SD10b	*	*Carex arenaria* dune, *Festuca ovina* sub-community.
SD11a	*	*Carex arenaria-Cornicularia aculeata* community, *Ammophila arenaria* sub-community.
SD11b	*	*Carex arenaria-Cornicularia aculeata* community, *Festuca ovina* sub-community.

Heath

H10	*	*Calluna vulgaris-Erica cinerea* heath, undifferentiated.
H11a	*	*Calluna vulgaris-Carex arenaria* dune heath, *Erica cinerea* sub-community.
H11b	**	*Calluna vulgaris-Carex arenaria* dune heath *Empetrum nigrum nigrum* sub-community
H11c	*	*Calluna vulgaris-Carex arenaria* dune heath, *Hypnum cupressiforme* sub-community.

Table 5.1 (continued) List of National Vegetation Classification types commonly found on sand dunes, grouped by habitat. * = present in Scotland. ** = provisional new dune NVC type, possibly restricted to dunes in Scotland. + = NVC dune vegetation type absent from surveyed Scottish dunes but characteristic of dunes elsewhere in Britain. **xx** = non-dune NVC vegetation type which, on dunes, is possibly restricted to dunes in Scotland. **T** = trace or uncertain status in Scotland (single site, single quadrat record).

Wet heaths and mires

M3	**xx**	*Eriophorum angustifolium* bog pool community.
M5	**xx**	*Carex rostrata - Sphagnum squarrosum* mire.
M6	**xx**	*Carex echinata - Sphagnum recurvum/auriculatum* mire.
M13	**xx**	*Schoenus nigricans - Juncus subnodulosus* mire.
M14	**xx**	*Schoenus nigricans - Narthecium ossifragum* mire.
M15	*	*Scirpus cespitosus-Erica tetralix* wet heath,
M16a	*	*Erica tetralix-Sphagnum compactum* wet heath, typical sub-community.
M16c	*	*Erica tetralix-Sphagnum compactum* wet heath, *Rhynchospora alba-Drosera intermedia* sub-community
M16?e	*	*Erica tetralix-Sphagnum compactum* wet heath, Provisional dune sub-community lacking *Sphagnum* spp.
M22	**xx**	*Juncus subnodulosus - Cirsium palustre* fen-meadow.
M23a	*	*Juncus effusus/acutiflorus-Galium palustre* rush-pasture, *Juncus acutiflorus* sub-community.
M23b	*	*Juncus effusus/acutiflorus-Galium palustre* rush-pasture, *Juncus effusus* sub-community.
M25	**xx**	*Molinia caerulea - Potentilla erecta* mire.
M26	**xx**	*Molinia caerulea - Crepis paludosa* mire.
M27	**xx**	*Filipendula ulmaria - Angelica sylvestris* mire.
M28	**xx**	*Iris pseudacorus - Filipendula ulmaria* mire.
M29	**xx**	*Hypericum elodes - Potamogeton polygonifolius* soakaway.

Dune slacks

SD13a	+	*Salix repens-Bryum pseudotriquetrum* dune slack, *Poa annua-Hydrocotyle vulgaris* sub-community.
SD13b	**T**	*Salix repens-Bryum pseudotriquetrum* dune slack, *Holcus lanatus-Festuca rubra* sub-community.
SD14a	**T**	*Salix repens-Campylium stellatum* dune slack, *Carex serotina-Drepanocladus sendtneri* sub-community.
SD14b	+	*Salix repens-Campylium stellatum* dune slack, *Rubus caesius-Galium palustre* sub-community.
SD14c	+	*Salix repens-Campylium stellatum* dune slack, *Bryum pseudotriquetrum-Aneura pinguis* sub-community.
SD14d	+	*Salix repens-Campylium stellatum* dune slack, *Festuca rubra* sub-community.

Table 5.1 (continued) List of National Vegetation Classification types commonly found on sand dunes, grouped by habitat. * = present in Scotland. ** = provisional new dune NVC type, possibly restricted to dunes in Scotland. + = NVC dune vegetation type absent from surveyed Scottish dunes but characteristic of dunes elsewhere in Britain. **xx** = non-dune NVC vegetation type which, on dunes, is possibly restricted to dunes in Scotland. **T** = trace or uncertain status in Scotland (single site, single quadrat record).

Dune slacks (continued)

SD15a	+	*Salix repens-Calliergon cuspidatum* dune slack, *Carex nigra* sub-community.
SD15b	**T**	*Salix repens-Calliergon cuspidatum* dune slack, *Equisetum variegatum* sub-community.
SD15c	+	*Salix repens-Calliergon cuspidatum* dune slack, *Carex flacca-Pulicaria dysenterica* sub-community.
SD15d	+	*Salix repens-Calliergon cuspidatum* dune slack, *Holcus lanatus-Angelica sylvestris* sub-community.
SD16a	+	*Salix repens-Holcus lanatus* dune slack, *Ononis repens* sub-community.
SD16b	+	*Salix repens-Holcus lanatus* dune slack, *Rubus caesius* sub-community.
SD16c	+	*Salix repens-Holcus lanatus* dune slack, *Prunella vulgaris-Equisetum variegatum* sub-community.
SD16d	**T**	*Salix repens-Holcus lanatus* dune slack, *Agrostis stolonifera* sub-community.
SD17a	+	*Potentilla anserina-Carex nigra* dune slack, *Festuca rubra-Ranunculus repens* sub-community.
SD17b	+	*Potentilla anserina-Carex nigra* dune slack, *Carex flacca* sub-community.
SD17c	*	*Potentilla anserina-Carex nigra* dune slack, *Caltha palustris* sub-community.
SD17d	*	*Potentilla anserina-Carex nigra* dune slack, *Hydrocotyle vulgaris-Ranunculus flammula* sub-community.

Swamps and tall-herb fens

S4a	*	*Phragmites australis* swamp,*Phragmites australis* sub-community.
S4d	**T**	*Phragmites australis* swamp,*Atriplex hastata* sub-community.
S6	*	*Carex riparia* swamp.
S8	*	*Scirpus lacustris* ssp. *lacustris* swamp, undifferentiated.
S10a	*	*Equisetum fluviatile* swamp, *Equisetum fluviatile* sub-community.
S12a	*	*Typha latifolia* swamp, *Typha latifolia* sub-community.
S12b	*	*Typha latifolia* swamp, *Mentha aquatica* sub-community.
S14	*	*Sparganium erectum* swamp, undifferentiated.
S19c	*	*Eleocharis palustris* swamp, *Agrostis stolonifera* sub-community.
S20b	*	*Scirpus lacustris* ssp. *tabernaemontani* swamp, *Agrostis stolonifera* sub-community.

Table 5.1 (continued) List of National Vegetation Classification types commonly found on sand dunes, grouped by habitat. * = present in Scotland. ** = provisional new dune NVC type, possibly restricted to dunes in Scotland. + = NVC dune vegetation type absent from surveyed Scottish dunes but characteristic of dunes elsewhere in Britain. **xx** = non-dune NVC vegetation type which, on dunes, is possibly restricted to dunes in Scotland. **T** = trace or uncertain status in Scotland (single site, single quadrat record).

Swamps and tall-herb fens (continued)

S21c	*	*Scirpus maritimus* swamp, *Potentilla anserina* sub-community.
S22	xx	*Glyceria fluitans* water-margin vegetation.
S27	xx	*Carex rostrata - Potentilla palustris* tall-herb fen.
S28b	*	*Phalaris arundinacea* tall-herb fen, *Epilobium hirsutum-Urtica dioica* sub-community.

Standing open water

A7	xx	*Nymphaea alba* community.
A9	xx	*Potamogeton natans* community.
A10	xx	*Polygonum amphibium* community.
A14	xx	*Myriophyllum alterniflorum* community.
A22	xx	*Littorella uniflora - Lobelia dortmanna* community.
A24	xx	*Juncus bulbosus* community.

Scrub and woodland

SD18a	*	*Hippophae rhamnoides* scrub, *Festuca rubra* sub-community.
SD18b	*	*Hippophae rhamnoides* scrub, *Urtica dioica-Arrhenatherum elatius* sub-community.
W1	*	*Salix cinerea-Galium palustre* woodland, undifferentiated.
W2	*	*Salix cinerea-Betula pubescens-Phragmites australis* woodland, undifferentiated.
W4	*	*Betula pubescens-Molinia caerulea* woodland, undifferentiated
W22	*	*Prunus spinosa-Rubus fruticosus* agg. scrub, undifferentiated.
W23	*	*Ulex europaeus-Rubus fruticosus* scrub, undifferentiated.
W25	T	*Pteridium aquilinum -Rubus fruticosus* agg. underscrub, undifferentiated.
W?	**	*Provisional Juniperus communis* dune scrub community.

Table 5.1 (continued) List of National Vegetation Classification types commonly found on sand dunes, grouped by habitat. * = present in Scotland. ** = provisional new dune NVC type, possibly restricted to dunes in Scotland. + = NVC dune vegetation type absent from surveyed Scottish dunes but characteristic of dunes elsewhere in Britain. **xx** = non-dune NVC vegetation type which, on dunes, is possibly restricted to dunes in Scotland. **T** = trace or uncertain status in Scotland (single site, single quadrat record).

Transitions to other habitats

Maritime cliff (from SD8 dune grassland)

MC8	*	*Festuca rubra-Armeria maritima* maritime grassland, undifferentiated.
MC8d	*	*Festuca rubra-Armeria maritima* maritime grassland, *Holcus lanatus* sub-community.

Saltmarsh		**(from various strandline, dune grassland, dune slack and swamp types)**
SM16	*	*Festuca rubra* saltmarsh, undifferentiated.
SM18	xx	*Juncus maritimus* saltmarsh.
SM19	xx	*Blysmus rufus* saltmarsh.
SM20	xx	*Eleocharis uniglumis* saltmarsh.
SM24	*	*Elymus pycnanthus* saltmarsh.
SM28	xx	*Elymus repens* saltmarsh.

5.3 Nationally rare and scarce plants on Scottish dunes

Nationally rare plants are defined as those occuring in 1 - 15 of the 10 x 10 km squares of the National Grid. Nationally scarce plants are those found in 16 - 100 10 x 10 km squares. Throughout Great Britain saltmarshes, shingle, maritime grasslands, cliffs, open areas, dunes and dune slacks taken together support 48 nationally rare and 66 nationally scarce species. These represent about 8% of the total British flora. Many of them have shown a marked decline since 1930, but only one dune species (curved sedge *Carex maritima*) in these sets is largely confined to Scotland and shows a major decline.

The majority of the nationally rare species characteristic of dunes are found in south-western, southern or western Britain, whilst most of the nationally scarce species have a predominantly southern, south-eastern or scattered distribution. This is because most of these plants belong to the Continental and the Mediterranean elements of the British flora and are reaching the northern and western limits of their range. The dunes of England, especially those in the southern half of the country, therefore support a disproportionate number of nationally rare and scarce plants. Scotland, as a result, has relatively few of these rare and scarce British species.

It is also important to note that many nationally rare and scarce plants found on the coast are not confined to coastal habitat, since some are plants of unstable, ever-changing conditions and others require a strong maritime influence (Table 5.2). Again, few such species are found on dunes in Scotland. Five nationally rare and twelve nationally scarce plants are wholly or mainly confined to dunes and dune slacks (Table 5.3). No nationally rare dune plants are found in Scotland. Five nationally scarce dune species are native to Scotland and are described briefly below.

Seaside centaury *Centaurium littorale* is a plant of open dunes, found mainly in the north and west of the British Isles. It is present on a transition from slack to saltmarsh at Morrich More.

Variegated horsetail *Equisetum variegatum* is a component of certain types of dune slack vegetation. It is largely confined to dune slacks over much of England and Wales, though it does occur inland in northern England and Scotland. Where suitable habitat exists populations can be quite large. Survey in 1991 found it at Bay of Quendale (a new Shetland record, its most northern British location) and, as a distinct ecotype, on mobile dunes at Crossapol on Coll.

Rush-leaved fescue *Festuca juncifolia* is a foredune species and grows mixed with red fescue *Festuca rubra* in the slightly more stabilised foredunes. It has a very scattered distribution on the east coast of Scotland (e.g. Aberlady Bay).

Baltic rush *Juncus balticus* is a plant of damp dune grassland and dune slacks. It is mainly found on the east and north coast of Scotland where it is very abundant at some sites (e.g. Morrich More).

Curved sedge *Carex maritima* is a plant of damp dune grassland, slacks and transitions to saltmarsh. It is largely confined to Scotland but is found on all coasts. It was recorded in the survey of Bay of Quendale (Shetland).

Table 5.2 Nationally rare and nationally scarce plants primarily associated with other habitats but which were recorded on British dunes during the national sand dune survey. * = known to occur on Scottish dunes. ** = recorded in at least one site in Scottish dune survey.

Nationally rare plants		Main habitat
Dryopteris cristata crested buckler-fern		Wet heaths
Matthiola sinuata sea stock		Sea cliffs
Viola kitiabeliana dwarf pansy		Coastal grassland
Silene conica striated catchfly		Sandy pastures
Petrorhagia nantuellii childing pink		Waste ground
Polycarpon tetraphyllum four-leaved all-seed		Sandy places
Geranium purpureum ssp *purpureum* little robin		Shingle
Geranium purpureum ssp *forsteri* little robin		Shingle
Ornithopus pinnatus orange bird's-foot		Open, sandy soil
Rumex rupestris shore dock		Beaches
Limonium bellidifolium matted sea-lavender		Upper saltmarsh
Scrophularia scorodonia balm-leaved figwort		Hedgebanks
Orobanche caryophllacea clove-scented broomrape		Dry grassland
Valerianella eriocarpa		Banks and walls
Allium ampeloprasum wild leek		Rocks
Allium babingtonii babington's leek		Rocks
Romulea columnae sand crocus		Coastal grassland
Liparis loeselii fen orchid		Fens
Himantoglossum hircinicum lizard orchid		Inland
Poa infirma early meadow-grass		Sandy places
Mibora minima		Wet sandy places
Nationally scarce plants		
Asplenium trichomanes maidenhair spleenwort		Rocks
Ophioglossum azoricum small adder's tongue		Coastal grassland
Ranunculus baudotii brackish water crowfoot	*	Saltmarshes, flats & creeks
Rhynchosinapis monensis Isle of Man cabbage	*	Shores and waste places
Raphanus maritimus sea radish		Waste places
Hornungia petraea rock hutchinsia		Limestone rock
Frankenia laevis sea-heath		Upper saltmarsh
Silene nutans Nottingham catchfly		Dry slopes
Dianthus deltoides maiden pink		Inland
Moenchia erecta upright chickweed		Gravelly pastures
Scilla autumnalis autumn squill		Coastal grassland
Suaeda fruticosa shrubby sea-blite		Shingle
Epipactis phyllanthes		Woods
Medicago minima small medick		Heaths
Trifolium ornithopoides bird's foot clover		Shores and waste places
Trifolium glomeratum clustered clover		Shores and waste places
Trifolium suffocatum suffocated clover		Sandy grassland
Cicuta virosa cowbane		Shallow water
Oenanthe pimpinelloides		Meadows

Nationally scarce plants (continued)		Main habitat
Thesium humifusum bastard toadflax		Calcareous grassland
Polygonum raii Ray's knotgrass		Sandy shores
Pyrola rotundifolia larger wintergreen		Fens, woods
Primula scotica Scottish primrose	**	Coastal grassland
Verbascum virgatum twiggy mullein		Waste places
Parentucellia viscosa yellow bartsia		Coastal grassland
Orobanche hederae ivy broomrape		Coastal districts
Goodyera repens creeping ladies tresses	**	Pine woods
Coralorhiza trifida coralroot orchid	*	Woods
Orchis ustulata burnt orchid		Calcareous grassland.
Aceras anthropophorum man orchid		Chalk
Arum italicum		Stony ground
Eleocharis acicularis slender spike-rush		Lakes and pools
Juncus acutus sharp rush		Open areas
Carex punctata dotted sedge		Rocks
Vulpia ambigua bearded fescue		Open and sandy places
Poa bulbosa bulbous poa		Coastal grassland
Hordeum marinum sea barley		Coastal grassland
Apera interrupta		Sandy fields
Parapholis incurva curved hard-grass		Sandy upper saltmarshes

Table 5.3 Nationally rare and nationally scarce plants found mainly or exclusively on dunes in Britain. ** = recorded in survey of Scottish dunes. + = introduced into Scotland.

		Number of 10x10 km squares in GB
Nationally rare species characteristic of dunes		
Orobanche caryophyllea bedstraw broomrape		2
Gentianella uliginosa dune gentian		5
Teucrium scordium water germander		3
Gnaphalium luteoalbum Jersey cudweed		1
Epipactis dunensis dune helleborine		9
Nationally scarce species characteristic of dunes		
Equisetum variegatum variegated horsetail	**	89
Erodium maritimum sea stork's-bill		77
Hippophae rhamnoides sea buckthorn	**+	36
Oenothera stricta fragrant evening primrose		32
Euphorbia portlandica Portland spurge		74
Euphorbia paralias sea spurge		92
Centaurium littorale seaside centaury	**	42
Juncus balticus Baltic rush	**	47
Carex maritima curved sedge	**	26
Festuca juncifolia rush-leaved fescue	**	27
Vulpia membranacea dune fescue		44
Corynephorus canescens grey hair-grass		16

6. Strandline and foredune communities, transitions to saltmarsh

6.1 NVC communities and rare species

Three strandline and foredune communities are recognised by the NVC. None is differentiated into sub-communities. All are associated with the upper beach, detritus deposited on the strandline, or with sand which has buried strand materials. They thus occur as a narrow but often very lengthy line on the upper beach. Total area (18.8 ha) of all types is low (Table 6.1). All communities become discontinuous and restricted as beach exposure increases, until the most exposed beaches have no strandline or foredune communities (Ardnave, Uidh, Allasdale, Bay of Quendale). Most dune systems have a very low extent of all strandline and foredune types, with only a few sheltered beaches attaining reasonable extents (Torrs Warren, Kilpheder, Middlequarter, Dunnet Links, Morrich More, Loch of Strathbeg). Under very sheltered conditions on accreting beaches they grade into saltmarsh and form part of a saltmarsh transition under such circumstances (Torrs Warren, Morrich More, Barry Links, Tentsmuir, Aberlady Bay). The rare oyster plant *Mertensia maritima* is associated with strandline communities (Rodwell in prep.) and was found at Sands of Forvie.

6.2 SD2 *Honkenya peploides - Cakile maritima* strandline community

This community is found throughout Scotland (Figure 6.1a). The constant species sea sandwort *Honkenya peploides* and sea rocket *Cakile maritima*, in an analysis of all Scottish NVC records, are rarely found together. *H. peploides* tends to be found on flat sand or fine gravel, with *C. maritima* preferring very low dunes formed over the strandline. Seeds of *H. peploides* are clearly plentiful upon the strand because the plant is also common inland in Western Isles sites where strand kelp is used for fertilising arable land in the machair. Total extent is 10.2 ha in surveyed sites (Table 6.1) and is thus low, reflecting the narrow beach zone to which it is restricted. This is the commonest and most extensive strandline community. It is generally very species-poor.

6.3 SD3 *Matricaria maritima - Galium aparine* strandline community

This community is scattered around the Scottish coast (Figure 6.1b) and is of much lower extent (0.7 ha) than the SD2 type. It is rare to find both constants sea mayweed *Matricaria maritima* and goosegrass *Galium aparine* together and, instead, a heterogeneous species set is common in which Babington's orache *Atriplex glabriuscula* and curled dock *Rumex crispus* are equally common. This type is more strictly associated with rotting strand material than the SD2 community.

6.4 SD4 *Elymus farctus* foredune community

Sand couch-grass *Elymus farctus* forms low dunes (generally <0.5 m high) on or above high water mark (springs) around all the Scottish coast (Figure 6.1c) but the community is often rare on exposed and eroding beaches. The community is very species-poor, reflecting extreme environmental conditions of instability. Total extent in surveys is 7.8 ha. The dunes migrate and can show a transition to SD5 and SD6 mobile dune types. On very exposed dune systems which cannot support foredunes *E. farctus* can be found in small quantities well inland, suggesting seeds can be dispersed over long distances by wind (>800 m on Tiree, into SD8d communities).

6.5 Transitions to saltmarsh

These important transitions are restricted to sheltered dune systems and hence are uncommon (Figure 6.1d), being found in only one west coast site (Torrs Warren) and several east coast locations (notably Morrich More with 199.5 ha, but also at Barry Links, Tentsmuir and Aberlady Bay). They generally involve SM16 *Festuca rubra* saltmarsh (the major transition at Morrich More), SM18c *Juncus maritimus* saltmarsh *Festuca arundinacea* sub-community and SM20 *Eleocharis uniglumis* saltmarsh (both under swampy conditions), though SM19 *Blysmus rufus* saltmarsh is common at Morrich More. The strandline zone in the transition is best shown by SM24 *Elymus pycnanthus* saltmarsh or SM28 *Elymus repens* saltmarsh (both often with SD3 species). Such transitions reflect prograding dune systems in which dune slacks will eventually be developed, often with an intermediate swamp phase (see Chapter 11). Most transition areas are only target-noted and extents of individual communities (and full floristic details) are incomplete.

Table 6.1 Strandline (SD2, SD3), foredune (SD4) and transitions to saltmarsh in surveyed Scottish dune systems. Areas in hectares. T = trace (generally target note). SMT = saltmarsh transition

Figure 6.1 Distribution of strandline, foredune and transitions to saltmarsh.
a. SD2; b. SD3; c. SD4; d. transitions to saltmarsh.

	SITE	SD2	SD3	SD4	Total Area	SMT
1	TORRS WARREN	0.93	0.68	0.07	1.68	2.51
2	TURNBERRY	T	T	T	T	-
3	TROON	T	-	T	T	-
4	LAGGAN BAY	-	T	T	T	-
5	ARDNAVE	-	-	T	T	-
6	KILLINALLAN	T	-	-	T	-
7	HOUGH BAY & BALEVULLIN	T	-	T	T	-
8	CROSSAPOL & GUNNA	T	-	-	T	-
9	VATERSAY	-	-	0.10	0.10	-
10	UIDH	-	-	-	-	-
11	TANGUSDALE	-	-	0.31	0.31	-
12	BORVE	-	T	-	T	-
13	ALLASDALE	-	-	-	-	-
14	CLEAT	T	-	0.03	0.03	-
15	FUDAY	0.01	-	-	0.01	-
16	KILPHEDER	1.11	-	T	1.11	-
17	HOWBEG	0.27	-	-	0.27	-
18	HOWMORE	0.57	-	-	0.57	-
19	DRIMSDALE	0.13	T	-	0.13	-
20	STILLIGARY	0.02	-	-	0.02	-
21	MIDDLEQUARTER	2.47	-	T	2.47	-
22	SOLLAS	-	-	T	-	-
23	SHEIGRA TO OLDSHOREMORE	0.40	0.07	0.47	0.47	-
24	AN FHARAID	T	-	-	-	-
25	SANDSIDE BAY	0.63	-	-	0.63	-
26	DUNNET LINKS	2.34	-	0.03	2.34	-
27	BAY OF QUENDALE	-	-	-	-	-
28	MORRICH MORE	0.60	T	3.70	4.30	199.50
29	LOCH OF STRATHBEG	0.46	-	1.87	2.33	T
30	SANDS OF FORVIE	T	T	0.18	0.18	T
31	FOVERAN	-	-	1.13	1.13	-
32	BARRY LINKS	T	T	T	T	5.24
33	TENTSMUIR	0.30	0.07	0.19	0.56	0.87
34	ABERLADY BAY	T	T	0.12	0.12	8.58
	Total area (hectares)	10.24	0.75	7.77	18.76	216.70

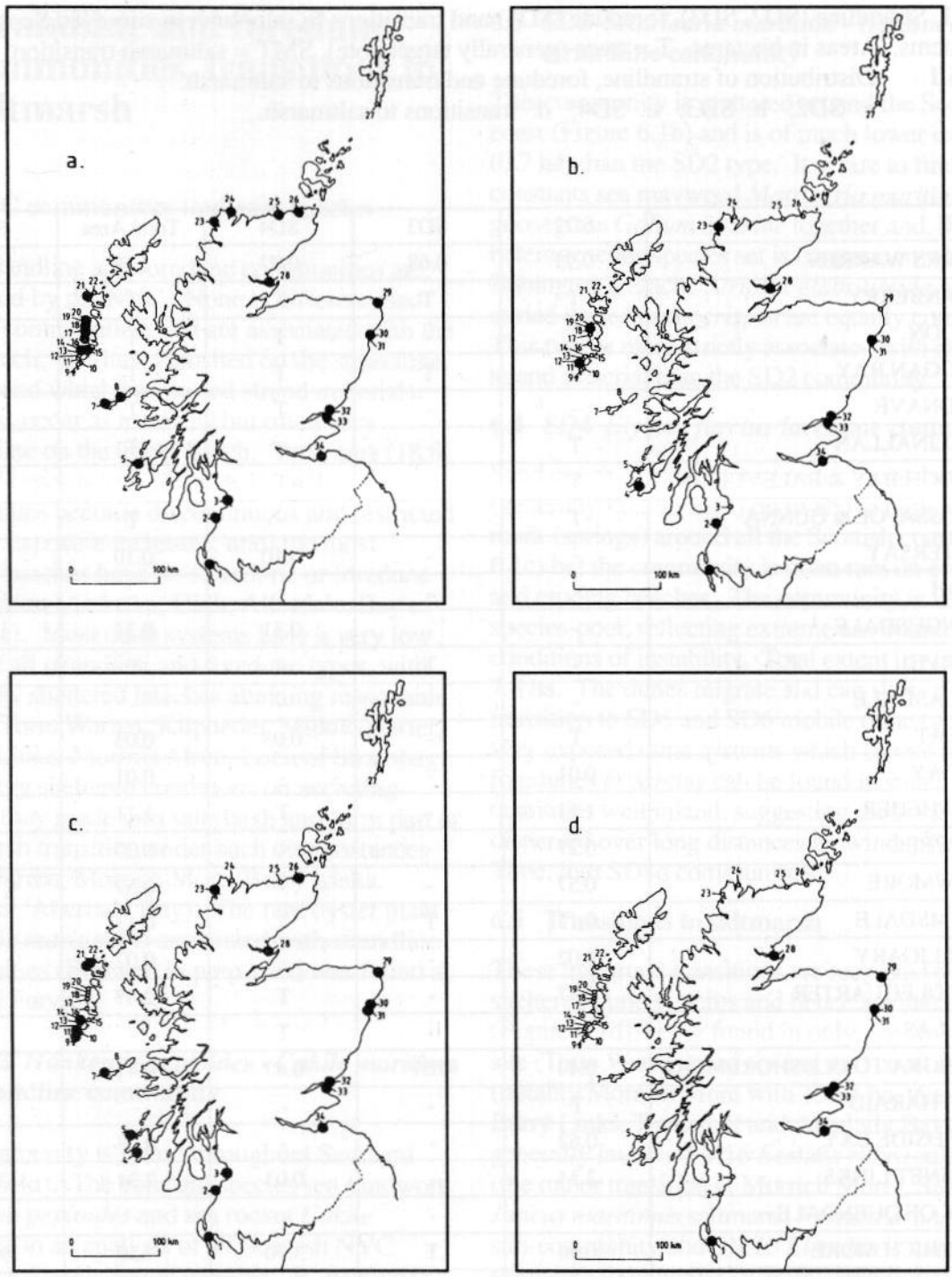


Figure 6.1 Distribution of strandline, foredune and transitions to saltmarsh.
a. SD2; b. SD3; c. SD4; d. transitions to saltmarsh.

○ Site surveyed - community absent
● Site surveyed - community present
Site names are listed in Table 1.1

7. Mobile dune communities

7.1 NVC communities and rare species

Two NVC communities (SD5 and SD6) are recognised as mobile dune types, with a total of ten sub-communities. All are present in the Scottish sites sampled. The SD5 community is dominated by sea lyme-grass *Leymus arenarius* but is not extensive in surveyed dunes, with a total area of 54.8 ha (Table 7.1). The SD6 community, dominated by marram grass *Ammophila arenaria,* is much more extensive with a total area of 268.2 ha (Table 7.2). The rare dune grass *Festuca juncifolia* is probably restricted to SD6 vegetation (Rodwell in prep.) and in Scotland to SD6e and SD6f stands in a few east coast sites (it is present at Tentsmuir and Aberlady Bay).

7.2 SD5 *Leymus arenarius* mobile dune community

Floristic detail for Loch of Strathbeg and Barry Links (Figure 7.1a) is insufficient to determine sub-community status and only the area of the community can be estimated for the two sites (1.1 ha, Table 7.1). Sub-communities SD5b and SD5c are most extensive and seem associated with sheltered prograding dune systems in which low rates of sand deposition allow *L. arenarius* to become the dominant dune-forming grass. Torrs Warren, Troon, Loch of Strathbeg, Barry Links, Tentsmuir and Morrich More have the community, with the latter two sites containing the bulk of the resource.

SD5a Species-poor sub-community

This is uncommon (Figure 7.1b) - it is only recorded at Torrs Warren and Morrich More. It is only extensive at Morrich More (27.4 ha, Table 7.1) where it forms distinct scattered dune hummocks and low ridges up to 2 m height, a foredune type associated with barrier islands beyond the outer strandplain.

SD5b *Elymus farctus* sub-community

This is recorded at Torrs Warren, Troon, Morrich More and Tentsmuir (Figure 7.1c) and has an area of 18.97 ha (Table 7.1). It represents a foredune - mobile dune transition zone in which low and often discontinuous sand ridges are developed just above the strandline. Small quantities of sand couch-grass *E. farctus* are mixed with *L. arenarius*.

SD5c *Festuca rubra* sub-community

This is recorded at Torrs Warren, Troon, Morrich More and Sheigra to Oldshoremore (Figure 7.1d), with a total extent of 7.31 ha. Its presence in the latter site is probably due to dune stabilisation measures and it might not be natural in such an exposed site. This type represents the most stable form of the SD5 community, with red fescue-grass *F. rubra* achieving modest cover values. It is most extensive at Morrich More where sand inputs are low enough for high covers of the moss *Bryum algovicum* to develop between *L. arenarius* stems. The sub-community there is dominant on the outer islands of the strandplain which act as a protection barrier for the main dune system.

Table 7.1 SD5 *Leymus arenarius* mobile dune community in surveyed Scottish dune systems. Areas in hectares. T = trace (generally target note).

	SITE	SD5	SD5a	SD5b	SD5c	Total area
1	TORRS WARREN	-	T	0.59	0.42	1.01
2	TURNBERRY	-	-	-	-	-
3	TROON	-	-	3.18	0.23	3.41
4	LAGGAN BAY	-	-	-	-	-
5	ARDNAVE	-	-	-	-	-
6	KILLINALLAN	-	-	-	-	-
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-	-
9	VATERSAY	-	-	-	-	-
10	UIDH	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-
12	BORVE	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-
14	CLEAT	-	-	-	-	-
15	FUDAY	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-
17	HOWBEG	-	-	-	-	-
18	HOWMORE	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-
20	STILLIGARY	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-
22	SOLLAS	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	-	0.06	0.06
24	AN FHARAID	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-
26	DUNNET LINKS	-	-	-	-	-
27	BAY OF QUENDALE	-	-	-	-	-
28	MORRICH MORE	-	27.40	8.70	6.60	42.70
29	LOCH OF STRATHBEG	0.21	-	-	-	0.21
30	SANDS OF FORVIE	-	-	-	-	-
31	FOVERAN	-	-	-	-	-
32	BARRY LINKS	0.93	-	-	-	0.93
33	TENTSMUIR	-	-	6.50	-	6.50
34	ABERLADY BAY	-	-	-	-	-
	Total area (hectares)	1.14	27.40	18.97	7.31	54.82

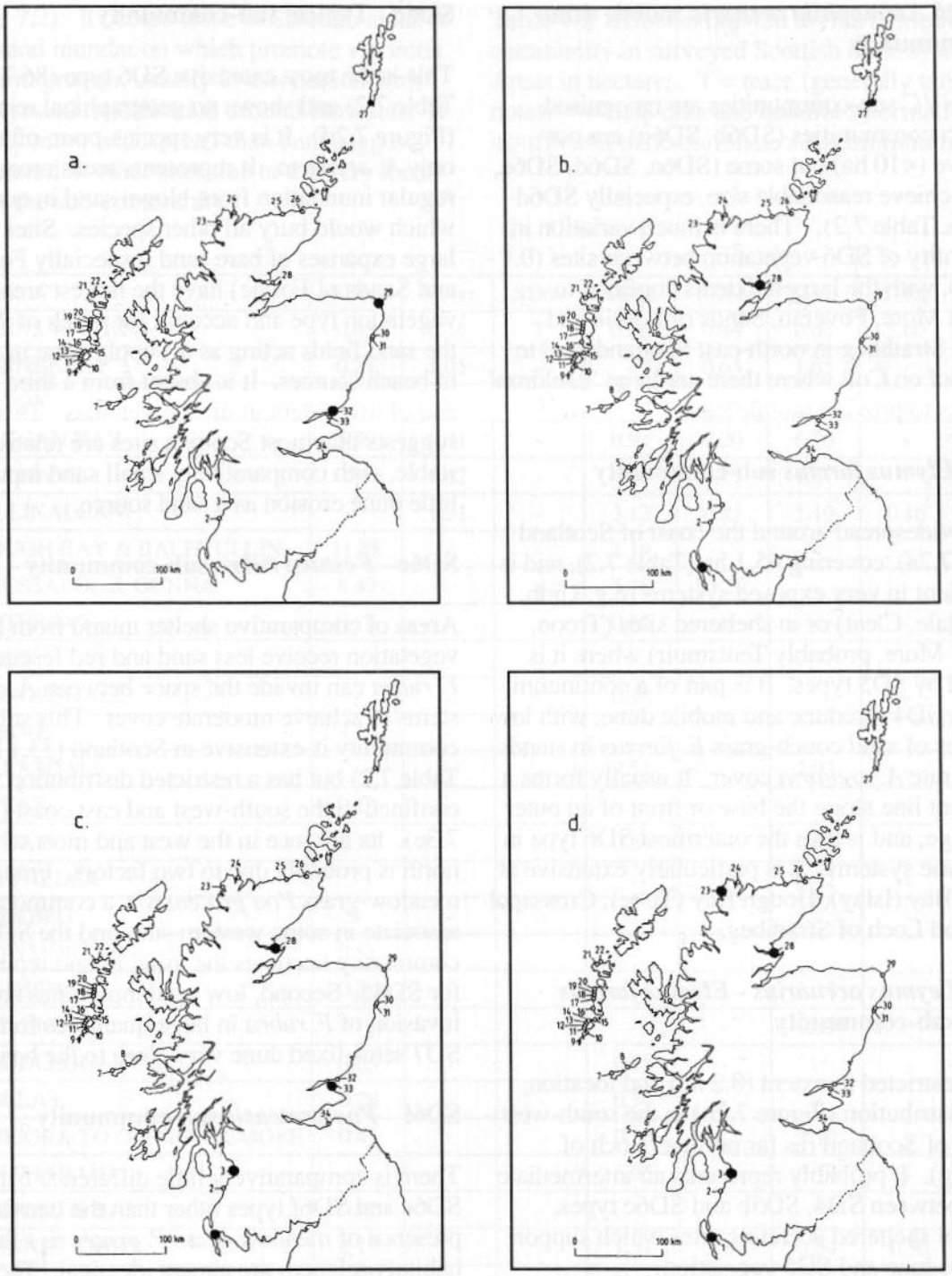


Figure 7.1 Distribution of SD5 *Leymus arenarius* mobile dune community in surveyed Scottish dunes.
a. SD5 undifferentiated community; b. SD5a species-poor sub-community; c. SD5b *Elymus farctus* sub-community; d. SD5c *Festuca rubra* sub-community.

○ Site surveyed - community absent
● Site surveyed - community present
Site names are listed in Table 1.1

7.3 SD6 *Ammophila arenaria* mobile dune community

Seven NVC sub-communities are recognised. Two sub-communities (SD6b, SD6g) are not extensive (<10 ha) but some (SD6a, SD6d, SD6e, SD6f) achieve reasonable size, especially SD6d (86.7 ha, Table 7.2). There is much variation in the quantity of SD6 vegetation between sites (0.1 - 33.7 ha), with the largest extents confined to Morrich More, Foveran, Sands of Forvie and Loch of Strathbeg in north-east Scotland, and to Crossapol on Coll where there are large 'cauldron' blowouts to provide mobile sand.

SD6a *Elymus farctus* sub-community

This is widespread around the coast of Scotland (Figure 7.2a), covering 45.1 ha (Table 7.2), and is only absent in very exposed systems (e.g. Uidh, Tangusdale, Cleat) or in sheltered sites (Troon, Morrich More, probably Tentsmuir) where it is replaced by SD5 types. It is part of a continuum between SD4 foredune and mobile dune, with low quantities of sand couch-grass *E. farctus* in stands of moderate *A. arenaria* cover. It usually forms a prominent line along the base or front of an outer dune ridge, and is thus the outermost SD6 type in many dune systems. It is particularly extensive at Laggan Bay (Islay), Hough Bay (Tiree), Crossapol (Coll) and Loch of Strathbeg.

SD6b *Leymus arenarius - Elymus farctus* sub-community

This is restricted in extent (8.2 ha) and location, with a distribution (Figure 7.2b) in the south-west and east of Scotland (as far north as Loch of Strathbeg). It probably represents an intermediate variant between SD4, SD5b and SD6c types, located in sheltered accreting sites which support good foredune and SD5 vegetation.

SD6c *Leymus arenarius* sub-community

This is similar in distribution to SD6b (Figure 7.2c), with a stronger confinement to the east coast of Scotland. It is found a short distance inland of the foredune zone in sheltered accreting sites. The largest extent (11.0 ha out of a total 13.58 ha) is found at Morrich More where this type is common on barrier island dunes and the outer strandplain.

SD6d Typical sub-community

This is the most extensive SD6 type (86.7 ha, Table 7.2) and shows no geographical restriction (Figure 7.2d). It is very species-poor, often with only *A. arenaria*. It represents areas receiving regular inundation from blown sand in quantities which would bury all other species. Sites with large expanses of bare sand (especially Foveran and Sands of Forvie) have the largest areas of this vegetation type and account for much of the area, the sand fields acting as a supply zone in addition to beach sources. It is absent from a third of sites, and of low extent in most other sites. This pattern suggests that most Scottish sites are relatively stable, with comparatively small sand inputs and little dune erosion as a sand source.

SD6e *Festuca rubra* sub-community

Areas of comparative shelter inland from SD6d vegetation receive less sand and red fescue-grass *F. rubra* can invade the space between *A. arenaria* stems to achieve moderate cover. This sub-community is extensive in Scotland (33.1 ha, Table 7.2) but has a restricted distribution which is confined to the south-west and east coast (Figure 7.3e). Its absence in the west and most of the north is probably due to two factors. First, meadow-grass *Poa pratensis* is a common associate in some western sites and the SD6f sub-community becomes the usual inland replacement for SD6d. Second, low sand input rates and rapid invasion of *F. rubra* in large quantities forms an SD7 semi-fixed dune very close to the beach.

SD6f *Poa pratensis* sub-community

There is comparatively little difference between SD6e and SD6f types other than the consistent presence of meadow-grass *P. pratensis* - their habitat prefences are almost identical. The SD6f sub-community is patchily common throughout Scotland and has no geographical restriction (Figure 7.2f). It is of greater extent (45.3 ha, Table 7.2) than SD6e.

SD6g *Carex arenaria* sub-community

Small patches of this sub-community (distinguished by a moderate cover of sand sedge *Carex arenaria)* are present in four Scottish sites (Figure 7.2g), giving a very small total extent (3.9

ha, Table 7.2). It occurs close to SD6d in areas of modest sand inundation which promote vigorous *C. arenaria* growth, usually in association with secondary sand mobilisation around blowouts. It is possibly more widespread than data suggest, being ignored in other sites due to the very local nature of the sub-community.

Table 7.2 SD6 *Ammophila arenaria* mobile dune community in surveyed Scottish dune systems. Areas in hectares. T = trace (generally target note). * = map data and quadrat information insufficient to discriminate sub-communities.

	SITE	SD6a	SD6b	SD6c	SD6d	SD6e	SD6f	SD6g	Total
1	TORRS WARREN	0.43	0.76	T	0.68	0.44	0.66	3.00	5.97
2	TURNBERRY	0.21	1.05	-	-	0.63	1.05	-	2.94
3	TROON	-	-	0.45	-	0.68	-	-	1.13
4	LAGGAN BAY	5.59	0.41	-	0.91	0.20	6.70	-	13.81
5	ARDNAVE	0.95	0.42	-	4.07	0.77	1.37	-	7.58
6	KILLINALLAN	-	1.21	-	3.13	0.91	5.10	0.16	10.51
7	HOUGH BAY & BALEVULLIN	11.88	-	-	1.19	-	-	-	13.07
8	CROSSAPOL & GUNNA	8.47	-	-	5.38	11.52	-	-	25.37
9	VATERSAY	0.13	-	-	0.05	-	-	-	0.18
10	UIDH	-	-	-	-	-	0.37	-	0.37
11	TANGUSDALE	-	-	-	0.10	-	-	-	0.10
12	BORVE	3.17	-	-	-	-	-	-	3.17
13	ALLASDALE	-	-	-	2.51	-	2.93	-	5.44
14	CLEAT	0.13	-	-	-	-	-	-	0.13
15	FUDAY	0.39	-	-	0.64	-	0.59	-	1.62
16	KILPHEDER	-	-	-	-	-	0.42	-	0.42
17	HOWBEG	-	-	-	-	-	-	-	-
18	HOWMORE	0.51	-	-	-	-	-	-	0.51
19	DRIMSDALE	0.29	-	-	-	-	1.12	-	1.41
20	STILLIGARY	-	-	-	-	-	0.39	-	0.39
21	MIDDLEQUARTER	0.55	-	-	0.55	-	-	-	1.10
22	SOLLAS	0.28	-	-	0.34	-	-	-	0.62
23	SHEIGRA TO OLDSHOREMORE	0.41	-	-	0.83	-	4.10	-	5.34
24	AN FHARAID	-	-	-	6.95	-	5.19	-	12.14
25	SANDSIDE BAY	0.42	-	-	-	-	-	-	0.42
26	DUNNET LINKS	1.17	-	-	1.31	5.37	0.54	0.30	8.69
27	BAY OF QUENDALE	T	-	-	0.48	1.37	-	-	1.85
28	MORRICH MORE	-	-	11.00	-	-	11.00	-	22.00
29	LOCH OF STRATHBEG	7.00	3.73	0.93	15.39	0.93	-	0.47	28.45
30	SANDS OF FORVIE	0.70	-	0.55	21.61	0.53	-	-	23.39
31	FOVERAN	1.35	0.48	0.28	18.18	9.72	3.73	-	33.74
32	BARRY LINKS	*	*	*	*	*	*	-	8.78
33	TENTSMUIR	*	*	*	*	*	*	-	6.12
34	ABERLADY BAY	1.12	0.15	0.37	2.36	-	-	-	4.00
	Total area (hectares)	45.15	8.21	13.58	86.66	33.07	45.26	3.93	250.64

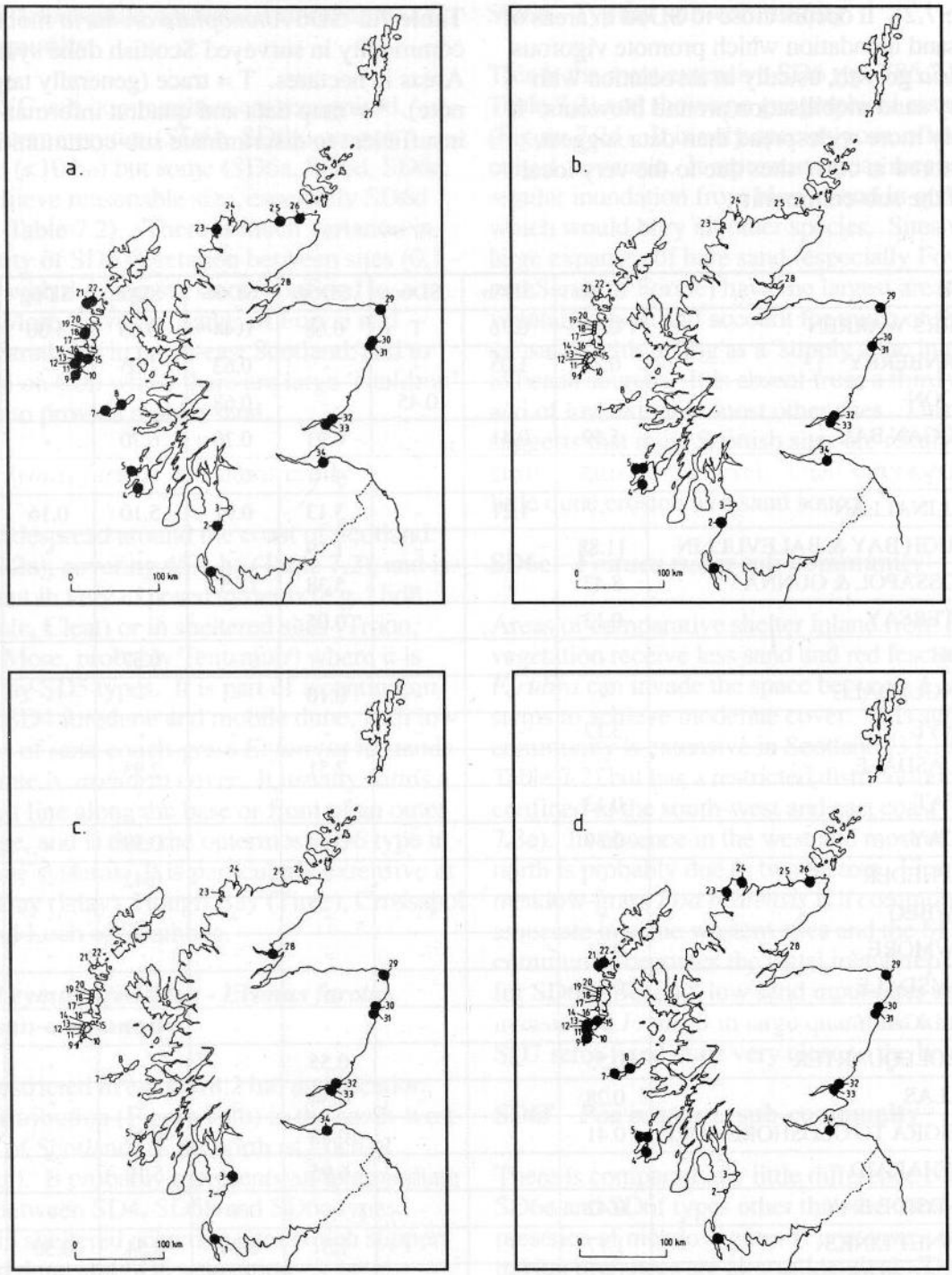


Figure 7.2 Distribution of SD6 *Ammophila arenaria* mobile dune sub-communities in surveyed Scottish dunes. a. SD6a *Elymus farctus* sub-community; b. SD6b *Leymus arenarius - Elymus farctus* sub-community; c. SD6c *Leymus arenarius* sub-community; d. SD6d Typical sub-community.

○ Site surveyed - community absent

● Site surveyed - community present

Site names are listed in Table 1.1

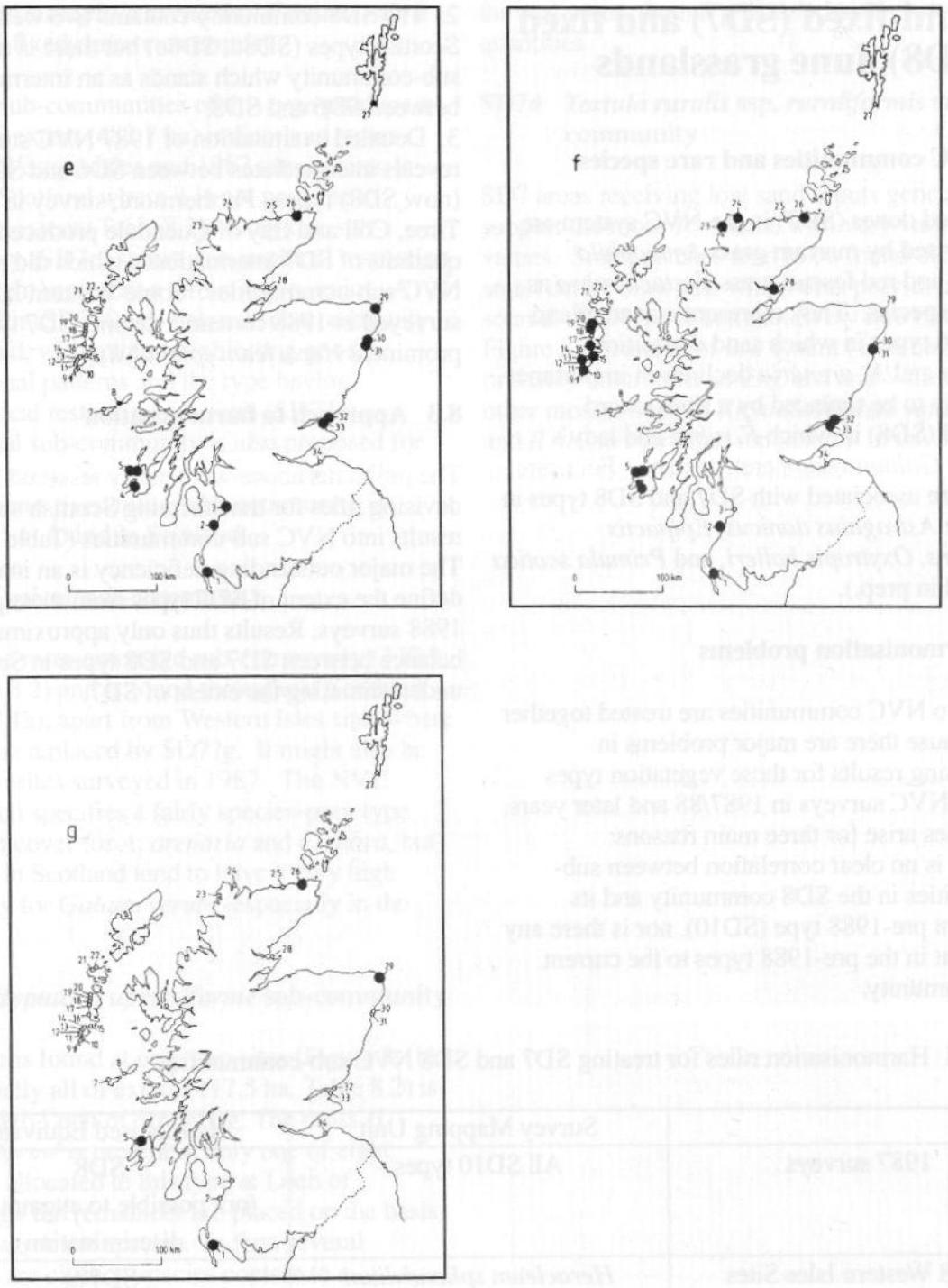


Figure 7.2 (continued) Distribution of SD6 *Ammophila arenaria* mobile dune sub-communities in surveyed Scottish dunes. e. SD6e *Festuca rubra* sub-community; f. SD6f *Poa pratensis* sub-community; g. SD6g *Carex arenaria* sub-community.

○ Site surveyed - community absent
● Site surveyed - community present
Site names are listed in Table 1.1

8. Semi-fixed (SD7) and fixed (SD8) dune grasslands

8.1 NVC communities and rare species

Semi-fixed dunes (SD7) in the NVC system are characterised by marram grass *Ammophila arenaria* and red fescue-grass *Festuca rubra* as constant species. They represent a zone inland from SD6 types in which sand deposition decreases and A. *arenaria* declines in importance, eventually to be replaced by a short sward grassland (SD8) in which *F. rubra* and lady's bedstraw *Galium verum* are constant. Four rare species are associated with SD7 and SD8 types in Scotland: *Astragalus danicus, Epipactis atrorubens, Oxytropis halleri,* and *Primula scotica* (Rodwell in prep.).

8.2 Harmonisation problems

These two NVC communities are treated together here because there are major problems in harmonising results for these vegetation types between NVC surveys in 1987/88 and later years. Difficulties arise for three main reasons:

1. There is no clear correlation between sub-communities in the SD8 community and its equivalent pre-1988 type (SD10), nor is there any equivalent in the pre-1988 types to the current SD7 community.
2. The SD8 community contains two well-defined Scottish types (SD8d, SD8e) but there is no SD7 sub-community which stands as an intermediate between SD6 and SD8.
3. Detailed examination of 1987 NVC surveys reveals intermediates between SD6 and SD10 (now SD8) types. Furthermore, survey in 1991 at Tiree, Coll and Bay of Quendale produced many quadrats of SD7 intermediates which did not fit NVC sub-communities. Some Western Isles sites surveyed in 1988 contain a distinct SD7 type with prominent *Heracleum sphondylium.*

8.3 Approach to harmonisation

The problems above were partly resolved by devising rules for transforming Scottish survey results into NVC sub-communities (Table 8.1). The major outstanding deficiency is an inability to define the extent of SD7 types from most pre-1988 surveys. Results thus only approximate the balance between SD7 and SD8 types in Scotland, underestimating the extent of SD7.

Table 8.1 Harmonisation rules for treating SD7 and SD8 NVC sub-communities.

	Survey Mapping Unit	Harmonised Equivalent
1987 surveys	All SD10 types	SD8 (not possible to attempt finer discrimination)
1988 Western Isles Sites	*Heracleum sphondylium* SR (Sand over rock) SD8b	SD7?g SD8d SD8d
1988 Morrich More survey	G2 G3 G4	20% area = SD7a 25% area = SD7a 75% area = SD8d 50% area = SD8/SD12 50% area = SD12
1991 surveys (Tiree, Coll, Bay of Quendale)	Provisional SD7?f sub-community	25% area = SD7a 75% area = SD8d

8.4 SD7 *Ammophila arenaria - Festuca rubra* semi-fixed dune community

The four sub-communities of this type produce a large SD7 extent (482.7 ha) in Scotland, apart from the Western Isles and 1987 survey sites in northern Scotland where it is not possible to determine extent (Table 8.2). Only one sub-community (SD7c) shows geographical restriction which might represent a climatic constraint. A further fifth (SD7?f) provisional sub-community is proposed, with variants exhibiting good successional patterns and the type having geographical restriction. A sixth (SD7?g) provisional sub-community is also proposed for samples rich in *Heracleum sphondylium*. The SD7e *Elymus pycnanthus* sub-community is probably not found in Scotland.

SD7a Typical sub-community

This is the most extensive sub-community (330.9 ha, Table 8.2) and is found throughout Scotland (Figure 8.1a), apart from Western Isles sites where it might be replaced by SD7?g. It might also be present in sites surveyed in 1987. The NVC description specifies a fairly species-poor type with high cover for *A. arenaria* and *F. rubra*, but quadrats in Scotland tend to have a very high constancy for *Galium verum* (especially in the west).

SD7b *Hypnum cupressiforme* sub-community

This type is found at only two sites (Figure 8.1b) and virtually all of extent (117.5 ha, Table 8.2) is restricted to Loch of Strathbeg. The moss *H. cupressiforme* is present in only one of eight quadrats allocated to this type at Loch of Strathbeg - the remainder are placed on the basis of other associate species. In fact, several quadrats are close in species content to a provisional SD7f *Galium verum* sub-community (see below).

SD7c *Ononis repens* sub-community

This sub-community probably represents a southern GB type reaching its northern limit in southern Scotland (Figure 8.1c). Extent is small (21.7 ha, Table 8.2). Rest-harrow *Ononis repens* is rare on the west coast of Scotland north of the Clyde Sea coast but reaches much further north on the east coast, though probably in only small quantities.

SD7d *Tortula ruralis* ssp. *ruraliformis* sub-community

SD7 areas receiving low sand inputs generally support the moss *T. ruralis*, with very varied cover values. Small patches tend to be found close to small active blowouts which thus provide a sand source. The type is comparatively rare (five sites, Figure 8.1d) and is of low extent (12.6 ha). It is probably commoner in England and Wales, with other mosses such as *Rhytidiadelphus squarrosus* and *R. triquetrus* often replacing it in the cooler and more moist Scottish climate.

Table 8.2 SD7 *Ammophila arenaria - Festuca rubra* semi-fixed dune community in surveyed Scottish dune systems. Areas in hectares. * = 1987 survey sites in which not possible to determine presence or extent of SD7 types with accuracy. P = possibly present on basis of quadrat floristic composition.

	SITE	SD7a	SD7b	SD7c	SD7d	TOTAL SD7 (excl. SD7?f and SD7?g)	SD7?f in 1991 surveys	SD7?g
1	TORRS WARREN	24.32	-	0.42	-	24.74		
2	TURNBERRY	-	-	0.63	-	0.63		
3	TROON	2.05	-	-	-	2.05		
4	LAGGAN BAY	4.36	-	-	0.61	4.97	P	
5	ARDNAVE	0.52	-	-	-	0.52	P	
6	KILLINALLAN	18.44	-	-	0.81	19.25	P	
7	HOUGH BAY & BALEVULLIN	15.00	-	-	5.37	20.37	59.85	
8	CROSSAPOL & GUNNA	87.44	-	-	3.47	90.91	349.76	
9	VATERSAY	-	-	-	-	-	P	
10	UIDH	-	-	-	-	-	P	
11	TANGUSDALE	-	-	-	-	-	P	
12	BORVE	-	-	-	-	-	P	
13	ALLASDALE	-	-	-	-	-	P	
14	CLEAT	-	-	-	-	-		
15	FUDAY	-	-	-	-	-	P	2.21
16	KILPHEDER	-	-	-	-	-	P	1.90
17	HOWBEG	-	-	-	-	-		3.33
18	HOWMORE	-	-	-	-	-	P	0.13
19	DRIMSDALE	-	-	-	-	-	P	
20	STILLIGARY	-	-	-	-	-		
21	MIDDLEQUARTER	-	-	-	-	-	0.83	
22	SOLLAS	-	-	-	-	-	P	5.10
23 *	SHEIGRA TO OLDSHOREMORE	-	-	-	-	-	P	P
24 *	AN FHARAID	-	-	-	-	-	P	P
25 *	SANDSIDE BAY	-	-	-	-	-	P	P
26 *	DUNNET LINKS	-	-	-	-	-	P	P
27	BAY OF QUENDALE	7.73	-	-	-	7.73	30.92	P
28	MORRICH MORE	44.40	-	-	-	44.40	P	
29	LOCH OF STRATHBEG	34.52	117.11	-	-	151.63	P	
30	SANDS OF FORVIE	61.49	-	-	-	61.49		
31	FOVERAN	13.48	-	-	-	13.48		
32	BARRY LINKS	-	-	11.48	-	11.48		
33	TENTSMUIR	3.56	-	6.06	-	9.62		
34	ABERLADY BAY	13.55	0.37	3.11	2.36	19.39		
	TOTALS	330.86	117.48	21.70	12.62	482.66		

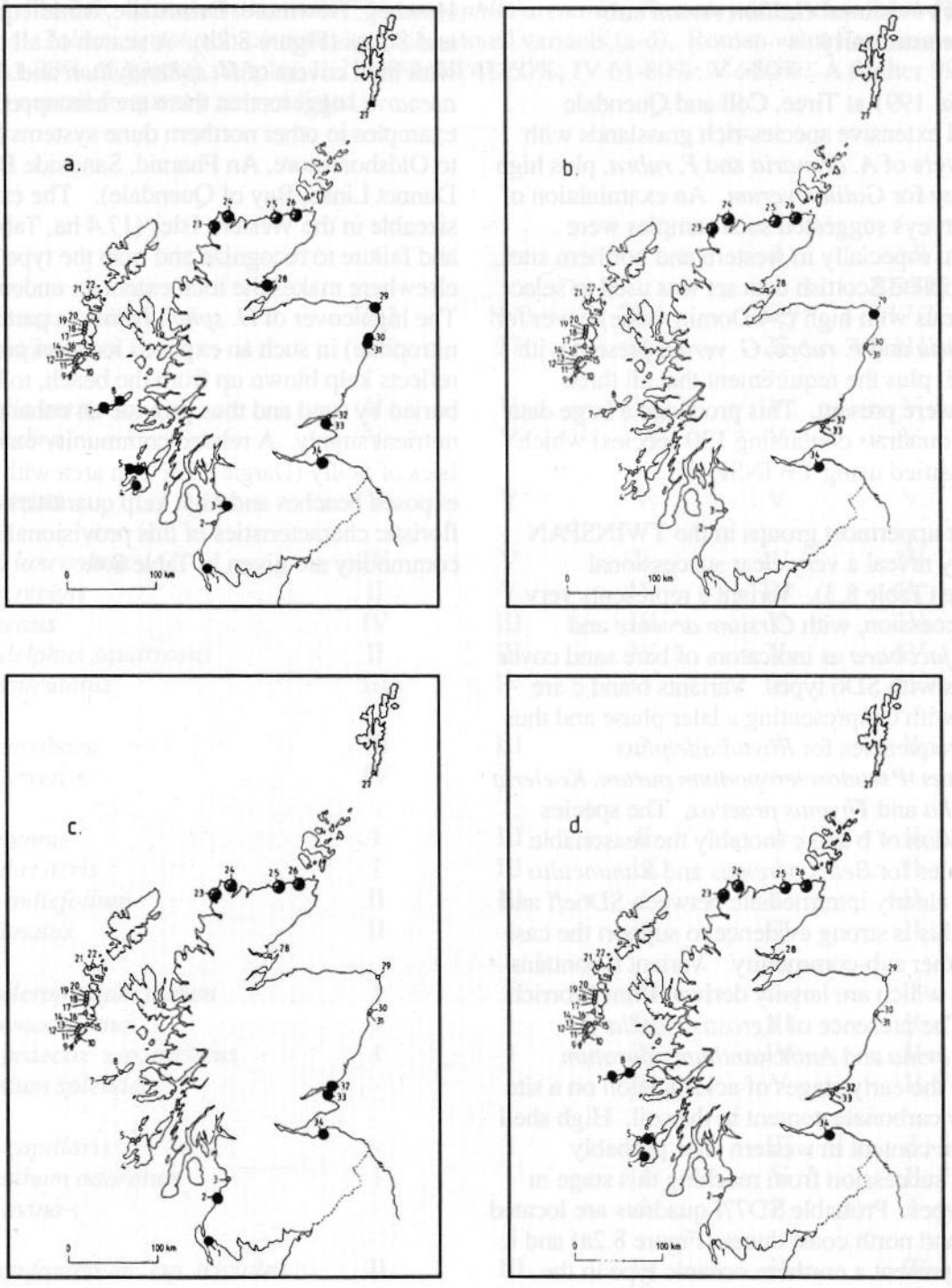


Figure 8.1 Distribution of SD7 *Ammophila arenaria - Festuca rubra* semi-fixed dune community in surveyed Scottish sites. a. SD7a Typical sub-community; b. SD7b *Hypnum cupressiforme* sub-community; c. SD7c *Ononis repens* sub-community; d. SD7d *Tortula ruralis ruraliformis* sub-community.

- ○ Site surveyed - community absent
- ● Site surveyed - community present
- ◒ 1987 survey site - SD7 status uncertain

Site names are listed in Table 1.1

SD7?f Provisional *Galium verum* sub-community

Survey in 1991 at Tiree, Coll and Quendale revealed extensive species-rich grasslands with high covers of *A. arenaria* and *F. rubra*, plus high constancy for *Galium verum*. An examination of other surveys suggested such samples were common, especially in western and northern sites. The complete Scottish data set was used to select all quadrats with high (>4 Domin value) cover for *A. arenaria* and *F. rubra, G. verum* present with cover >3, plus the requirement that all three species were present. This produced a large data set (111 quadrats containing 130 species) which was classified using TWINSPAN.

The four uppermost groups in the TWINSPAN hierarchy reveal a very clear successional sequence (Table 8.3). Variant a represents very early succession, with *Cirsium arvense* and *Senecio jacobaea* as indicators of bare sand cover and links with SD6 types. Variants b and c are similar, with c representing a later phase and thus higher frequencies for *Rhytidiadelphus squarrosus, Pseudoscleropodium purum, Koeleria macrantha* and *Thymus praecox*. The species composition of b and c (notably the reasonable frequencies for *Bellis perennis* and *Ranunculus acris*) is clearly intermediate between SD6e/f and SD8d - this is strong evidence to support the case for a further sub-community. Variant d contains quadrats which are largely derived from Morrich More. The presence of *Agrostis capillaris, Festuca ovina* and *Anthoxanthum odoratum* suggests the early stages of acidification on a site with low carbonate content in the soil. High shell carbonate content in western sites probably prevents succession from reaching this stage in SD7?f types. Probable SD7?f quadrats are located in west and north coast dunes (Figure 8.2a) and it might represent a northern oceanic type in the SD7 complex.

SD7?g Provisional *Heracleum sphondylium* sub-community

Several sites in the Western Isles have a distinct vegetation (with plentiful hogweed *Heracleum sphondylium* amidst *A. arenaria* tussocks and reasonable quantities of *Festuca rubra*) sited immediately inland of the outer dune ridge. It is mapped as a separate unit in site surveys of Fuday, Howbeg, Howmore, Drimsdale, Middlequarter and Sollas (Figure 8.2b). A search of all quadrats with high covers of *H. sphondylium* and *A. arenaria* suggests that there are unmapped examples in other northern dune systems (Sheigra to Oldshoremore, An Fharaid, Sandside Bay, Dunnet Links, Bay of Quendale). The extent is sizeable in the Western Isles (17.4 ha, Table 7.2) and failure to recognize and map the type elsewhere makes the total extent an underestimate. The high cover of *H. sphondylium* (a partial nitrophile) in such an exposed location probably reflects kelp blown up from the beach, to be buried by sand and thus provide an enhanced nutrient supply. A related community exists in the Isles of Scilly (Dargie 1991), an area with very exposed beaches and high kelp quantities. The floristic characteristics of this provisional sub-community are given in Table 8.4.

Table 8.3 Floristic characteristics of SD7?f *Ammophila arenaria - Festuca rubra* semi-fixed dune, provisional *Galium verum* sub-community successional variants (a-d). Roman values are frequency classes: I 1-20% of quadrat samples; II 21-40%; III 41-60%; IV 61-80%; V >80%. A further 99 species of low (I) overall frequency are not listed.

	a	b	c	d	All SD7?f
Mean species per quadrat	13.3	16.0	20.4	20.9	17.7
Quadrat total per group	21	37	26	27	111
Ammophila arenaria	V	V	V	V	V
Festuca rubra	V	V	V	V	V
Galium verum	V	V	V	V	V
Plantago lanceolata	IV	V	V	IV	IV
Trifolium repens	II	V	IV	IV	IV
Poa pratensis	IV	III	III	V	IV
Rhytidiadelphus squarrosus	II	III	IV	V	IV
Lotus corniculatus	III	IV	IV	III	IV
Senecio jacobaea	III	III	I	I	II
Cirsium arvense	IV	I	-	-	I
Bellis perennis	I	III	II	I	II
Ranunculus acris	I	III	III	I	II
Achillea millefolium	II	III	I	I	II
Holcus lanatus	II	I	III	III	II
Pseudoscleropodium purum	I	I	III	I	I
Koeleria macrantha	I	I	III	III	II
Thymus praecox ssp. arcticus	I	I	IV	IV	II
Hylocomium splendens	-	-	III	V	II
Agrostis capillaris	-	I	I	III	I
Anthoxanthum odoratum	I	-	I	V	II
Festuca ovina	-	-	I	II	I
Cerastium fontanum ssp. triviale	II	III	IV	V	III
Carex arenaria	I	III	II	IV	III
Thalictrum minus	II	III	II	I	II
Rhytidiadelphus triquetrus	I	I	II	IV	II
Campanula rotundifolia	I	II	II	IV	II
Homalothecium lutescens	I	III	III	-	II
Tortula ruralis ssp. ruraliformis	II	II	I	-	II
Linum catharticum	I	I	II	II	II
Euphrasia officinalis agg.	I	I	II	II	II
Luzula campestris	-	I	II	III	II

Table 8.4 Provisional SD7?g *Ammophila arenaria- Festuca rubra* semi-fixed dune, *Heracleum sphondylium* sub-community. Roman values are frequency classes: II 21-40%; III 41-60%; IV 61-80%; V >80%. A further 44 species with frequency <20% (class I) are excluded from the table (frequency based on presence in 14 quadrats from 11 sites).

	FREQUENCY CLASS	DOMIN RANGE	MODAL DOMIN SCORE
Ammophila arenaria	V	5 - 10	7
Festuca rubra	V	4 - 8	5
Heracleum sphondylium	V	4 - 8	5
Galium verum	V	2 - 6	3
Plantago lanceolata	IV	2 - 6	3
Senecio jacobaea	III	2 - 5	3
Lotus corniculatus	III	2 - 6	4
Poa pratensis	III	2 - 5	3
Achillea millefolium	II	2 - 4	4
Centaurea nigra	II	3 - 7	4
Trifolium repens	II	1 - 6	5
Agrostis stolonifera	II	3 - 5	3
Holcus lanatus	II	2 - 5	3
Ranunculus acris	II	2 - 5	2
Thalictrum minus	II	2 - 6	3
Vicia sativa	II	2 - 5	3
Arrhenatherum elatius	II	4 - 7	5
Cerastium fontanum triviale	II	2 - 3	3
Rhytidiadelphus triquetrus	II	4 - 8	4
Rhytidiadelphus squarrosus	II	3 - 6	5

Mean number of species per quadrat = 13.3 (range 9-17)

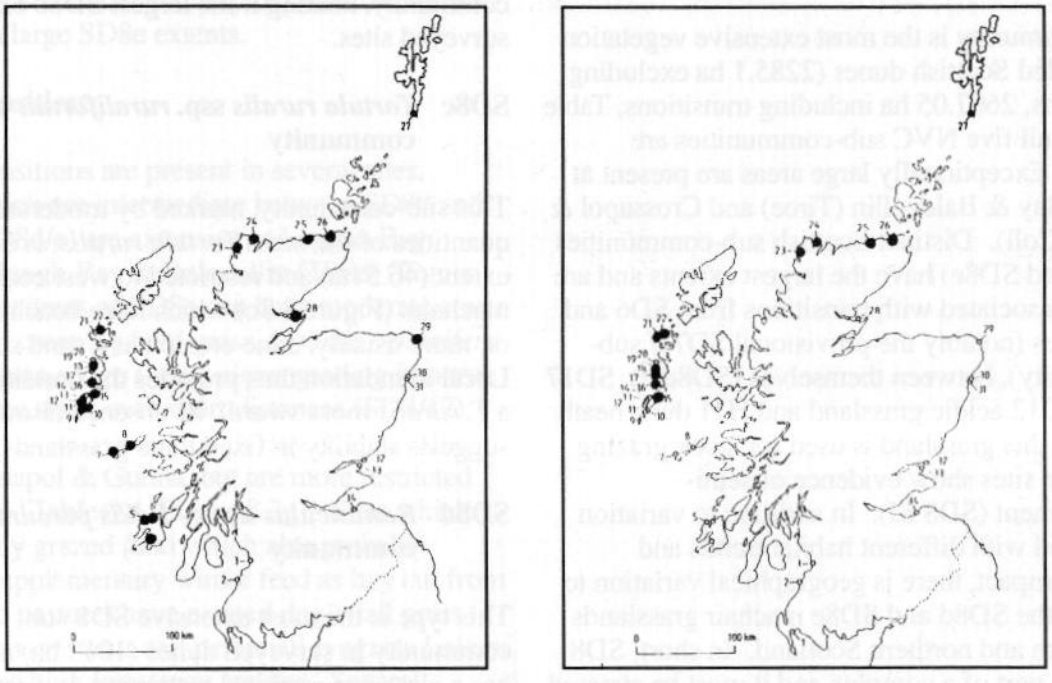


Figure 8.2 Distribution of SD7 *Ammophila arenaria - Festuca rubra* semi-fixed dune provisional sub-communities in Scotland. a. SD7?f *Galium verum* sub-community; b. SD7?g *Heracleum sphondylium* sub-community.

○ No quadrat evidence - sub-community presumed absent
● Quadrat evidence - sub-community presumed present
Site names are listed in Table 1.1

8.5 SD8 *Festuca rubra - Galium verum* fixed dune grassland community

This community is the most extensive vegetation on sampled Scottish dunes (2285.1 ha excluding transitions, 2607.05 ha including transitions, Table 8.4) and all five NVC sub-communities are present. Exceptionally large areas are present at Hough Bay & Balevullin (Tiree) and Crossapol & Gunna (Coll). Distinct Scottish sub-communities (SD8d and SD8e) have the largest extents and are closely associated with transitions from SD6 and SD7 types (notably the provisional SD7?f sub-community), between themselves (SD8d/e), SD17 slack, SD12 acidic grassland and H11 dune heath. Much of this grassland is used for stock grazing and some sites show evidence of semi-improvement (SD8 SI). In addition to variation associated with different habitat trends and grazing impact, there is geographical variation to produce the SD8d and SD8e machair grasslands of western and northern Scotland. In short, SD8 types are part of a complex and it must be stressed that all variability might not be covered by current NVC types. The NVC account (Rodwell in prep.) stresses the complexity of SD8 types and illustrates the uncertain phytosociological affinities of the group. It deserves detailed examination on a GB scale to clarify relationships.

SD8a Typical sub-community

This is a southern type, reaching higher latitudes on the east coast of Scotland (Figure 8.3a). It tends to be poorer in species content and is perhaps less grazed than other sub-communities. It seems more restricted in its Scottish distribution than the NVC account portrays. It has a relatively low extent (52.4 ha) and suggests that undergrazing of SD8 grasslands is rare in Scotland.

SD8b *Luzula campestris* sub-community

This sub-community with field woodrush *L. campestris* is an eastern and southwestern type (Figure 8.3b) and is more species-rich. It probably reflects grazing on sands with low to moderate shell carbonate content, allowing indicators of leaching into the sward. It is extensive (350.2 ha) and large areas are found at Morrich More, Loch of Strathbeg and Barry Links on the east coast. Morrich More also contains a large expanse (54.3 ha) of SD8/SD12 transitional grassland with close affinities to the SD8b sub-community, making it the largest SD8b expanse in surveyed sites.

SD8c *Tortula ruralis* ssp. *ruraliformis* sub-community

This sub-community, marked by moderate to high quantities of the moss *Tortula ruralis*, is of low extent (46.5 ha) and restricted to west coast machairs (Figure 8.3c) which have beach inputs or, more usually, dune erosion as a sand supply. Local inundation thus provides the conditions for a *T. ruralis* moss sward. Its absence elsewhere suggests stability in fixed dune grasslands.

SD8d *Ranunculus acris - Bellis perennis* sub-community

This type is the most extensive SD8 sub-community in surveyed dunes (1013 ha) and it it has a clear geographical restriction to western and northern dune systems (Figure 8.3d). It is usually a grazed short sward which is very rich in species (20-30 species per quadrat is normal). The preferential species meadow buttercup *Ranunculus acris* and daisy *Bellis perennis* can achieve high covers, especially under heavy grazing by sheep and cattle. A notable feature of some samples is varied bryophyte content reflecting hyperoceanic conditions, including the moss *Calliergon cuspidatum* which is normally confined to dune slacks. The largest extents are found at Hough Bay & Balevullin (Tiree) and Crossapol & Gunna (Coll), though other major areas are present at Allasdale and Fuday (Western Isles), plus Dunnet Links and Bay of Quendale.

SD8e *Prunella vulgaris* sub-community

This sub-community is less extensive (388.9 ha) than SD8d but it has a similar distribution (Figure 8.3e) apart from absence in several Western Isles sites. It occupies wetter habitats (dune depressions and flat machair areas with some capillary influence from groundwater) and grades in several sites to SD17 dune slack. Intricate SD8d and SD8e mosaics are present in parts of the Tiree, Coll and Bay of Quendale sites, controlled by microtopography (hummock and hollow distribution). The SD8d preferentials are often present but damper conditions also allow self-heal

Prunella vulgaris to be present in almost all quadrats. Ardnave, Hough Bay & Balevullin, Crossapol & Gunna, and Bay of Quendale are all sites with large SD8e extents.

SD8 Transitions

Three transitions are present in several sites. Areas which are intermediate between SD8d and SD8e (SD8d/e) are extensive at Laggan Bay (Islay), Hough Bay & Balevullin (Tiree) (Figure 8.3f). Wet areas of SD8e can have moderate cover values for creeping bent-grass *Agrostis stolonifera* and common sedge *Carex nigra,* grading into true SD17 dune slack over short distances (SD8/17). These are extensive at Hough Bay & Balevullin and Crossapol & Gunna, but are more restricted elsewhere (Table 8.4, Figure 8.3g). Sites which are heavily grazed (and which also probably receive supplementary winter feed as hay cut from improved pasture) have crested dog's-tail grass *Cynosurus cristatus* and perennial ryegrass *Lolium perenne* as high frequency species. Several surveys have mapped these as semi-improved (Figure 8.3h) and such areas are extensive at Ardnave (Islay), Hough Bay & Balevullin (Tiree) and Dunnet Links. Three other SD8 transitions are not mapped here. Areas on the edge of dune systems close to cliffs, or around low rock headlands covered by sand (common in island sites), receive sea spray in higher quantities than the normal sward. Maritime cliff species (thrift *Armeria maritima,* sea plantain *Plantago maritima* and stag's horn plantain *P. coronopus*) usually occur in the SD8 sward but full maritime cliff vegetation is rarely developed - such areas are therefore recorded as SD8 types. A transition to acidic dune grassland (SD8/SD12) is extensive at Morrich More, and there is a small area of transition to dune heath (SD8/H11) at Laggan Bay (Table 8.4).

Table 8.5 SD8 *Festuca rubra - Galium verum* fixed dune community and associated transitions (SD8/SD17, SD8/H11, SD8/SD12, Semi-improved - SD8 SI) in surveyed Scottish dune systems. Areas in hectares. T = trace (generally target note). * = 1987 survey site, no discrimination possible between SD8 sub-communities.

	SITE	SD8	SD8a	SD8b	SD8c	SD8d	SD8e	SD8d/e	8/17	8/H11	8/12 SI	SD8	TOTAL
1	TORRS WARREN	-	-	0.04	-	-	-	-	-	-	-	-	0.04
2	TURNBERRY	-	0.21	2.63	-	-	-	-	-	-	-	-	2.84
3	TROON	-	-	24.81	-	-	-	-	-	-	-	-	24.81
4	LAGGAN BAY	-	14.94	27.19	2.84	2.03	2.03	23.22	0.41	1.22	-	-	73.88
5	ARDNAVE	-	16.53	-	6.61	4.20	19.50	-	0.15	-	-	70.82	117.81
6	KILLINALLAN	-	7.30	-	-	-	110.60	-	-	-	-	6.59	124.49
7	HOUGH BAY & BALEVULLIN	-	-	-	T	243.29	92.71	64.71	22.61	-	-	39.54	462.86
8	CROSSAPOL & GUNNA	-	-	-	-	312.04	71.37	-	34.17	-	-	13.36	430.94
9	VATERSAY	-	-	-	12.33	57.48	6.11	-	-	-	-	-	75.92
10	UIDH	-	-	-	-	1.85	1.59	-	-	-	-	-	3.44
11	TANGUSDALE	-	-	-	2.47	20.53	-	-	-	-	-	-	23.00
12	BORVE	-	-	-	1.20	38.01	-	-	-	-	-	-	39.21
13	ALLASDALE	-	-	-	-	59.18	-	-	-	-	-	-	59.18
14	CLEAT	-	-	-	-	7.97	-	-	-	-	-	-	7.97
15	FUDAY	-	-	-	-	115.72	-	-	-	-	-	-	115.72
16	KILPHEDER	-	-	-	-	20.17	0.08	-	-	-	-	-	20.25
17	HOWBEG	-	-	-	-	4.26	0.27	-	-	-	-	-	4.53
18	HOWMORE	-	-	-	-	3.30	-	-	-	-	-	-	3.30
19	DRIMSDALE	-	-	-	-	24.35	7.00	-	-	-	-	-	31.35
20	STILLIGARY	-	-	-	1.44	7.96	6.79	-	-	-	-	-	16.19
21	MIDDLEQUARTER	-	-	-	-	9.55	0.55	-	-	-	-	-	10.10
22	SOLLAS	-	-	-	19.58	28.50	5.28	-	-	-	-	2.99	56.35
23 *	SHEIGRA TO OLDSHOREMORE	51.85	-	-	-	-	-	-	1.11	-	-	-	52.96
24 *	AN FHARAID	55.40	-	-	-	-	-	-	-	-	-	-	55.40
25 *	SANDSIDE BAY	28.69	-	-	-	-	-	-	-	-	-	1.19	29.88
26 *	DUNNET LINKS	210.48	-	-	-	-	-	-	2.76	-	-	60.42	270.90
27	BAY OF QUENDALE QUENDALE	-	-	-	-	52.39	65.05	-	-	-	-	3.33	120.77
28	MORRICH MORE	-	-	107.90	-	-	-	-	-	-	54.30	T	162.20
29	LOCH OF STRATHBEG	-	7.46	69.05	-	-	-	-	1.87	-	-	5.13	83.51
30	SANDS OF FORVIE	-	2.46	8.26	-	-	-	-	-	-	-	-	10.72
31	FOVERAN	-	-	0.24	-	-	-	-	-	-	-	-	0.54
32	BARRY LINKS	-	T	71.56	-	-	-	-	-	-	-	-	71.56
33	TENTSMUIR	-	T	35.63	-	-	-	-	-	-	-	-	35.63
34	ABERLADY BAY	-	3.48	2.86	-	-	-	-	-	-	-	-	6.34
	TOTAL (hectares)	346.42	52.38	350.17	46.47	1012.78	388.93	87.93	63.08	1.22	54.30	203.37	2607.05

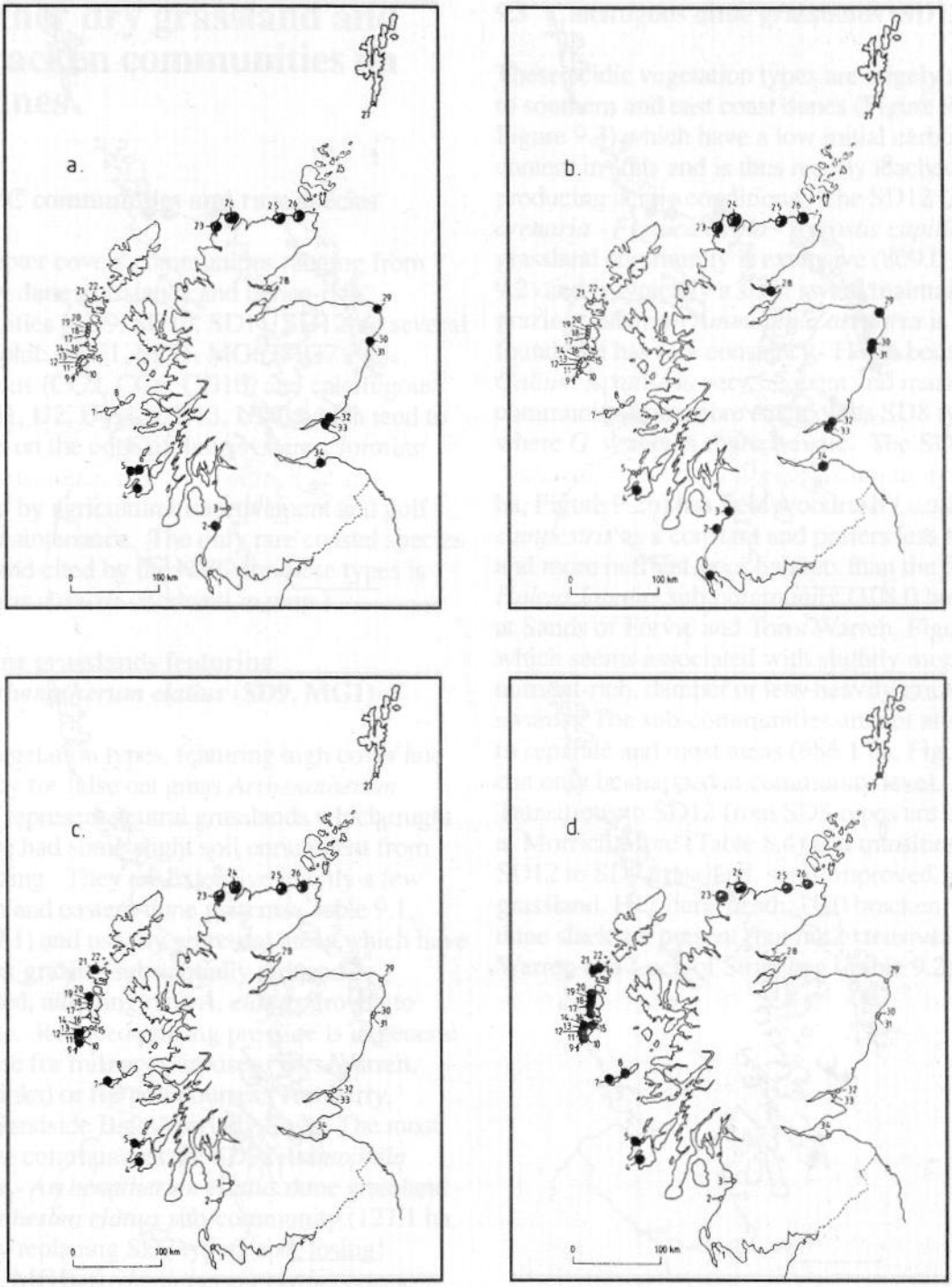


Figure 8.3 Distribution of SD8 *Festuca rubra - Galium verum* fixed dune sub-communities in surveyed Scottish dunes. a. SD8a Typical sub-community; b. SD8b *Luzula campestris* sub-community; c. SD8c *Tortula ruralis* ssp. *ruraliformis* sub-community; d. SD8d *Ranunculus acris - Bellis perennis* sub-community.

- ○ Site surveyed - community absent
- ● Site surveyed - community present
- ◒ 1987 survey site - SD8 sub-communities uncertain

Site names are listed in Table 1.1

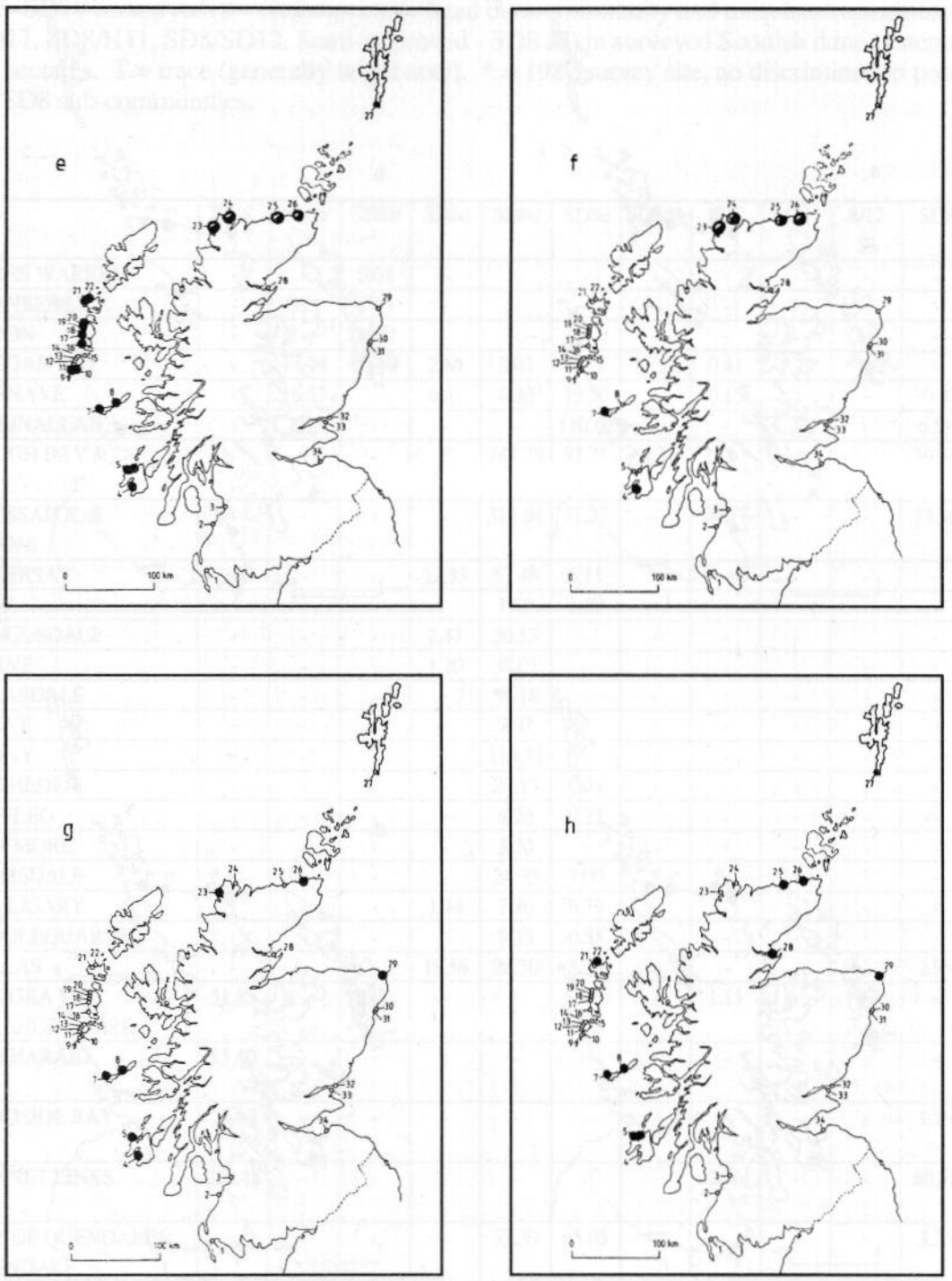


Figure 8.3 (continued) Distribution of SD8 *Festuca rubra - Galium verum* fixed dune sub-communities and selected transitions in surveyed Scottish dunes. e. SD8e *Prunella vulgaris* sub-community; f. SD8d/e transition; g. SD8/SD17 transition to dune slack; h. SD8 SI (semi-improved grassland) transition.

- ○ Site surveyed - community absent
- ● Site surveyed - community present
- ◒ 1987 survey site - SD8 sub-communities uncertain

Site names are listed in Table 1.1

9. Other dry grassland and bracken communities on dunes

9.1 NVC communities and rare species

This chapter covers communities ranging from other dry dune grasslands and lichen-rich communities (SD9, SD10, SD11, SD12) to several mesotrophic (MG1, MG5, MG6, MG7), calcicolous (CG2, CG6, CG10) and calcifugous types (U1, U2, U4, U5, U13, U20) which tend to be found on the edge of dune systems, forming either transition zones over bedrock or areas modified by agricultural improvement and golf course maintenance. The only rare coastal species in Scotland cited by the NVC for these types is *Astragalus danicus* (Rodwell in prep.).

9.2 Dune grasslands featuring *Arrhenatherum elatius* (SD9, MG1)

These vegetation types, featuring high cover and constancy for false oat grass *Arrhenatherum elatius,* represent neutral grasslands which might also have had some slight soil enrichment from past grazing. They are extensive in only a few southern and eastern dune systems (Table 9.1, Figure 9.1) and usually represent areas which have had stock grazing substantially reduced or eliminated, allowing rank *A. elatius* growth to dominate. Reduced grazing pressure is in general due to use for military purposes (Tors Warren, Barry Links) or for golf courses (Turnberry, Troon, Sandside Bay, Aberlady Bay). The most extensive communities are SD9a *Ammophila arenaria - Arrhenatherum elatius* dune grassland - *Arrhenatherum elatius* sub-community (127.1 ha, probably replacing SD7 types) and, losing marram, MG1a *Arrhenatherum elatius* coarse grassland - *Festuca rubra* sub-community (167.8 ha, probably replacing SD8 types). The SD9b *Geranium sanguineum* sub-community was not found in surveyed Scottish sites, though it is common in north-east England. The only other MG1 type is much less extensive (MG1e *Centaurea nigra* sub-community). The best examples of most types are found at Aberlady Bay in East Lothian.

9.3 Calcifugous dune grasslands (SD12)

These acidic vegetation types are largely restricted to southern and east coast dunes (Figure 9.2 and Figure 9.3) which have a low initial carbonate content in soils and is thus readily leached, producing acidic conditions. The SD12 *Carex arenaria - Festuca ovina - Agrostis capillaris* dune grassland community is extensive (809.0 ha, Table 9.2) and is typically a short sward maintained by grazing. Marram *Ammophila arenaria* is still found, but has low constancy. Heath bedstraw *Galium saxatile* is very frequent and marks this community from more calcicolous SD8 types where *G. verum* is characteristic. The SD12a *Anthoxanthum odoratum* sub-community (14.9 ha, Figure 9.2b) has field woodrush *Luzula campestris* as a constant and prefers less acidic and more nutrient-poor habitats than the SD12b *Holcus lanatus* sub-community (108.0 ha, mainly at Sands of Forvie and Torrs Warren, Figure 9.2c) which seems associated with slightly more nutrient-rich, damper or less-heavily grazed swards. The sub-communities are not always easy to separate and most areas (686.1 ha, Figure 9.2a) can only be mapped at community level. Transitions to SD12 from SD8 types are extensive at Morrich More (Table 8.4) and transitions from SD12 to SD9 grassland, semi-improved MG5/6 grassland, H11 dune heath, U20 bracken, SD17 dune slack are present (but not extensive) at Torrs Warren and Loch of Strathbeg (Table 9.2).

Table 9.1 SD9 *Ammophila arenaria - Arrhenatherum elatius* dune grassland and MG1 *Arrhenatherum elatius* coarse grassland in surveyed Scottish dune systems. Areas in hectares.

	SITE	SD9a	MG1a	MG1e	Totals
1	TORRS WARREN	32.24	4.30	-	36.54
2	TURNBERRY	5.57	-	0.63	6.20
3	TROON	-	1.25	-	1.25
4	LAGGAN BAY	-	-	-	-
5	ARDNAVE	-	-	-	-
6	KILLINALLAN	-	-	-	-
7	HOUGH BAY & BALEVULLIN	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-
9	VATERSAY	-	-	-	-
10	UIDH	-	-	-	-
11	TANGUSDALE	-	-	-	-
12	BORVE	-	-	-	-
13	ALLASDALE	-	-	-	-
14	CLEAT	-	-	-	-
15	FUDAY	-	-	-	-
16	KILPHEDER	-	-	-	-
17	HOWBEG	-	-	-	-
18	HOWMORE	-	-	-	-
19	DRIMSDALE	-	-	-	-
20	STILLIGARY	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-
22	SOLLAS	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	-	-
24	AN FHARAID	-	-	-	-
25	SANDSIDE BAY	-	-	12.07	12.07
26	DUNNET LINKS	23.71	-	-	-
27	BAY OF QUENDALE	-	-	-	-
28	MORRICH MORE	-	-	-	-
29	LOCH OF STRATHBEG	-	-	-	-
30	SANDS OF FORVIE	-	3.16	-	3.16
31	FOVERAN	0.36	-	-	0.36
32	BARRY LINKS	21.20	21.20	-	42.40
33	TENTSMUIR	-	0.30	-	0.30
34	ABERLADY BAY	44.00	137.60	-	181.60
	Totals (hectares)	127.08	167.81	12.70	307.59

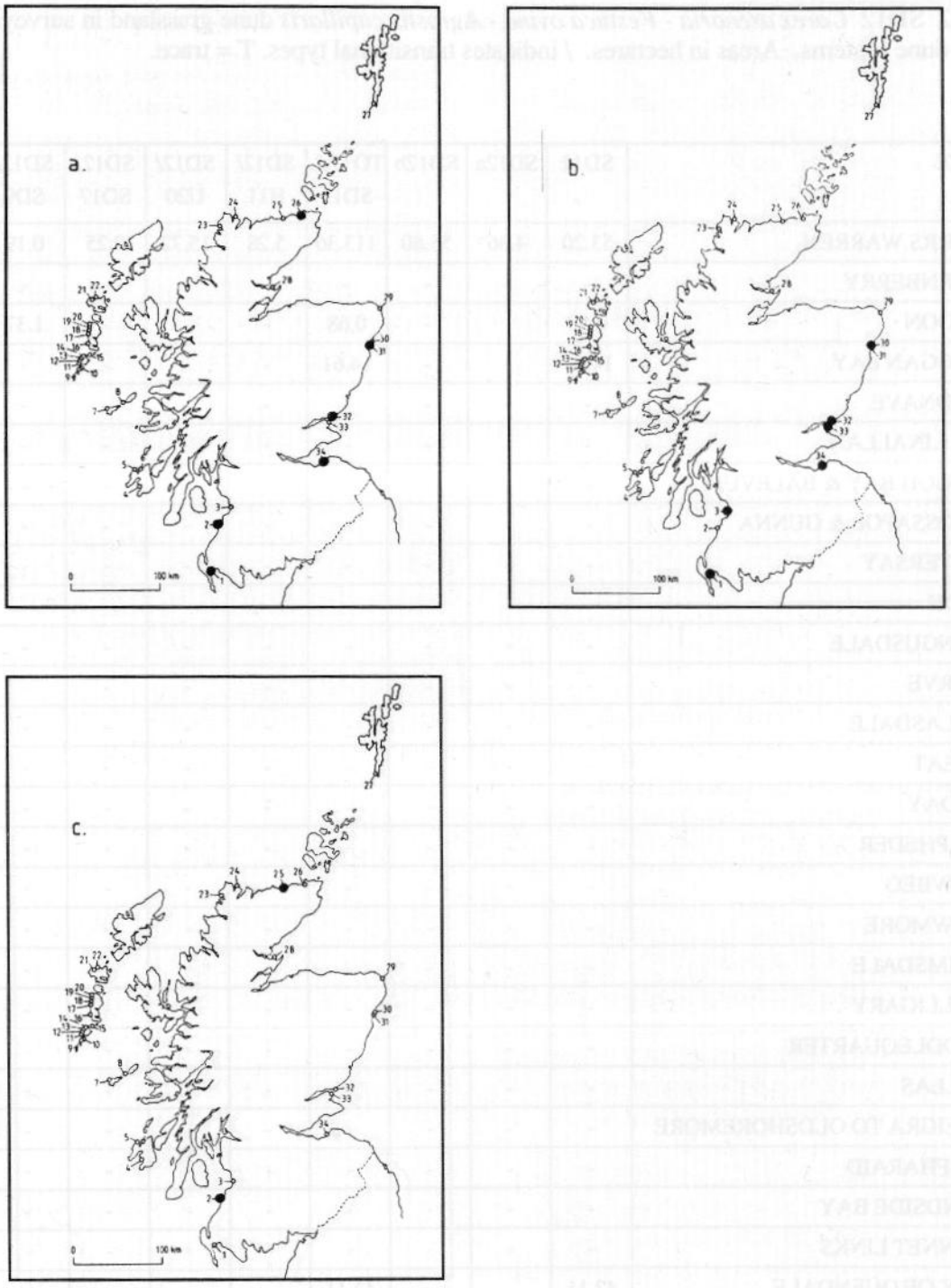


Figure 9.1 Distribution of SD9 *Ammophila arenaria - Arrhenatherum elatius* dune grassland and MG1 *Arrhenatherum elatius* coarse grassland in surveyed Scottish sites. a. SD9a *Arrhenatherum elatius* sub-community; b. MG1a *Festuca rubra* sub-community; c. MG1e *Centaurea nigra* sub-community.

- ○ Site surveyed - community absent
- ● Site surveyed - community present

Site names are listed in Table 1.1

Table 9.2 SD12 *Carex arenaria - Festuca ovina - Agrostis capillaris* dune grassland in surveyed Scottish dune systems. Areas in hectares. / indicates transitional types. T = trace.

	SITE	SD12	SD12a	SD12b	TOTAL SD12	SD12/ H11	SD12/ U20	SD12/ SD17	SD12/ SD9	SD12/ MG5
1	TORRS WARREN	53.20	4.36	55.80	113.36	5.28	15.72	0.25	0.19	-
2	TURNBERRY	-	-	-	-	-	-	-	-	-
3	TROON	0.68	-	-	0.68	-	-	-	1.37	-
4	LAGGAN BAY	14.61	-	-	14.61	-	-	-	-	-
5	ARDNAVE	-	-	-	-	-	-	-	-	-
6	KILLINALLAN	-	-	-	-	-	-	-	-	-
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-	-	-	-	-	-
9	VATERSAY	-	-	-	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-	-	-	-	-
12	BORVE	-	-	-	-	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-	-	-	-	-
14	CLEAT	-	-	-	-	-	-	-	-	-
15	FUDAY	-	-	-	-	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-	-	-	-	-
17	HOWBEG	-	-	-	-	-	-	-	-	-
18	HOWMORE	-	-	-	-	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-	-	-	-	-
20	STILLIGARY	-	-	-	-	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-	-	-	-	-
22	SOLLAS	-	-	-	-	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	-	-	-	-	-	-	-
24	AN FHARAID	-	-	-	-	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	-	-	-	-	-	-
27	BAY OF QUENDALE	42.11	-	-	42.11	-	-	-	-	-
28	MORRICH MORE	54.30	-	-	54.30	-	-	-	-	-
29	LOCH OF STRATHBEG	8.40	-	-	8.40	-	-	1.86	-	0.93
30	SANDS OF FORVIE	17.48	T	52.00	69.48	-	-	-	-	-
31	FOVERAN	9.98	9.89	0.10	19.97	2.72	-	-	-	-
32	BARRY LINKS	285.24	-	-	285.24	-	-	-	-	-
33	TENTSMUIR	190.31	-	-	190.31	-	-	-	-	-
34	ABERLADY BAY	9.82	0.62	0.10	10.54	-	-	-	-	-
	Totals	686.13	14.87	108.00	809.00	8.00	15.72	2.11	1.56	0.93

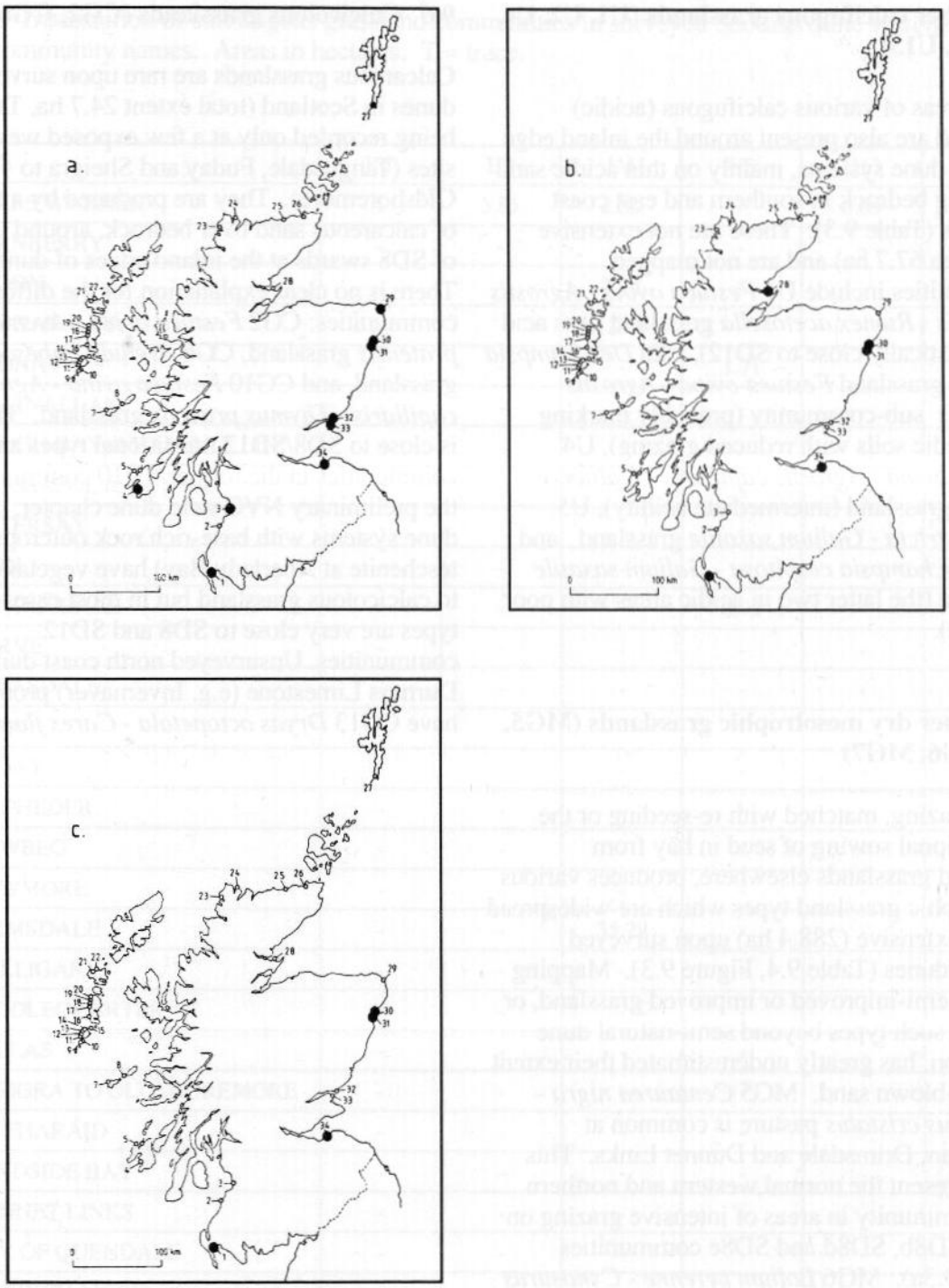


Figure 9.2 Distribution of SD12 *Carex arenaria - Festuca ovina - Agrostis capillaris* dune grassland community in surveyed Scottish dunes. a. SD12 undifferentiated community; b. SD12a *Anthoxanthum odoratum* sub-community; c. SD12b *Holcus lanatus* sub-community.

- ○ Site surveyed - community absent
- ● Site surveyed - community present

Site names are listed in Table 1.1

9.4 Other calcifugous grasslands (U1, U2, U4, U5, U13)

Small areas of various calcifugous (acidic) grassland are also present around the inland edge of some dune systems, mainly on thin acidic sand overlying bedrock in southern and east coast locations (Table 9.3). These are not extensive (total area 67.7 ha) and are not mapped. Communities include U1 *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland (less acid and floristically close to SD12), U2a *Deschampsia flexuosa* grassland *Festuca ovina - Agrostis capillaris* sub-community (probably marking more acidic soils with reduced grazing), U4 *Festuca ovina - Agrostis capillaris - Galium saxatile* grassland (intermediate acidity), U5 *Nardus stricta - Galium saxatile* grassland and U13 *Deschampsia cespitosa - Galium saxatile* grassland (the latter two in acidic areas with poor drainage).

9.5 Other dry mesotrophic grasslands (MG5, MG6, MG7)

Stock grazing, matched with re-seeding or the unintentional sowing of seed in hay from improved grasslands elsewhere, produces various mesotrophic grassland types which are widespread but not extensive (288.4 ha) upon surveyed Scottish dunes (Table 9.4, Figure 9.3). Mapping only as semi-improved or improved grassland, or ignoring such types beyond semi-natural dune vegetation, has greatly underestimated their extent on wind-blown sand. MG5 *Centaurea nigra - Cynosurus cristatus* pasture is common at Killinallan, Drimsdale and Dunnet Links. This may represent the normal western and northern coast community in areas of intensive grazing on former SD8b, SD8d and SD8e communities (Figure 9.3a). MG6 *Lolium perenne - Cynosurus cristatus* pasture is infrequent (Figure 9.3b) and is only extensive at Dunnet Links. MG7 *Lolium perenne* ley is only extensive on the east coast (Loch of Strathbeg, Sands of Forvie, Figure 9.3c). The latter two communities are produced by re-seeding, either for agricultural improvement or for golf courses and amenity grassland. Wet mesotrophic grasslands are also found on dunes but these are covered in Chapter 10.

9.6 Calcicolous grasslands (CG2, CG6, CG10)

Calcareous grasslands are rare upon surveyed dunes in Scotland (total extent 24.7 ha, Table 9.5), being recorded only at a few exposed west coast sites (Tangusdale, Fuday and Sheigra to Oldshoremore). They are produced by a thin layer of calcareous sand over bedrock, around the edges of SD8 swards at the inland edges of dunes. There is no clear explanation for the different communities: CG2 *Festuca ovina - Avenula pratensis* grassland, CG6 *Avenula pubescens* grassland, and CG10 *Festuca ovina - Agrostis capillaris - Thymus praecox* grassland. The latter is close to SD8/SD12 transitional types and sub-communities in the former SD10 community of the preliminary NVC sand dune chapter. Some dune systems with base-rich rock outcrops (e.g. teschenite at Aberlady Bay) have vegetation akin to calcicolous grassland but in most cases such types are very close to SD8 and SD12 communities. Unsurveyed north coast dunes over Durness Limestone (e.g. Invernaver) probably have CG13 *Dryas octopetala - Carex flacca* heath.

Table 9.3 Distribution of calcifugous grassland communities in surveyed Scottish dune systems. See text for community names. Areas in hectares. T = trace.

	SITE	U1	U2	U4	U5	U13	Totals
1	TORRS WARREN	T	5.85	2.68	-	0.89	9.42
2	TURNBERRY	-	-	-	-	-	-
3	TROON	-	-	2.94	-	-	2.94
4	LAGGAN BAY	-	-	12.80	-	-	12.80
5	ARDNAVE	-	-	-	1.71	-	1.71
6	KILLINALLAN	-	-	-	-	-	-
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-	-	-
9	VATERSAY	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-
11	TANGUSDALE	-	-	-	0.93	-	0.93
12	BORVE	-	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-	-
14	CLEAT	-	-	-	-	-	-
15	FUDAY	-	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-	-
17	HOWBEG	-	-	-	-	-	-
18	HOWMORE	-	-	-	-	-	-
19	DRIMSDALE	-	-	35.29	-	-	35.29
20	STILLIGARY	-	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-	-
22	SOLLAS	-	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	-	-	-	-
24	AN FHARAID	-	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	-	-	-
27	BAY OF QUENDALE	-	-	-	-	-	-
28	MORRICH MORE	-	-	-	-	-	-
29	LOCH OF STRATHBEG	-	-	-	3.73	-	3.73
30	SANDS OF FORVIE	-	T	-	-	-	T
31	FOVERAN	-	-	-	-	-	-
32	BARRY LINKS	-	-	-	-	-	-
33	TENTSMUIR	-	-	-	-	-	-
34	ABERLADY BAY	-	0.90	-	-	-	0.90
	Totals	T	6.75	53.71	6.37	0.89	67.72

Table 9.4 Other dry mesotrophic grasslands on surveyed Scottish dune systems. Areas in hectares.

	SITE	MG5	MG6	MG7	Totals
1	TORRS WARREN	-	-	0.32	0.32
2	TURNBERRY	-	-	-	-
3	TROON	-	-	-	-
4	LAGGAN BAY	-	-	-	-
5	ARDNAVE	3.90	T	T	3.90
6	KILLINALLAN	25.67	6.09	-	31.76
7	HOUGH BAY & BALEVULLIN	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-
9	VATERSAY	-	-	-	-
10	UIDH	-	-	-	-
11	TANGUSDALE	-	-	-	-
12	BORVE	-	-	-	-
13	ALLASDALE	-	-	-	-
14	CLEAT	-	-	-	-
15	FUDAY	-	-	-	-
16	KILPHEDER	-	2.07	-	2.07
17	HOWBEG	-	-	-	-
18	HOWMORE	1.65	-	-	1.65
19	DRIMSDALE	24.36	-	-	24.36
20	STILLIGARY	2.07	-	-	2.07
21	MIDDLEQUARTER	2.75	-	-	2.75
22	SOLLAS	1.90	-	2.71	4.61
23	SHEIGRA TO OLDSHOREMORE	-	-	1.34	1.34
24	AN FHARAID	-	-	0.81	0.81
25	SANDSIDE BAY	-	-	-	-
26	DUNNET LINKS	94.36	39.54	-	133.90
27	BAY OF QUENDALE	-	-	-	-
28	MORRICH MORE	-	-	-	-
29	LOCH OF STRATHBEG	-	-	20.99	20.99
30	SANDS OF FORVIE	-	-	56.75	56.75
31	FOVERAN	-	-	1.11	1.11
32	BARRY LINKS	-	-	-	-
33	TENTSMUIR	-	-	-	-
34	ABERLADY BAY	-	-	-	-
	Totals	156.66	47.70	84.03	288.39

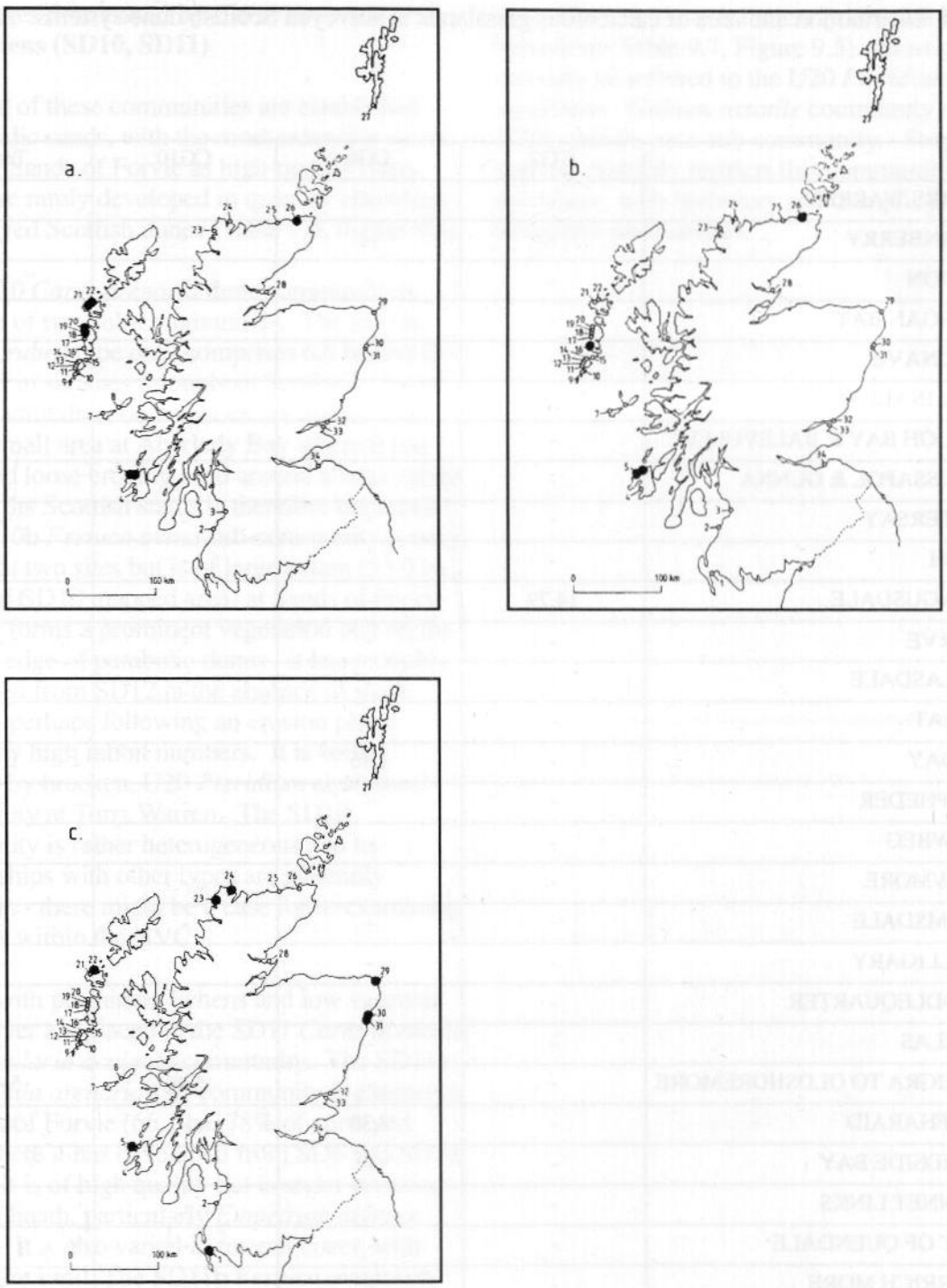


Figure 9.3 Distribution of selected mesotrophic grasslands (MG5, MG6, MG7) in surveyed Scottish dune systems. a. MG5 *Centaurea nigra - Cynosurus cristatus* pasture; b. MG6 *Lolium perenne - Cynosurus cristatus* pasture; c. MG7 *Lolium perenne* leys.

○ Site surveyed - community absent

● Site surveyed - community present

Site names are listed in Table 1.1

Table 9.5 Distribution and area of calcicolous grasslands in surveyed Scottish dune systems. Areas in hectares.

	SITE	CG2	CG6	CG10	Totals
1	TORRS WARREN	-	-	-	-
2	TURNBERRY	-	-	-	-
3	TROON	-	-	-	-
4	LAGGAN BAY	-	-	-	-
5	ARDNAVE	-	-	-	-
6	KILLINALLAN	-	-	-	-
7	HOUGH BAY & BALEVULLIN	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-
9	VATERSAY	-	-	-	-
10	UIDH	-	-	-	-
11	TANGUSDALE	14.79	-	-	14.79
12	BORVE	-	-	-	-
13	ALLASDALE	-	-	-	-
14	CLEAT	-	-	-	-
15	FUDAY	-	1.16	-	1.16
16	KILPHEDER	-	-	-	-
17	HOWBEG	-	-	-	-
18	HOWMORE	-	-	-	-
19	DRIMSDALE	-	-	-	-
20	STILLIGARY	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-
22	SOLLAS	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	5.44	5.44
24	AN FHARAID	-	3.30	-	3.30
25	SANDSIDE BAY	-	-	-	-
26	DUNNET LINKS	-	-	-	-
27	BAY OF QUENDALE	-	-	-	-
28	MORRICH MORE	-	-	-	-
29	LOCH OF STRATHBEG	-	-	-	-
30	SANDS OF FORVIE	-	-	-	-
31	FOVERAN	-	-	-	-
32	BARRY LINKS	-	-	-	-
33	TENTSMUIR	-	-	-	-
34	ABERLADY BAY	-	-	-	-
	Totals	14.79	4.46	5.44	24.69

9.7 Dunes dominated by *Carex arenaria* and lichens (SD10, SD11)

The bulk of these communities are established upon acidic sands, with the most extensive stands found at Sands of Forvie as high-quality types which are rarely developed in quantity elsewhere in surveyed Scottish dunes (Table 9.6, Figure 9.4).

The SD10 *Carex arenaria* dune community is made up of two sub-communities. The SD10a *Festuca rubra* type only comprises 6.6 ha and is scattered in six sites throughout Scotland. Apart from quadrat data, descriptions are absent apart from a small area at Aberlady Bay where it has colonised loose eroding sand around a large rabbit warren. Its Scottish status is therefore uncertain. The SD10b *Festuca ovina* sub-community is only present at two sites but is of large extent (53.0 ha, 98.6% of SD10 mapped area) at Sands of Forvie where it forms a prominent vegetation belt on the western edge of parabolic dunes - it has probably developed from SD12 in the absence of stock grazing, perhaps following an erosion phase caused by high rabbit numbers. It is being invaded by bracken, U20 *Pteridium aquilinum* community at Torrs Warren. The SD10 community is rather heterogeneous and its relationships with other types are generally uncertain - there might be a case for re-examining its status within the NVC.

Stands with prominent lichens and low vascular plant cover are placed in the SD11 *Carex arenaria - Cornicularia aculeata* community. The SD11a *Ammophila arenaria* sub-community is extensive at Sands of Forvie (66.1 ha, 78% of surveyed area) where it has developed from SD6 and SD7a dunes. It is of high quality but is under invasion by dune heath, particularly *Empetrum nigrum nigrum*. It is also varied in overall cover, with much bare sand. The SD11b *Festuca ovina* sub-community is recorded for Tentsmuir but quadrat and map information are insufficient to split it from SD11a. It is therefore estimated at half (15.1 ha) SD11 map area.

9.8 Bracken communities on dunes (U20, W25)

Bracken *Pteridium aquilinum* is uncommon on Scottish dunes (171.3 ha) and is only extensive at Torrs Warren where it is clearly invasive in behaviour (Table 9.7, Figure 9.5). Most stands can only be referred to the U20 *Pteridium aquilinum - Galium saxatile* community or to the U20c species-poor sub-community. Stock grazing probably restricts this community elsewhere, with herbivory and trampling operating as control mechanisms.

Table 9.6 SD10 *Carex arenaria* dune community and SD11 *Carex arenaria - Cornicularia aculeata* dune community in surveyed Scottish dune systems. Areas in hectares.

	SITE	SD10a	SD10b	TOTAL SD10	SD10/ U20	SD11a	SD11b	TOTAL SD11
1	TORRS WARREN	1.04	0.76	1.80	13.68	3.12	-	3.12
2	TURNBERRY	-	-	-	-	-	-	-
3	TROON	-	-	-	-	-	-	-
4	LAGGAN BAY	-	-	-	-	-	-	-
5	ARDNAVE	-	-	-	-	-	-	-
6	KILLINALLAN	-	-	-	-	-	-	-
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-	-	-	-
9	VATERSAY	-	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-	-	-
12	BORVE	-	-	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-	-	-
14	CLEAT	-	-	-	-	-	-	-
15	FUDAY	-	-	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-	-	-
17	HOWBEG	-	-	-	-	-	-	-
18	HOWMORE	-	-	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-	-	-
20	STILLIGARY	-	-	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-	-	-
22	SOLLAS	-	-	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	0.22	-	0.22	-	-	-	-
24	AN FHARAID	0.08	-	0.08	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	-	-	-	-
27	BAY OF QUENDALE	-	-	-	-	-	-	-
28	MORRICH MORE	-	-	-	-	-	-	-
29	LOCH OF STRATHBEG	3.27	-	-	-	-	-	-
30	SANDS OF FORVIE	-	53.05	53.05	-	66.15	-	66.15
31	FOVERAN	1.77	-	1.77	-	0.33	-	0.33
32	BARRY LINKS	-	-	-	-	-	-	-
33	TENTSMUIR	-	-	-	-	15.12	15.12	30.24
34	ABERLADY BAY	0.20	-	0.20	-	-	-	-
	Totals	6.58	53.81	60.39	13.68	84.72	15.12	99.84

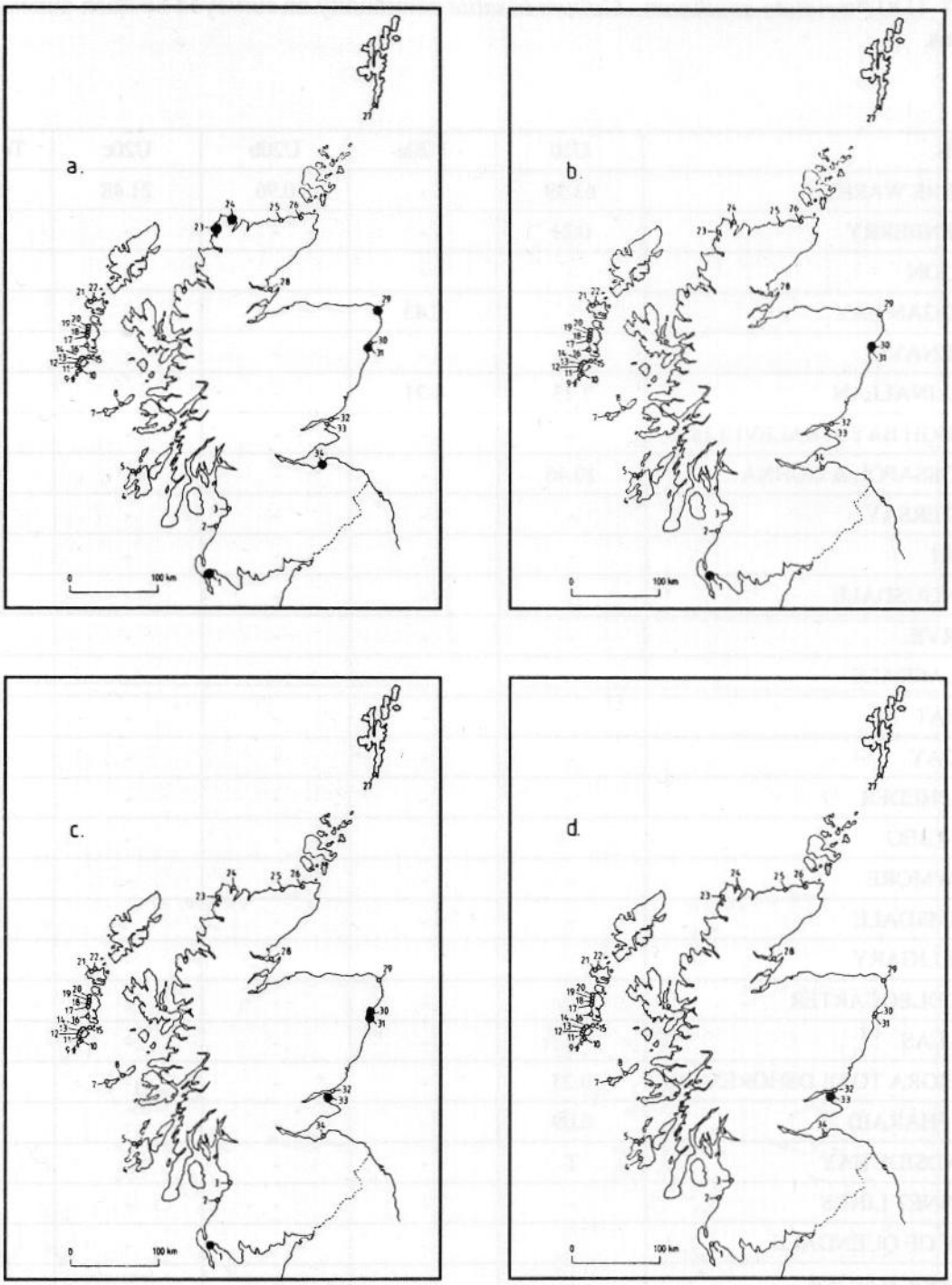


Figure 9.4 Distribution of SD10 *Carex arenaria* dune community and SD11 *Carex arenaria - Cornicularia aculeata* dune community in surveyed Scottish sites. a. SD10a *Festuca rubra* sub-community; b. SD10b *Festuca ovina* sub-community; c. SD11a *Ammophila arenaria* sub-community; d. SD11b *Festuca ovina* sub-community.

○ Site surveyed - community absent

● Site surveyed - community present

Site names are listed in Table 1.1

Table 9.7 U20 *Pteridium aquilinum - Galium saxatile* community on surveyed Scottish dunes. Areas in hectares.

	SITE	U20	U20a	U20b	U20c	Total U20
1	TORRS WARREN	63.39	-	0.96	21.48	85.83
2	TURNBERRY	0.21	-	-	-	0.21
3	TROON	-	-	-	-	-
4	LAGGAN BAY	-	2.43	-	-	2.43
5	ARDNAVE	-	-	-	-	-
6	KILLINALLAN	1.13	4.21	-	-	5.34
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-
8	CROSSAPOL & GUNNA	10.46	-	-	-	10.46
9	VATERSAY	-	-	-	-	-
10	UIDH	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-
12	BORVE	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-
14	CLEAT	-	-	-	-	-
15	FUDAY	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-
17	HOWBEG	-	-	-	-	-
18	HOWMORE	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-
20	STILLIGARY	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-
22	SOLLAS	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	0.23	-	-	-	0.23
24	AN FHARAID	0.09	-	-	-	0.09
25	SANDSIDE BAY	T	-	-	-	T
26	DUNNET LINKS	-	-	-	-	-
27	BAY OF QUENDALE	-	-	-	-	-
28	MORRICH MORE	-	-	-	-	-
29	LOCH OF STRATHBEG	-	-	-	-	-
30	SANDS OF FORVIE	-	-	-	-	-
31	FOVERAN	-	-	-	-	-
32	BARRY LINKS	-	-	-	-	-
33	TENTSMUIR	-	-	-	-	-
34	ABERLADY BAY	0.47	-	-	-	0.4
	Totals	75.77	6.64	0.96	21.48	105.06

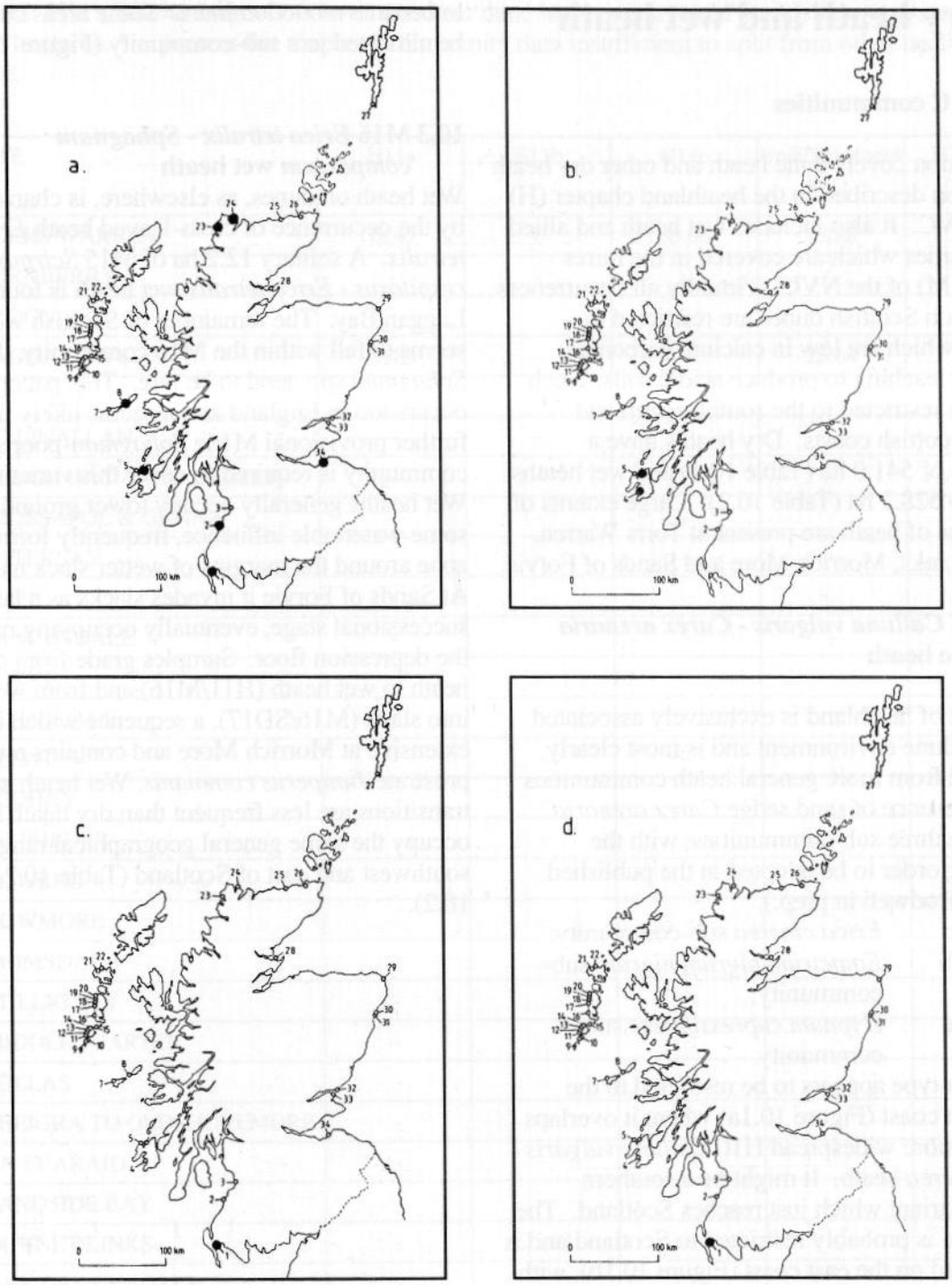


Figure 9.5 Distribution of U20 *Pteridium aquilinum - Galium saxatile* community in surveyed Scottish dunes. a. Undifferentiated U20 community. b. U20a *Anthoxanthum odoratum* sub-community; c. U20b *Vaccinium myrtillus* sub-community; d. U20c Species-poor sub-community.

○ Site surveyed - community absent

● Site surveyed - community present

Site names are listed in Table 1.1

10. Dry heath and wet heath

10.1 NVC communities

This section covers dune heath and other dry heath vegetation described in the heathland chapter (H) of the NVC. It also includes wet heath and allied communities which are covered in the mires chapter (M) of the NVC. Virtually all occurrences of heath on Scottish dunes are restricted to systems which are low in calcium carbonate, allowing leaching to produce acidic soils. Such sands are restricted to the southwestern and eastern Scottish coasts. Dry heaths have a coverage of 541.0 ha (Table 10.1) and wet heaths extend to 528.2 ha (Table 10.2). Large extents of both types of heath are present at Torrs Warren, Dunnet Links, Morrich More and Sands of Forvie.

10.2 H11 *Calluna vulgaris - Carex arenaria* dune heath

This type of heathland is exclusively associated with the dune environment and is most clearly separated from more general heath communities by the presence of sand sedge *Carex arenaria*. There are three sub-communities, with the following order to be adopted in the published chapter (Rodwell in prep.):

- H11a *Erica cinerea* sub-community;
- H11b *Empetrum nigrum nigrum* sub-community;
- H11c *Hypnum cupressiforme* sub-community.

The H11a type appears to be restricted to the southwest coast (Figure 10.1a) where it overlaps with the more widespread H10 *Calluna vulgaris - Erica cinerea* heath. It might be a southern oceanic variant which just reaches Scotland. The H11b type is probably restricted to Scotland and is widespread on the east coast (Figure 10.1b), with a very large extent at Sands of Forvie where crowberry *Empetrum nigrum* is invasive, forming circular patches in SD11 vegetation as the first stage in transition to heath. The H11c type has a similar distribution to H11b (Figure 10.1c) and is varied in moss composition - *Hypnum cupressiforme* is present infrequently and is often replaced by *Pleurozium schreberi* and *Hylocomium splendens*. It could be only a late succession stage to east coast dune heaths in which ling *Calluna vulgaris* supplants *E. nigrum* to become monodominant. Some areas could not be allocated to a sub-community (Figure 10.1d).

10.3 M16 *Erica tetralix - Sphagnum compactum* wet heath

Wet heath on dunes, as elsewhere, is characterised by the occurrence of cross-leaved heath *Erica tetralix*. A solitary 12.2 ha of M15 *Scirpus cespitosus - Erica tetralix* wet heath is found at Laggan Bay. The remainder of Scottish wet heath seems to fall within the M16 community, though *Sphagnum* spp. tend to be rare. This pattern occurs too in England and it seems likely that a further provisional M16e *Sphagnum*-poor sub-community is required to cover this variation. Wet heaths generally occupy lower ground under some watertable influence, frequently forming a zone around the margins of wetter slack habitats. At Sands of Forvie it invades slacks as a late successional stage, eventually occupying most of the depression floor. Samples grade from dry heath to wet heath (H11/M16) and from wet heath into slack (M16/SD17), a sequence which is extensive at Morrich More and contains much prostrate *Juniperus communis*. Wet heath and its transitions are less frequent than dry heath but occupy the same general geographical range in the southwest and east of Scotland (Table 10.2, Figure 10.2).

Table 10.1 H11 *Calluna vulgaris - Carex arenaria* dune heath in surveyed Scottish dune systems. Areas in hectares. * = present but map and community data insufficient to split from other heathland. T = trace.

	SITE	H11a	H11b	H11c	Undifferentiated H11	H11 Total
1	TORRS WARREN	78.47	-	35.08	53.88	167.43
2	TURNBERRY	-	-	-	-	-
3	TROON	-	-	-	-	-
4	LAGGAN BAY	9.42	-	-	26.64	36.06
5	ARDNAVE	-	-	-	-	-
6	KILLINALLAN	-	-	-	-	-
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-	-
9	VATERSAY	-	-	-	-	-
10	UIDH	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-
12	BORVE	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-
14	CLEAT	-	-	-	-	-
15	FUDHAY	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-
17	HOWBEG	-	-	-	-	-
18	HOWMORE	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-
20	STILLIGARY	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-
22	SOLLAS	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	-	-	-
24	AN FHARAID	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-
26	DUNNET LINKS	-	25.98	-	-	25.98
27	BAY OF QUENDALE	-	-	-	-	-
28	MORRICH MORE	-	5.10	55.10	60.20	
29	LOCH OF STRATHBEG	-	-	-	-	-
30	SANDS OF FORVIE	-	210.95	*	-	210.95
31	FOVERAN	-	1.52	-	-	1.52
32	BARRY LINKS	-	*	26.94	-	26.94
33	TENTSMUIR	-	*	11.97	-	11.97
34	ABERLADY BAY	-	-	T	-	-
	Totals	87.89	243.55	129.09	80.52	541.05

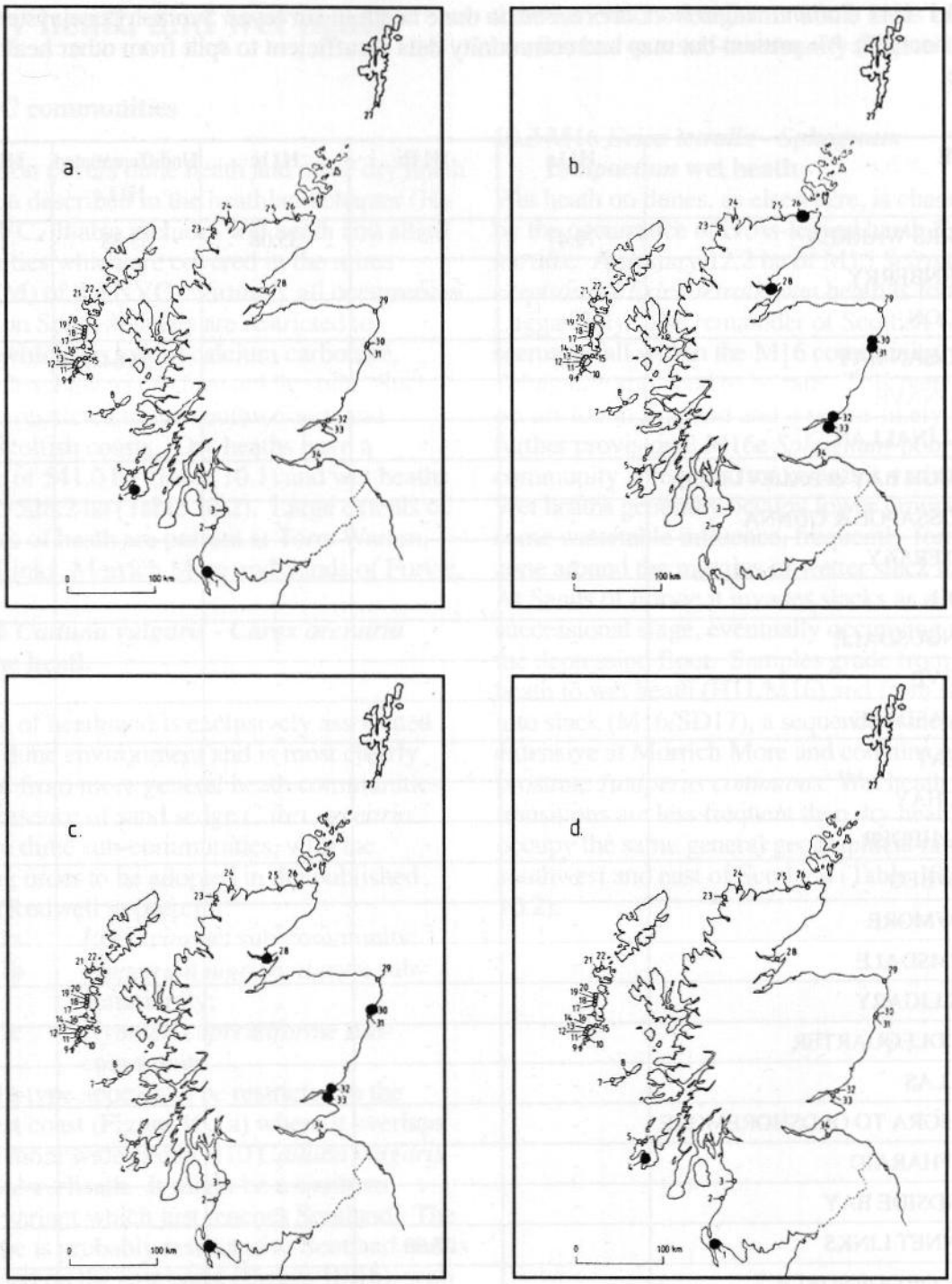


Figure 10.1 Distribution of H11 *Calluna vulgaris - Carex arenaria* dune heath in surveyed Scottish dunes. a. H11a *Erica cinerea* sub-community; b. H11b *Empetrum nigrum nigrum* sub-community; c. *Hypnum cupressiforme* sub-community; d. Undifferentiated H11 types.

○ Site surveyed - community absent
● Site surveyed - community present
Site names are listed in Table 1.1

Table 10.2 M15 *Scirpus cespitosus - Erica tetralix* wet heath, M16 *Erica tetralix - Sphagnum compactum* wet heath, and transitions in surveyed Scottish dune systems. Areas in hectares.

	SITE	M15	M16e	U20/M16	H11/M16	M16/SD17	M16/M23a	TOTAL all types
1	TORRS WARREN	-	11.80	4.64	24.56	-	8.98	49.98
2	TURNBERRY	-	-	-	-	-	-	-
3	TROON	-	-	-	-	-	-	-
4	LAGGAN BAY	12.20	5.47	-	-	-	5.47	23.14
5	ARDNAVE	-	-	-	-	-	-	-
6	KILLINALLAN	-	-	-	-	-	-	-
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-	-	-	-
9	VATERSAY	-	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-	-	-
12	BORVE	-	-	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-	-	-
14	CLEAT	-	-	-	-	-	-	-
15	FUDAY	-	-	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-	-	-
17	HOWBEG	-	-	-	-	-	-	-
18	HOWMORE	-	-	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-	-	-
20	STILLIGARY	-	-	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-	-	-
22	SOLLAS	-	-	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	4.26	-	-	-	-	4.26
24	AN FHARAID	-	-	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	51.08	-	-	51.08
27	BAY OF QUENDALE	-	-	-	-	-	-	-
28	MORRICH MORE	-	T	-	90.00	178.20	-	268.20
29	LOCH OF STRATHBEG	-	-	-	-	-	-	-
30	SANDS OF FORVIE	-	T	-	99.51	-	-	99.51
31	FOVERAN	-	-	-	-	-	-	-
32	BARRY LINKS	-	-	-	20.10	-	-	20.10
33	TENTSMUIR	-	-	-	11.97	-	-	11.97
34	ABERLADY BAY	-	-	-	-	-	-	-
	TOTALS	12.20	21.53	4.64	297.22	178.20	14.45	528.24

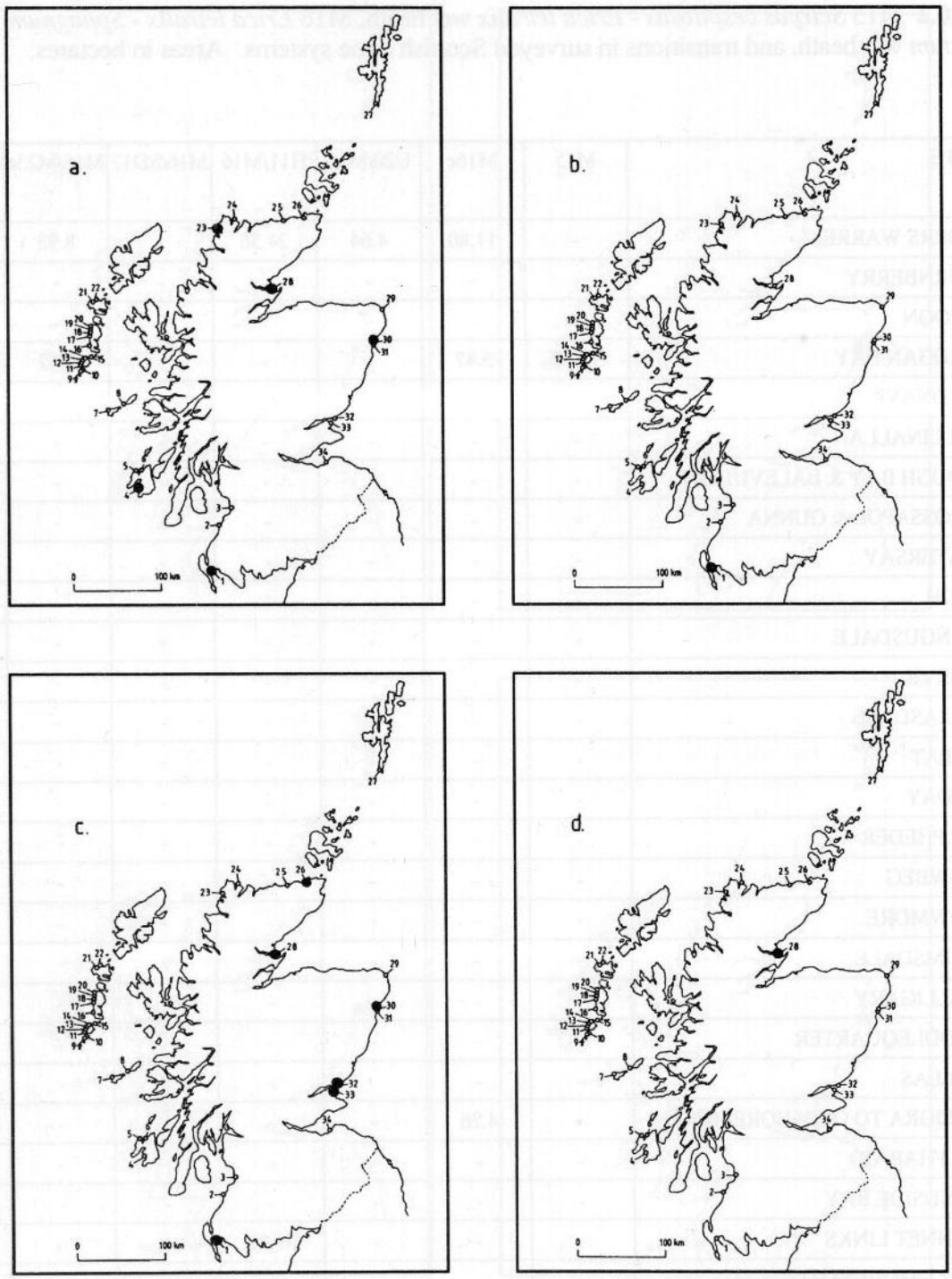


Figure 10.2 Distribution of M16 *Erica tetralix - Sphagnum compactum* wet heath and transitions in surveyed Scottish dune systems. a. M16e provisional *Sphagnum*-poor sub-community; b. bracken - wet heath (U20/M16) transition; c. dry heath - wet heath transition (H11/M16); d. wet heath - slack transition (M16/SD17).

○ Site surveyed - community absent
● Site surveyed - community present
Site names are listed in Table 1.1

11. Dune wetlands

11.1 NVC communities and rare species

Dune wetlands comprise dune slack communities (SD13, SD14, SD15, SD16, SD17 - Table 11.1), plus a wide range of mire (NVC M chapter - Table 11.2), swamp and tall-herb fen (NVC S chapter - Table 11.3), wet mesotrophic grassland types (NVC MG chapter - Table 11.4) and aquatic vegetation (NVC A chapter - Table 11.5). This diversity of types reflects the range of conditions in which dune wetland is established, including peatlands on the inner edge of many dunes and the swampy edges of open water in similar conditions. Curved sedge *Carex maritima* was found in slack conditions at Bay of Quendale and Baltic rush *Juncus balticus* is common in slacks of some east and north coast dunes.

11.2 Dune slack communities (SD13-SD17) and wet mesotrophic grassland

Scottish dunes have a poor range of slack communities, with only the SD17 *Potentilla anserina - Carex nigra* community widespread (Table 11.1). A careful selection of all quadrats failed to find more than one or two individual cases of SD13, SD14 and SD15 types (all at Torrs Warren). The SD16 *Salix repens - Holcus lanatus* community is extensive in the south east of Scotland (total area 133.3 ha), especially at Barry Links, but clear sub-communities are not present in Scottish quadrat data (Figure 11.1a). The SD17 community is poorly represented in the west and north of Scotland, area data suggesting that it is a southwest and east coast type in Scotland (Figure 11.1b) with a total extent of 202.6 ha. The SD17c *Caltha palustris* and SD17d *Hydrocotyle vulgaris - Ranunculus flammula* sub-communities are predominant types, though many samples cannot be differentiated below community level. Analysis by TWINSPAN of several wetland data sets suggests that the SD17 community is part of a moisture continuum from drier SD8e conditions to wetter *Carex nigra* poor fen (of uncertain NVC status, often recorded as a transition rather than a single community). This vegetation type is commoner in the west and north, together with samples close to MG11 *Festuca rubra - Agrostis stolonifera - Potentilla anserina* mesotrophic grassland (Figure 11.1c). Other wet mesotrophic grasslands show little pattern to their distribution (Table 11.4).

11.3 Mire (M) communities on sand dunes

A diverse set of mires (excluding M15 and M16 wet heath - see Chapter 10) is found on surveyed dunes (Table 11.2), with a total mire extent of 233.8 ha. Only one type is extensive - M23 *Juncus effusus/acutiflorus - Galium palustre* rush-pasture (156.5 ha). A wide range of types is found at two sites in particular, Torrs Warren and Killinallan. Both have sand overlying poorly-drained bedrock at the rear of the dune system, allowing mire types typical of adjoining land to occur in dune habitat. Such mires are a characteristic of Scottish dunes, reflecting their extent outwith dunes in a cool and moist climate.

11.4 Swamps and tall-herb fens on Scottish dunes

As with mires, a diverse set of swamp and fen types is present covering an area of 247.3 ha. The majority are of small extent and occupy the margins of open water. Some also occur in a transition zone to saltmarsh, notably in east coast dune systems as at Aberlady Bay. The most extensive true swamp is the S19 *Eleocharis palustris* community, followed by S4 *Phragmites australis* swamp. Tall-herb fens are poorly represented. Some western sites have yellow flag *Iris pseudacorus* and common sedge *Carex nigra* poor fen types which do not fit other NVC communities.

An examination of *I. pseudacorus* samples revealed a very diverse mix of associated wetland species and no clear environmental pattern apart from a reduction in diversity as *I. pseudacorus* cover increased. The species appears to invade a range of wetland types at random, introducing structural diversity and reducing species numbers by partial shading and litter accumulation, in some respects behaving as a wetland equivalent to bracken *Pteridium aquilinum*. It is now known that *I. pseudacorus* is common within several mire, swamp and mesotrophic grassland grasslands in Scotland and Ireland, a feature which is not emphasised in the NVC (Dr A.J.C. Malloch, personal communication).

The *Carex nigra* poor fen type is diverse and shows habitat gradations. It is particularly extensive in slacks at Morrich More (95.8 ha) on the east coast, in a species-rich form with frequent *Festuca rubra, Salix repens, Potentilla erecta, Festuca ovina, Molinia caerulea, Erica tetralix* and prostrate *Juniperus communis* (ssp. *alpina*) - see Table 12.2 (Group D). However, it is most frequent in the west (Figure 11.1d) and probably varies in composition according to degree of local wetness, ranging from SD17c and SD17d transitions to wetter species-poor stands which have high frequencies of *Agrostis stolonifera, Juncus articulatus, Holcus lanatus* and the moss *Calliergon cuspidatum*. Further analysis might suggest an additional slack or swamp NVC community to cover the variation represented in these common stands which, at present, is a prominent misfit.

11.5 Aquatic communities

Open water bodies are frequent in some large Scottish dune systems but were considered to be outside the scope of the survey and were thus not sampled thoroughly. Their origins are varied, ranging from kettlehole depressions at Sands of Forvie, to lochans developed in machair backslopes butting on to adjacent bedrock (e.g. Loch Bhasapol, Tiree), and to long narrow stretches of open water in old slacks on prograding dunes (Morrich More). Water margins allow swamp communities to develop and these merge into aquatic communities as water depth increases. The range of aquatic vegetation types recorded is low (Table 11.5) due to undersampling which prevents any conclusion on geographical pattern. Likewise, total extent of communities and open water (51.8 ha) is a major underestimate since large water bodies were generally excluded from area measurement (e.g. Loch of Strathbeg).

Table 11.1 Distribution of dune slack types in surveyed Scottish dunes. Areas in hectares. T = trace.

	SITE	SD13	SD14	SD15	SD16	SD17	TOTALS
1	TORRS WARREN	T	T	0.30	0.10	1.60	2.00
2	TURNBERRY	-	-	-	-	-	-
3	TROON	-	-	-	-	-	-
4	LAGGAN BAY	-	-	-	-	1.40	1.40
5	ARDNAVE	-	-	-	-	30.20	30.20
6	KILLINALLAN	-	-	-	1.00	1.80	2.80
7	HOUGH BAY & BALEVULLIN	-	-	-	-	6.50	6.50
8	CROSSAPOL & GUNNA	-	-	-	-	9.10	9.10
9	VATERSAY	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-	-
12	BORVE	-	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-	-
14	CLEAT	-	-	-	-	-	-
15	FUDAY	-	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-	-
17	HOWBEG	-	-	-	-	-	-
18	HOWMORE	-	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-	-
20	STILLIGARY	-	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-	-
22	SOLLAS	-	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	-	-	-	-
24	AN FHARAID	-	-	-	-	0.50	0.50
25	SANDSIDE BAY	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	T	T	T
27	BAY OF QUENDALE	-	-	-	-	11.30	11.30
28	MORRICH MORE	-	-	-	-	90.0	90.00
29	LOCH OF STRATHBEG	-	-	-	-	12.6	12.60
30	SANDS OF FORVIE	-	-	-	12.90	4.80	17.70
31	FOVERAN	-	-	-	0.10	4.10	4.20
32	BARRY LINKS	-	-	-	98.80	20.50	119.30
33	TENTSMUIR	-	-	-	20.40	3.80	24.20
34	ABERLADY BAY	-	-	-	-	4.40	4.40
	TOTALS	T	T	0.3	133.30	202.60	336.20

Table 11.2 Distribution of mire communities in surveyed Scottish sand dunes. Areas in hectares. T = trace. Trans. = transitional types. Site area totals exclude transitions.

	SITE	M3	M5	M6	M13	M14	M22	M23	M25	M26	M27	M28	M29	Trans.	Totals
1	TORRS WARREN	1.0	4.0	8.5	-	-	-	43.8	10.2	0.6	0.1	0.1	0.1	35.0	61.9
2	TURNBERRY	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	TROON	-	-	-	-	-	-	0.5	-	-	-	-	-	-	0.5
4	LAGGAN BAY	-	-	-	-	-	-	2.3	-	-	-	-	-	4.6	16.7
5	ARDNAVE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	KILLINALLAN	-	-	-	2.5	5.1	2.1	0.6	1.1	1.9	-	4.1	-	9.8	17.4
7	HOUGH BAY &	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BALEVULLIN														
8	CROSSAPOL &	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	GUNNA														
9	VATERSAY	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-	-	-	-	-	1.5	-	-	1.5	
12	BORVE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	CLEAT	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
15	FUDAY	-	-	-	-	-	-	-	-	-	-	T	-	-	T
16	KILPHEDER	-	-	-	-	-	-	0.9	-	-	1.5	1.8	-	6.5	4.2
17	HOWBEG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	HOWMORE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-	-	T	T	-	-	-	-	3.4	T
20	STILLIGARY	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	SOLLAS	-	-	-	-	-	-	-	-	-	-	0.7	-	-	0.7
23	SHEIGRA TO	-	-	-	-	-	-	0.3	7.7	-	-	-	-	5.5	8.0
	OLDSHOREMORE														
24	AN FHARAID	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	BAY OF QUENDALE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	MORRICH MORE	-	-	-	-	-	-	7.0	-	-	-	-	-	-	7.0
29	LOCH OF	-	-	-	-	-	-	1.9	-	-	-	-	-	-	1.9
	STRATHBEG														
30	SANDS OF FORVIE	-	-	-	-	-	-	28.6	2.1	-	-	-	-	-	30.7
31	FOVERAN	-	-	-	-	-	-	-	-	-	-	-	-		
32	BARRY LINKS	-	-	-	-	-	-	9.0	-	-	4.3	-	-	-	13.3
33	TENTSMUIR	-	-	-	-	-	-	61.6	-	-	-	-	-	-	61.6
34	ABERLADY BAY	-	-	-	-	-	-	-	-	-	16.3	-	-	-	16.3
	TOTALS	1.0	4.0	8.5	2.5	5.1	2.1	156.5	21.1	2.5	22.2	8.2	0.1	64.9	233.8

Table 11.3 Distribution of swamp and tall-herb fen communities in surveyed Scottish dune systems. Areas in hectares. T = trace. Trans. = transitional types. Site area totals exclude transitions.

	SITE	S4	S6	S8	S9	S10	S12	S14	S18	S19	S20	S21	S22	S27	S28	Iris nigra fen	Carex	Trans.	Totals
1	TORRS WARREN	-	-	-	2.2	0.1	0.1	-	-	0.2	-	2.4	T	1.8	0.3	-	0.5	1.0	7.6
2	TURNBERRY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
3	TROON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
4	LAGGAN BAY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	ARDNAVE	-	-	-	-	-	-	-	-	0.1	-	-	0.1	-	-	-	-	7.3	0.2
6	KILLINALLAN	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	0.6	0.3
7	HOUGH BAY &	-	-	-	-	-	-	-	-	-	-	-	T	-	-	T	-	-	T
	BALEVULLIN																		
8	CROSSAPOL &	-	-	-	-	-	-	-	-	-	-	-	T	-	-	T	-	-	T
	GUNNA																		
9	VATERSAY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	TANGUSDALE	1.0	-	-	-	0.5	-	-	-	0.2	-	-	-	-	-	0.6	-	-	2.3
12	BORVE	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	6.8	0.1
13	ALLASDALE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	-	0.8	4.0
14	CLEAT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	FUDAY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	1.7	1.0
16	KILPHEDER	0.5	-	-	-	0.7	-	-	-	0.5	1.7	-	-	0.1	-	6.5	12.9	6.8	22.9
17	HOWBEG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	-		
18	HOWMORE	-	-	-	-	T	-	-	-	T	1.5	-	-	-	-	-	1.0	4.3	1.5
19	DRIMSDALE	3.8	-	-	-	-	-	-	-	0.1	-	-	-	T	-	1.4	1.8	6.7	7.1
20	STILLIGARY	-	-	-	-	-	-	-	-	0.4	0.3	-	-	0.4	-	-	3.2	16.4	4.3
21	MIDDLEQUARTER	2.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	2.5	3.0
22	SOLLAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	7.3	1.5
23	SHEIGRA TO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	OLDSHOREMORE																		
24	AN FHARAID	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	2.8	-	7.4	3.8
27	BAY OF	-	-	-	-	-	-	-	-	-	-	-	T	-	-	T	-	-	T
	QUENDALE																		
28	MORRICH MORE	-	-	-	-	2.5	-	-	-	9.4	-	-	-	-	-	-	95.8	-	107.7
29	LOCH OF	1.4	-	0.5	1.4	0.5	-	-	-	0.5	-	-	-	-	0.9	-	1.9	7.0	7.1
	STRATHBEG																		
30	SANDS OF FORVIE	-	-	-	1.6	T	-	-	-	2.0	-	-	-	T	-	-	-	-	3.6
31	FOVERAN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	BARRY LINKS	2.1	-	-	-	-	-	-	-	-	-	-	-	-	1.1	-	-	-	3.2
33	TENTSMUIR	0.1	-	-	-	-	-	-	-	-	-	1.1	-	-	-	-	-	-	1.2
34	ABERLADY BAY	0.1	0.3	-	-	-	T	T	1.2	2.0	0.2	T	-	-	T	-	-	-	3.8
	TOTALS	11.9	0.3	0.5	5.2	4.3	0.1	0.3	1.2	15.5	3.7	3.5	0.1	2.3	3.3	15.3	119.7	77.8	247.3

Table 11.4 Distribution of wet mesotrophic grasslands in surveyed Scottish dune sites. Areas in hectares. T = trace.

	SITE	MG8	MG9	MG10	MG11	MG12	MG13	TOTALS
1	TORRS WARREN	-	-	T	T	T	T	T
2	TURNBERRY	-	-	-	-	-	-	-
3	TROON	-	-	-	-	-	-	-
4	LAGGAN BAY	-	-	-	-	-	-	-
5	ARDNAVE	T	-	-	1.71	-	-	1.71
6	KILLINALLAN	-	-	4.33	-	-	-	4.33
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-	-	T
8	CROSSAPOL & GUNNA	-	-	-	-	-	-	T
9	VATERSAY	-	-	-	0.94	-	-	0.94
10	UIDH	-	-	-	0.09	-	-	0.09
11	TANGUSDALE	-	-	-	2.57	-	-	2.57
12	BORVE	-	-	-	6.85	-	-	6.85
13	ALLASDALE	-	-	-	T	-	-	T
14	CLEAT	-	-	-	-	-	-	-
15	FUDAY	-	-	-	1.69	-	-	1.69
16	KILPHEDER	14.42	-	3.25	3.44	-	1.76	22.87
17	HOWBEG	1.20	-	-	-	-	1.20	2.40
18	HOWMORE	-	-	-	3.69	-	-	3.69
19	DRIMSDALE	-	-	-	1.27	-	-	1.27
20	STILLIGARY	0.52	-	3.00	22.18	-	-	25.70
21	MIDDLEQUARTER	-	-	-	-	-	-	-
22	SOLLAS	5.81	-	0.41	3.57	-	-	9.79
23	SHEIGRA TO OLDSHOREMORE	-	-	-	1.60	-	-	1.60
24	AN FHARAID	-	-	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-	-	-
26	DUNNET LINKS	-	-	25.68	-	-	-	25.68
27	BAY OF QUENDALE	-	-	-	-	-	-	-
28	MORRICH MORE	-	T	3.50	-	-	-	3.50
29	LOCH OF STRATHBEG	-	8.32	5.59	-	-	-	13.91
30	SANDS OF FORVIE	-	-	-	-	-	4.57	4.57
31	FOVERAN	-	-	0.96	-	-	-	0.96
32	BARRY LINKS	-	-	-	-	-	-	-
33	TENTSMUIR	-	-	28.31	-	-	-	28.31
34	ABERLADY BAY	-	-	-	-	T	-	T
	TOTALS	21.95	8.32	75.03	49.66	T	7.53	162.49

Table 11.5 Distribution of aquatic communities and open water in surveyed Scottish dunes. Areas in hectares. T = trace (generally from target note records). See Table 5.1 for listing of community types.

	SITE	A7	A9	A10	A14	A22	A24	OPEN WATER	TOTAL
1	TORRS WARREN	0.2	-	-	-	0.6	-	7.9	8.7
2	TURNBERRY	-	-	-	-	-	-	-	-
3	TROON	-	-	-	-	-	-	-	-
4	LAGGAN BAY	-	-	-	-	-	-	1.6	1.6
5	ARDNAVE	-	-	-	-	-	-	1.9	1.9
6	KILLINALLAN	-	0.3	-	-	-	-	-	0.3
7	HOUGH BAY & BALEVULLIN	-	T	-	T	-	-	0.3	0.3
8	CROSSAPOL & GUNNA	-	T	-	T	-	-	1.2	1.2
9	VATERSAY	-	-	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-	-	-	-
12	BORVE	-	-	-	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-	-	-	-
14	CLEAT	-	-	-	-	-	-	-	-
15	FUDAY	-	-	-	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-	-	-	-
17	HOWBEG	-	-	-	-	-	-	-	-
18	HOWMORE	-	-	-	-	-	-	2.5	2.5
19	DRIMSDALE	-	-	-	-	-	-	20.2	20.2
20	STILLIGARY	-	-	-	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-	-	-	-
22	SOLLAS	-	-	-	-	-	-	1.0	1.0
23	SHEIGRA TO OLDSHOREMORE	-	-	-	-	-	-	-	-
24	AN FHARAID	-	-	-	-	-	-	0.2	0.2
25	SANDSIDE BAY	-	-	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	-	-	-	-	-
27	BAY OF QUENDALE	-	-	-	-	-	-	2.5	2.5
28	MORRICH MORE	-	-	-	T	-	T	2.5	2.5
29	LOCH OF STRATHBEG	-	-	-	-	-	-	-	-
30	SANDS OF FORVIE	-	-	T	-	-	T	8.3	8.3
31	FOVERAN	-	-	-	-	-	-	-	-
32	BARRY LINKS	-	-	-	-	-	-	0.2	0.2
33	TENTSMUIR	-	-	-	-	-	-	-	-
34	ABERLADY BAY	-	-	-	-	-	-	0.4	0.4
	TOTALS	0.2	0.3	T	T	0.6	T	50.7	51.8

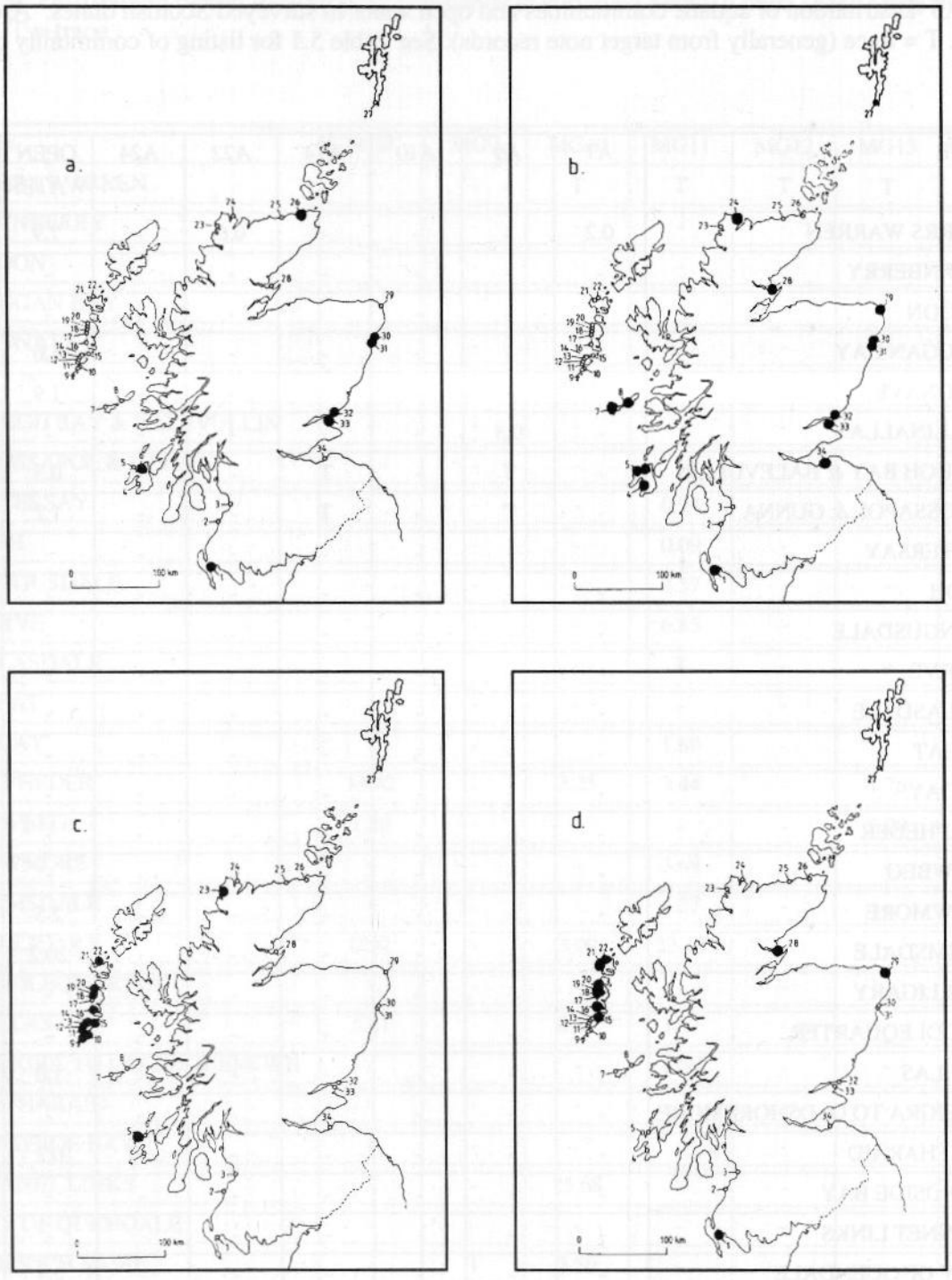


Figure 11.1 Distribution of selected dune wetland communities in surveyed Scottish dunes. a. SD16 *Salix repens - Holcus lanatus* dune slack community; b. SD17 *Potentilla anserina - Carex nigra* dune slack community; c. MG11 *Festuca rubra - Agrostis stolonifera - Potentilla anserina* inundation grassland; d. non-NVC *Carex nigra* poor fen types.

○ Site surveyed - community absent
● Site surveyed - community present
Site names are listed in Table 1.1

12. Dune scrub and woodland

12.1 NVC communities and rare species

Scottish dunes possess only a limited number of scrub and woodland types (Table 5.1), of small total extent (188.2 ha, Table 12.1). These patterns are the result of a long grazing history on most sites, plus the effects of exposure in western and northern dunes. Succession to dune woodland is therefore virtually absent from surveyed Scottish sites. All woodland communities are confined to southern dune systems (Figure 12.1). The only NVC type further north is W23 *Ulex europaeus - Rubus fruticosus* agg. scrub, though there is plentiful *Juniperus communis communis* and *J. communis alpina* at Morrich More, some of which might deserve NVC recognition. No rare species on dunes are associated with native woodland or scrub, though *Goodyera repens* is found in pine plantations on some Scottish dunes (e.g. Tentsmuir).

12.2 Dune woodland

The largest extents are found at Torrs Warren, Barry Links and Tentsmuir, mainly as willow *Salix* spp. scrub, together with alder *Alnus glutinosa* scrub at Tentsmuir. These stands probably occur in dune areas lacking grazing in recent times. Quadrat records are few, suggesting under-recording, and samples are not easily placed into NVC communities or sub-communities which might themselves lack dune woodland and scrub data.

12.3 Dune scrub

Mature sea buckthorn *Hippophae rhamnoides* scrub (SD18b *Urtica dioica - Arrhenatherum elatius* sub-community) is present in three sites in southeast Scotland where it has been introduced. It is steadily expanding at Aberlady Bay which also has the early successional SD18a *Festuca rubra* sub-community. The community is invasive and can reduce conservation interest, though mature stands are attractive to birds for nesting and winter food (Ranwell 1972). A limited amount of control is practised at Aberlady Bay LNR by pulling young shoots and suckers.

The gorse *Ulex europaeus* (W23) scrub community is the most extensive woodland/scrub type in Scotland. Bramble *Rubus fruticosus* agg. is absent from quadrat records which are few for sites other than Morrich More. It is probably under-recorded as a community and data are insufficient for reviewing successional, habitat or regional trends in Scotland. At Morrich More it is invading and spreading into a range of SD8/SD12 and SD12 grassland types, from dry to more moist conditions, including stands with *Juniperus communis communis*.

An important characteristic of Morrich More is a moderate extent (c. 10 ha) of juniper *Juniperus communis*. Floristic details are given in Table 12.2, based on four quadrat groups derived from TWINSPAN analysis. It occurs as a mosaic with SD12 grassland (Group a) and SD12/H11/M16 grassland/heath transitions (Groups b and c). Prostrate individuals might represent *J. communis alpina* and these also extend into wet heath and slack habitats over a wide area (Group d). Together the groups illustrate a fine sequence from dry to wet habitats within which the ratio of erect to prostrate *J. communis* falls as wetter conditions are approached. It is probable that *J. communis* was once much more widespread at Morrich More. It is common on the eastern strandplain and there is a thin scatter of individual bushes further west where it has been almost eradicated by fires resulting from military usage of the area. Scattered *J. communis* bushes are also found further north at Cuthill, Dornoch and Coull Links. There is thus some evidence for a provisional *Juniperus communis* dune scrub community. Its potential as an NVC type deserves review, especially since other *Juniperus* species (*J. oxycedrus, J. phoenicea*) are a common and important component of Mediterranean dune habitats (Doody 1991).

Table 12.1 Woodland and scrub communities in surveyed Scottish dunes. Areas in hectares. T=trace. Jc scrub= *Juniperus communis* scrub.

	SITE	W1	W2a	W4	W22	W23	SD18a	SD18b	Jc scrub	Totals
1	TORRS WARREN	28.40	-	5.34	-	4.06	-	-	-	37.80
2	TURNBERRY	-	-	-	-	-	-	-	-	-
3	TROON	-	-	-	-	5.59	-	-	-	-
4	LAGGAN BAY	-	-	-	-	-	-	-	-	-
5	ARDNAVE	-	-	-	-	-	-	-	-	-
6	KILLINALLAN	-	-	-	0.31	-	-	-	-	0.31
7	HOUGH BAY & BALEVULLIN	-	-	-	-	-	-	-	-	-
8	CROSSAPOL & GUNNA	-	-	-	-	-	-	-	-	-
9	VATERSAY	-	-	-	-	-	-	-	-	-
10	UIDH	-	-	-	-	-	-	-	-	-
11	TANGUSDALE	-	-	-	-	-	-	-	-	-
12	BORVE	-	-	-	-	-	-	-	-	-
13	ALLASDALE	-	-	-	-	-	-	-	-	-
14	CLEAT	-	-	-	-	-	-	-	-	-
15	FUDAY	-	-	-	-	-	-	-	-	-
16	KILPHEDER	-	-	-	-	-	-	-	-	-
17	HOWBEG	-	-	-	-	-	-	-	-	-
18	HOWMORE	-	-	-	-	-	-	-	-	-
19	DRIMSDALE	-	-	-	-	-	-	-	-	-
20	STILLIGARY	-	-	-	-	-	-	-	-	-
21	MIDDLEQUARTER	-	-	-	-	-	-	-	-	-
22	SOLLAS	-	-	-	-	-	-	-	-	-
23	SHEIGRA TO OLDSHOREMORE	-	-	-	-	-	-	-	-	-
24	AN FHARAID	-	-	-	-	-	-	-	-	-
25	SANDSIDE BAY	-	-	-	-	-	-	-	-	-
26	DUNNET LINKS	-	-	-	-	-	-	-	-	-
27	BAY OF QUENDALE	-	-	-	-	-	-	-	-	-
28	MORRICH MORE	T	-	T	-	39.70	-	-	10.00	49.70
29	LOCH OF STRATHBEG	-	-	-	-	T	-	-	-	T
30	SANDS OF FORVIE	-	-	T	-	7.03	-	-	-	7.03
31	FOVERAN	-	-	T	-	0.10	-	-	-	0.10
32	BARRY LINKS	17.23	1.52	1.01	-	-	-	2.45	-	22.21
33	TENTSMUIR	-	42.82	-	-	-	-	2.75	-	45.57
34	ABERLADY BAY	-	-	-	-	0.75	1.74	17.40	-	19.89
	TOTALS	45.63	44.34	6.35	0.31	57.23	1.74	22.60	10.00	188.20

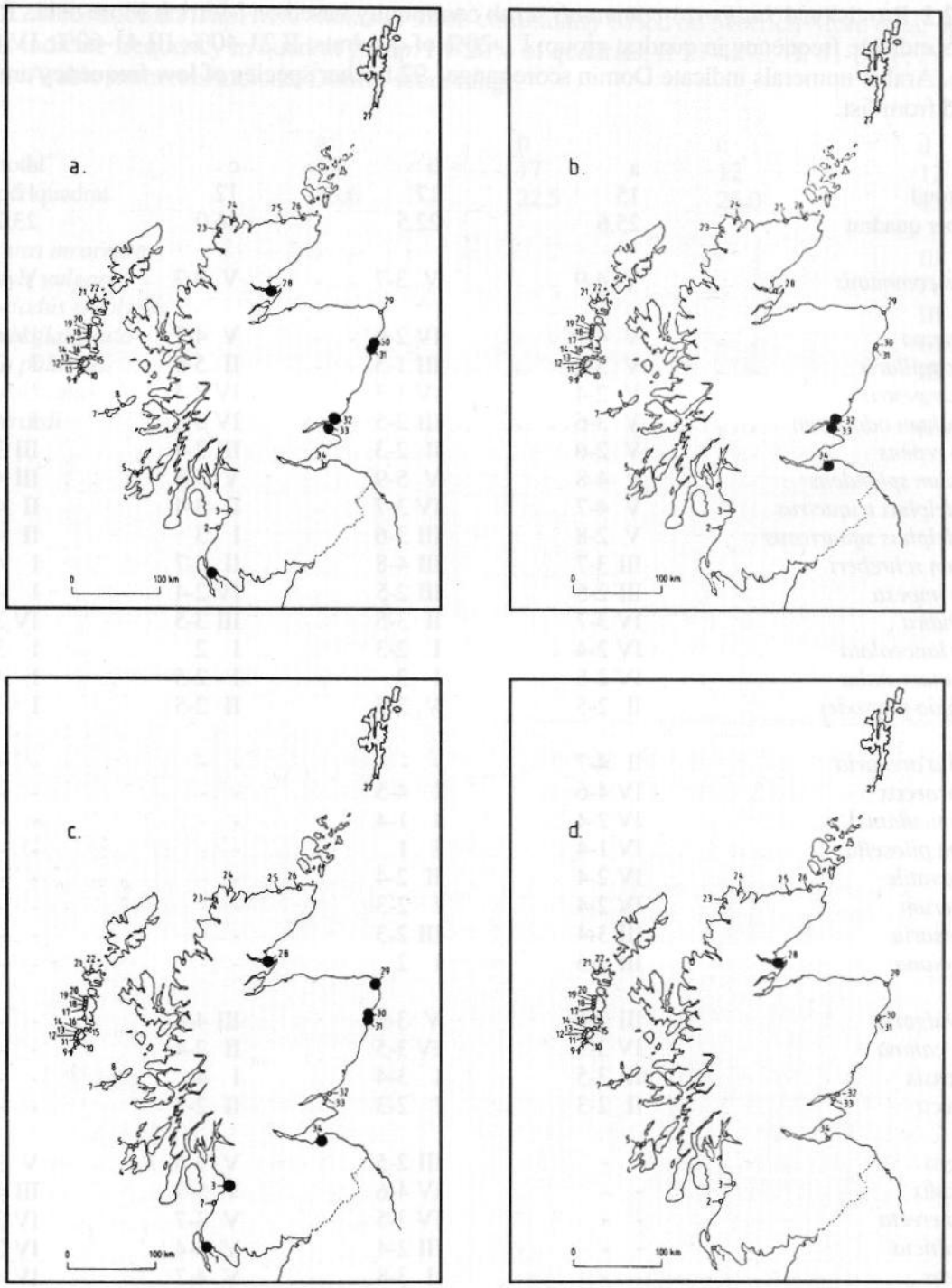


Figure 12.1 Distribution of selected woodland and scrub communities on surveyed Scottish dune sites. a. all woodland types (W1 *Salix cinerea - Galium palustre* woodland; W2a *Salix cinerea - Betula pubescens - Phragmites australis* woodland, *Alnus glutinosa* sub-community, W4 *Betula pubescens - Molinia caerulea* woodland); b. SD18 *Hippophae rhamnoides* dune scrub; c. W23 *Ulex europaeus - Rubus fruticosus* agg. scrub community; d. *Juniperus communis* scrub.

○ Site surveyed - community absent
● Site surveyed - community present
Site names are listed in Table 1.1

Table 12.2 Provisional *Juniperus communis* scrub community based on Morrich More data. Roman numerals indicate frequency in quadrat group: I 1-20% of quadrats; II 21-40%; III 41-60%; IV 61-80%; V >80%. Arabic numerals indicate Domin score range. 92 further species of low frequency are excluded from list.

Group	a	b	c	d
Quadrat total	15	17	12	12
Species per quadrat	25.6	22.5	26.0	23.2
Juniperus communis	V 4-9	V 3-7	V 4-7	V 4-6
Festuca ovina	V 4-7	IV 2-6	V 4-7	IV 4-7
Agrostis capillaris	V 3-6	III 1-5	II 5-6	I 3
Luzula campestris	V 2-4	IV 1-3	IV 2-3	I 4
Anthoxanthum odoratum	V 3-6	III 2-5	IV 3-5	I 4
Trifolium repens	V 2-6	II 2-3	III 2-4	III 3-5
Hylocomium splendens	V 4-8	V 5-9	V 5-8	III 4-6
Rhytidiadelphus triquetrus	V 4-7	IV 3-7	II 3-4	II 4-7
Rhytidiadelphus squarrosus	V 2-8	III 3-6	I 3	II 4
Pleurozium schreberi	III 3-7	III 4-8	II 2-7	I 4
Cladonia impexa	III 2-5	III 2-5	IV 2-4	I 4
Festuca rubra	IV 3-7	II 3-5	III 3-5	IV 3-6
Plantago lanceolata	IV 2-4	I 2-3	I 2	I 3
Koeleria macrantha	IV 2-5	I 3	I 2-5	I 4
Hypogymnia physodes	II 2-5	V 3-5	II 2-5	I 3
Ammophila arenaria	II 4-7	- -	- -	- -
Thymus praecox	IV 4-6	I 4-5	- -	- -
Lotus corniculatus	IV 2-4	I 1-4	- -	- -
Hieracium pilosella	IV 1-4	I 1	- -	- -
Galium saxatile	IV 2-4	II 2-4	- -	- -
Galium verum	IV 2-4	I 2-3	- -	- -
Carex arenaria	III 3-4	III 2-3	- -	- -
Viola riviniana	III 2-5	I 2	- -	- -
Calluna vulgaris	III 2-6	V 3-9	III 4-8	- -
Peltigera canina	IV 3-5	IV 3-5	II 2-4	- -
Poa pratensis	III 3-5	I 3-4	I 4	- -
Carex flacca	II 2-3	I 2-3	II 2-3	- -
Carex nigra	- -	III 2-5	V 3-5	V 3-6
Erica tetralix	- -	IV 4-6	V 5-7	III 4-6
Potentilla erecta	- -	IV 3-5	V 3-7	IV 3-5
Juncus balticus	- -	III 2-4	V 3-4	IV 2-4
Salix repens	- -	II 3-8	V 4-7	IV 4-7
Molinia caerulea	- -	I 3	IV 4-7	V 5-7
Empetrum nigrum nigrum	- -	III 3-6	II 3-4	I 4-5
Carex panicea	- -	II 3-4	IV 3-6	III 3-5
Calliergon cuspidatum	- -	- -	IV 5-7	V 7-9
Schoenus nigricans	- -	- -	II 2-6	IV 4-8
Carex pulicaris	- -	- -	III 2-4	III 3-4
Pinguicula vulgaris	- -	- -	III 2-4	III 1-4
Prunella vulgaris	- -	- -	II 1-5	II 3-4
Viola palustris	- -	- -	I 3	III 3-6
Cardamine pratensis	- -	- -	II 3	III 1-3
Eriophorum angustifolium	- -	- -	II 3-4	II 3-4
Agrostis stolonifera	- -	- -	II 2-4	IV 4-6

Table 12.2 Provisional *Juniperus communis* scrub community based on Morrich More data. Roman numerals indicate frequency in quadrat group: I 1-20% of quadrats; II 21-40%; III 41-60%; IV 61-80%; V >80%. Arabic numerals indicate Domin score range.

Group	a	b	c	d
Quadrat total	15	17	12	12
Species per quadrat	25.6	22.5	26.0	23.2
Dactylorhiza incarnata	- -	- -	- -	III 1-3
Hydrocotyle vulgaris	- -	- -	- -	IV 2-6
Drepanocladus revolvens	- -	- -	- -	III 4-7
Ranunculus flammula	- -	- -	- -	III 3-4
Parnassia palustris	- -	- -	- -	III 2-4
Juncus articulatus	- -	- -	- -	II 3-4
Juncus gerardi	- -	- -	- -	II 4-5

13. Ruderal vegetation on sand dunes

13.1 Backgound

Ruderal vegetation on dunes is largely the product of tillage, with the only extensive area of cultivated land being restricted to the Western Isles. Rigg and furrow topography is common in sites elsewhere (e.g. Crossapol and Gunna, Sands of Forvie) and in the past arable land was probably extensive in many dune systems. Vegetation data from fallows are available in Western Isles site reports (c. 108 quadrats). An account of agriculture and associated vegetation patterns is given by Crawford (1989) for North and South Uist. An NVC ruderal vegetation chapter has yet to be completed and therefore no comparison with NVC data can be made.

13.2 Western Isles land use

Crofting land in North and South Uist is used for arable cultivation of potato, short oats and rye. Management is often on a 1 year crop - 1 year fallow system, though longer fallows are also present. Herbicide application remains uncommon and the weed flora is sufficient to support winter stock grazing after harvest. This is also applied to fallow land. Crawford (1989) stresses that there is much detailed variability in management practice but, in general, techniques are traditional and resemble a land use system which has probably operated continuously since medieval times. There are signs of progressive agriculture being introduced, particularly on the larger land holdings of North Uist.

13.3 Vegetation patterns in old-field successions

Analysis by Crawford (1989) suggests a *Festuca rubra* ruderal community is typical, comprising eight sub-communities for cereal land and fallows, plus two sub-communities for potato cultivation:

Cereal sub-communities, fallow for 1 year

a. *Vicia cracca;*
b. *Bromus hordeaceus;*
c. *Prunella vulgaris;*
d. *Honkenya peploides;*
e. *Arenaria serpyllifolia;*
f. *Lolium perenne;*
g. *Potentilla anserina;*
h. *Myosotis arvensis;*

Potato sub-communities, fallow for 1 year

a. *Erodium cicutarium;*
b. *Ranunculus repens.*

A larger quadrat data set covering a wider time range is available from Western Isles sites, involving 108 samples. These were analysed in 1991 as part of this national study, using TWINSPAN to group quadrats for interpretation. Several sub-divisions fit the groupings of Crawford but the wider time span allows a clear old-field succession to be identified, made up of three stages described below.

1. **Recently abandoned land (one year since harvest)**
   Crop species are still present (*Solanum tuberosum, Avena strigosa, Secale cereale*), accompanied by several ruderals of high frequency which are largely absent from sites more than 1 year old since tillage: *Myosotis arvensis, Sonchus asper, Chrysanthemum segetum, Viola arvensis, Stellaria media, Anchusa arvensis, Papaver rhoeas, Polygonum aviculare, Sinapis arvensis.* Average species richness is 14.7 species per quadrat.

2. **Early succession (two to three years since harvest)**
   Crop species and most of the above ruderals disappear. The resulting sward is very varied in composition but the bulk of biomass is made up of *Festuca rubra, Agrostis stolonifera, Trifolium repens* and *Ranunculus repens.* Associated species are *Cerastium diffusum, Arenaria serpyllifolia, Myosotis arvensis,* and *Viola lutea.* This stage has the highest diversity: an average of 16.3 species per quadrat.

3. **Late succession (three or more years since harvest)**
   Sward composition becomes close to Western Isles SD8 *Festuca rubra - Galium verum* dune grassland types (SD8d, SD8e). High cover values are shown by *Festuca rubra* and *Trifolium repens,* with high frequencies for

Plantago lanceolata, Euphrasia officinalis agg. , *Galium verum, Rhytidiadelphus squarrosus, Potentilla anserina, Rhinanthus minor, Bellis perennis, Ranunculus acris* and *Prunella vulgaris*. Diversity is slightly reduced to 15.1 species per quadrat, probably due to vigorous growth by dominant species. This diversity level is well below that typical of SD8 swards (c. 28 species per quadrat) which probably is the result of continuous year-to-year grazing with little relaxation of grazing pressure, thus maintaining a short and fairly open turf which can accommodate more species (including bryophytes).

13.4 Significance

These fallow land successions are part of the last vestiges of a formerly extensive land use system on Scottish dunes. The species-rich turf of the extensive mature SD8 grasslands have probably been derived from such fallow successions in the past and are now maintained by stock grazing practices. Full understanding of the hyperoceanic SD8 dune grasslands needs therefore to take account of grassland origin and the link, over time, between old-field succession and the production of a very species-rich mature SD8 sward under purely pastoral conditions. Traditional land management is seen as an essential component in maintaining the biodiversity of fallow land and machair grasslands, mainly within the context of designation as an Environmentally Sensitive Area (ESA).

14. The nature conservation value of Scottish dunes

14.1 Assessing nature conservation value

A full conservation evaluation of Scottish dunes is only possible with comprehensive information on the geomorphology, flora, fauna and vegetation types of all of the Scottish dune resource. This study is based on a limited sample of 34 (often large) sites which comprise 30.7% of dune and machair/links area in Scotland but which only represent c. 5% of all Scottish dune sites (see 1.4). Full geomorphological information and complete flora/fauna lists were not available for most of the 34 study sites and these attributes were not a requirement of this survey. Assessment of conservation value must therefore rely largely on vegetation data and this is used here in relation to the major citeria used for assessing individual sites in the Nature Conservation Review (Ratcliffe 1971, 1977, 1986): size and diversity, naturalness, rarity, fragility, typicalness, position in ecological/geographical unit, recorded history and educational value, potential value, and intrinsic appeal. Some attention is given here to patterns derived from all 34 survey sites but it is stressed here that such results are drawn from a limited, possibly non-random, sample and thus might not represent trends in the complete dune resource.

14.2 Size and diversity

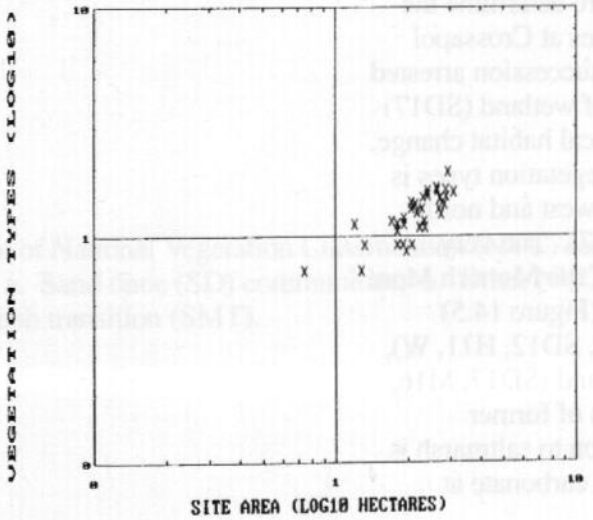
Size can be measured in terms of the extent of a site or in terms of the number or density of species/habitats which it contains - the former is examined here. Diversity can be represented as species/habitat totals or densities, usually restricting the measure to types which naturally occur in the environment under study (to avoid artificial inflation of results by including recently introduced species/habitats). The overall diversity of sampled Scottish dunes is reflected in the large total of National Vegetation Classification (NVC) dune (SD) communities and sub-communities recorded (Table 5.1): 38 out of the GB total of 52, with ten slack types absent because these tend to be rare and centred on south-western England and South Wales. In addition there appear to be at least two new potential NVC types in Scottish sites which might be restricted to Scotland. About 70 non-dune NVC types (H, MG, CG, U, M, S, A, W, SM) were also recorded, contributing much to dune diversity. Such diversity reflects four major types of gradient which operate upon Scottish dunes: successional/stabilisation trends, moisture gradients, transitions to other coastal habitats (especially saltmarsh), and transitions to other non-maritime habitats in inland sectors.

As might be expected, the number of vegetation types found in sampled dunes (Table 14.1) increases with the size of the dune system because there is more space available for successional sequences to develop and for moisture gradients to be established, together with marginal transitions. The relationship is strongest in log-log form (Figure 14.1) and is statistically significant ($P<0.01$), the best-fit line being log10 vegetation types = 0.340 + 0.409 log10 site area ($R^2 = 0.632$). Small sites fit the relationship poorly, and much of the scatter about the remainder of the line appears to be due to higher numbers of vegetation types in southern sites (i.e. location, and not just size, is also important in determining vegetation diversity).

Table 14.1 Totals of vegetation types found in surveyed Scottish dune systems.

	SITE	NUMBER OF DUNE (SD) VEGETATION TYPES	NUMBER OF NON-DUNE VEGETATION TYPES	NUMBER OF TRANSITION VEGETATION TYPES	TOTAL OF VEGETATION TYPES	SITE AREA (HECTARES)
1	TORRS WARREN	32	36	11	79	846.9
2	TURNBERRY	13	0	0	13	16.0
3	TROON	11	3	1	15	84.0
4	LAGGAN BAY	18	6	5	29	202.8
5	ARDNAVE	14	9	3	36	256.0
6	KILLINALLAN	15	13	3	31	262.2
7	HOUGH BAY & BALEVULLIN	11	6	3	20	505.3
8	CROSSAPOL & GUNNA	9	6	2	17	579.1
9	VATERSAY	7	1	0	8	120.5
10	UIDH	4	1	0	5	5.5
11	TANGUSDALE	5	8	0	13	82.8
12	BORVE	5	2	1	8	64.0
13	ALLASDALE	4	2	1	7	92.7
14	CLEAT	4	0	1	5	18.8
15	FUDAY	7	4	1	12	228.0
16	KILPHEDER	7	15	2	24	114.2
17	HOWBEG	5	2	1	8	20.7
18	HOWMORE	5	7	1	13	64.5
19	DRIMSDALE	7	11	2	20	192.7
20	STILLIGARY	5	8	1	14	52.0
21	MIDDLEQUARTER	7	3	1	11	64.1
22	SOLLAS	8	8	2	18	153.0
23	SHEIGRA TO OLDSHOREMORE	12	6	2	20	116.0
24	AN FHARAID	9	3	0	12	166.2
25	SANDSIDE BAY	7	0	1	8	79.6
26	DUNNET LINKS	13	6	4	23	690.3
27	BAY OF QUENDALE	10	3	1	14	221.0
28	MORRICH MORE	14	16	5	35	1267.8
29	LOCH OF STRATHBEG	18	13	6	37	450.2
30	SANDS OF FORVIE	19	17	2	38	762.5
31	FOVERAN	17	5	1	23	140.4
32	BARRY LINKS	18	10	2	30	788.7
33	TENTSMUIR	19	7	2	28	507.2
34	ABERLADY BAY	24	16	1	41	425.5

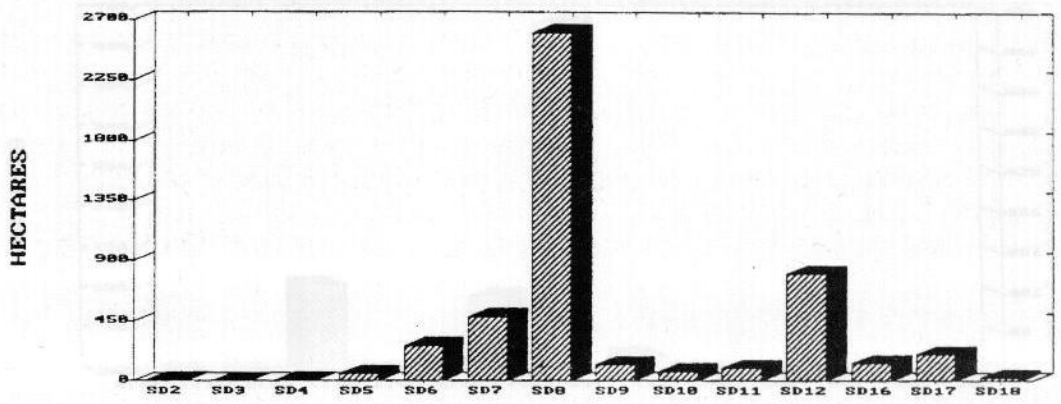
Figure 14.1 Relationship between site area and total of vegetation types recorded in surveyed Scottish dune sites.



The overall diversity and extent of NVC communities within sampled Scottish dunes are presented in Figure 14.2. The successional sequence of increasing stability is illustrated by the successive rises in extent from mobile dune (SD5, SD6) to semi-fixed (SD7) and to fixed dune grassland (SD8), with acidic dune grassland (SD12) and dune heath (H11) representing further successional stages on sands low in carbonate, permitting leaching and the development of acidic soils. The high extents of SD8 and SD12 vegetation also reflect grazing which has maintained much dune habitat as a plagioclimax, with relatively little proceeding further as succession to scrub (SD18, W). Moisture gradients account for moderate extents of SD16, SD17, wet heath (M16), wet mesotrophic grassland (MGWET), mire (M), swamp (S) and aquatic (A) vegetation which together cover a large dune area, reflecting the high rainfall levels of much of Scotland. Transitions to inland vegetation types are shown by the extent of calcifugous grassland (U), bracken (U20), calciphilous grassland (CG), dry mesotrophic grassland (MG1, MG5, MG6, MG7), plus the strong presence of all non-dune wetlands. The only relatively common transition to other coastal habitat is to saltmarsh (SMT).

Individual dune systems show considerable variability in the pattern of diversity for vegetation types. This variability reflects contrasting dune geomorphology (see 3.1) and land use differences between sites. Acidic soils, extensive terrain close to the water table, plus low grazing levels explain small grassland extents and large areas of heathland, mire and bracken at Torrs Warren (Figure 14.3). Very high carbonate levels and moderately high grazing pressure determine the small range in NVC communities at Crossapol and Gunna (Figure 14.4), with succession arrested at SD8 and only small extents of wetland (SD17) and bracken (U20) providing local habitat change. This lack of large numbers of vegetation types is probably characteristic of most west and north coast sites (Table 14.1, sites 7-27). The very extensive and flat strandplain of the Morrich More has a full suite of communities (Figure 14.5) representing succession (SD5-8, SD12, H11, W), plus an even larger area of wetland (SD17, M16, S) which has developed in areas of former saltmarsh. A very large transition to saltmarsh is also found (SMT). Soils low in carbonate at Sands of Forvie explain the low extent of SD8 grassland (Figure 14.6), plus large areas of SD10, SD11 and SD12 communities. Wet and dry heath (H11, M16) are most extensive and are possibly aided by lack of stock grazing, enabling spread into former grassland and slack. Despite its size, there is only a relatively small proportion of wetland (SD16, SD17, M16, M as major types) and this might reflect lower rainfall levels and the topography of dunes which lacks the very large areas of flat or low-lying ground found in many large surveyed dunes. Active dune building is very limited in area at Aberlady Bay (Figure 14.7) and extensive stable dunes are dominated by mesotrophic grassland types (SD9, MG1) on sands with a moderate carbonate content. These neutral grasslands probably reflect former areas of grazed dune which have been managed for several decades as rough on golf courses, with non-stock herbivores (rabbits, roe deer) continuing in insufficient numbers to stop the loss of what might have been large areas of SD8 grassland merging into more acidic SD12 types.

These examples of site vegetation diversity emphasise the individuality of sites, with the most diverse in terms of vegetation types being found in areas where all four controls of variation are operative. It is possible that particular types of dune system exist, each with a similar community spectrum. The site sample here is, unfortunately, too small to examine such an idea which would be a useful aid in grouping sites and ensuring that typical ranges of dune diversity are conserved.



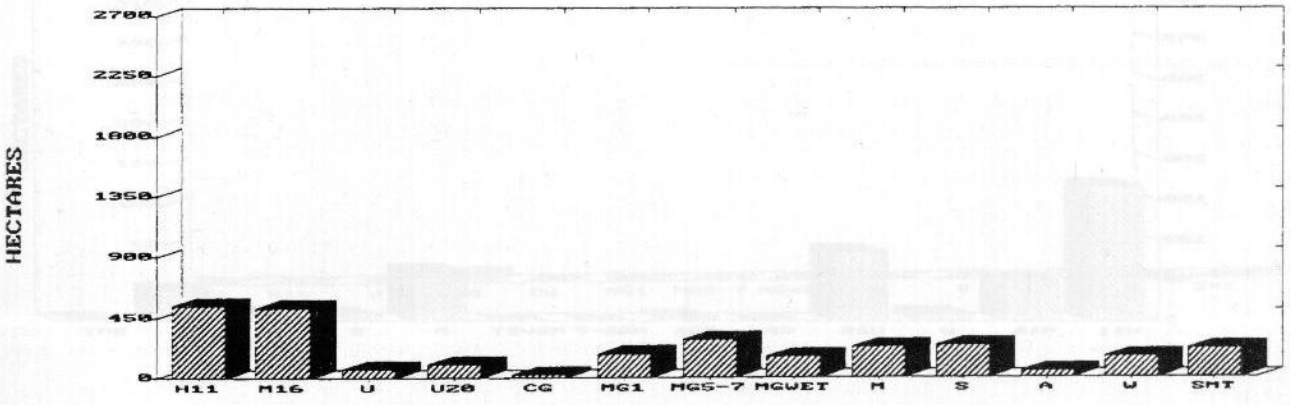


Figure 14.2 The extent of National Vegetation Classification (NVC) communities in all 34 surveyed dune sites in Scotland. a. Sand dune (SD) communities; b. Other NVC communities or community aggregates, plus saltmarsh transition (SMT).

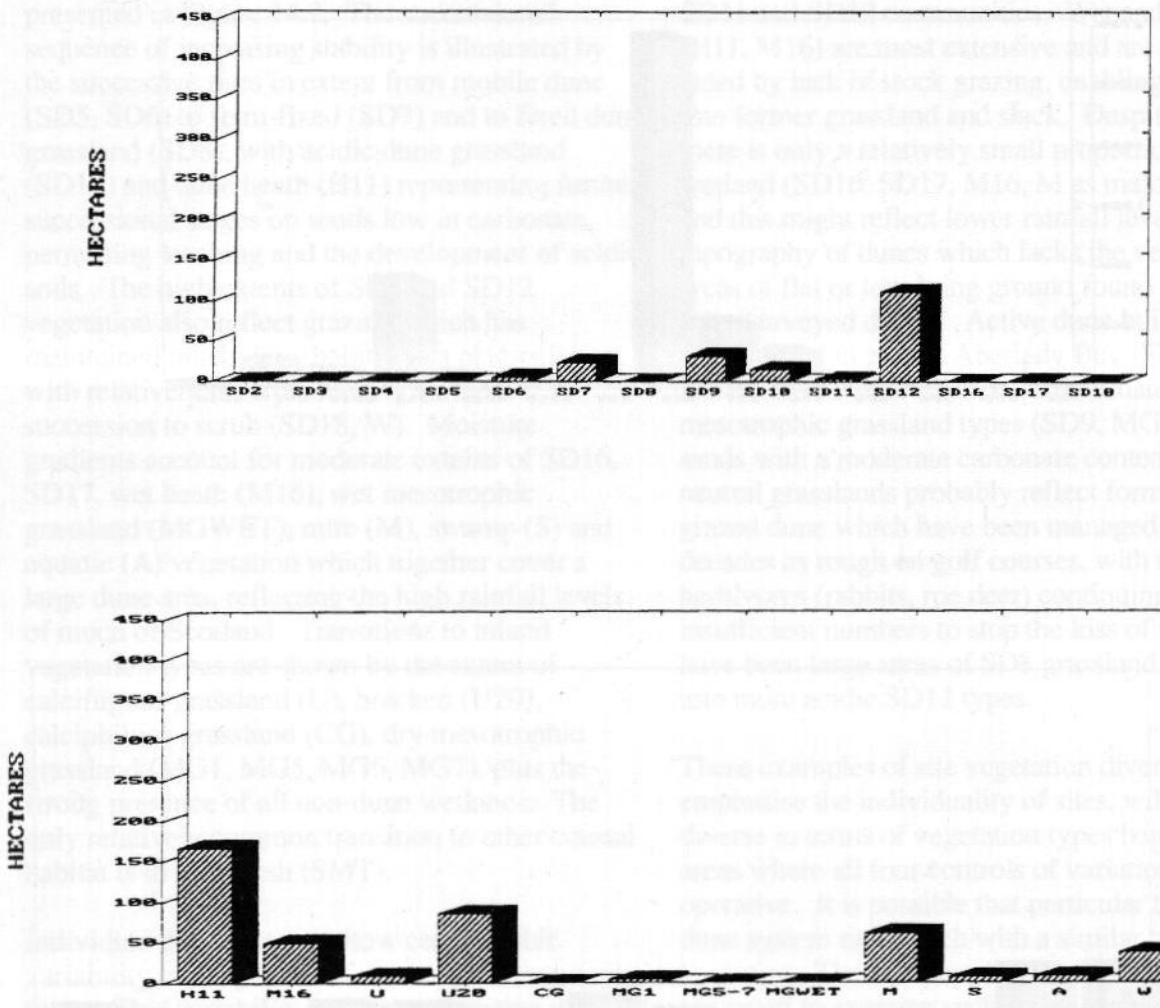
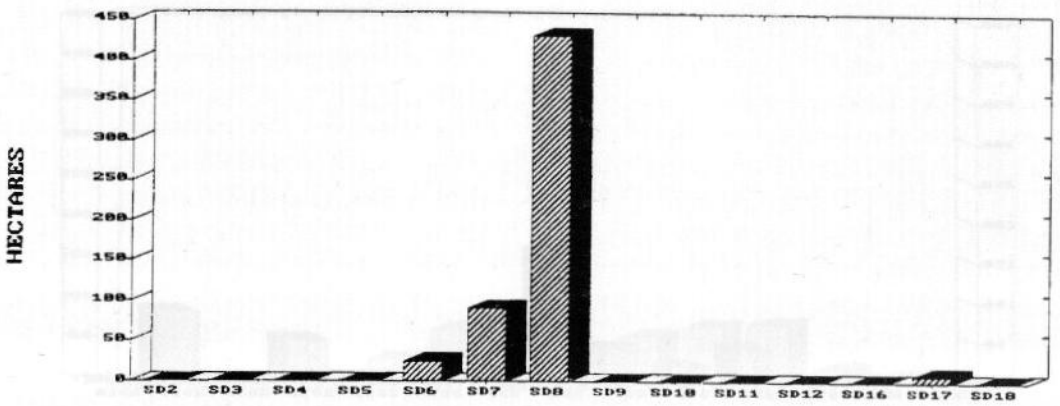


Figure 14.3 The extent of National Vegetation Classification (NVC) communities at Tors Warren, Dumfries and Galloway (Site 1). a. Sand dune (SD) communities; b. Other NVC communities or community aggregates, plus saltmarsh transition (SMT).



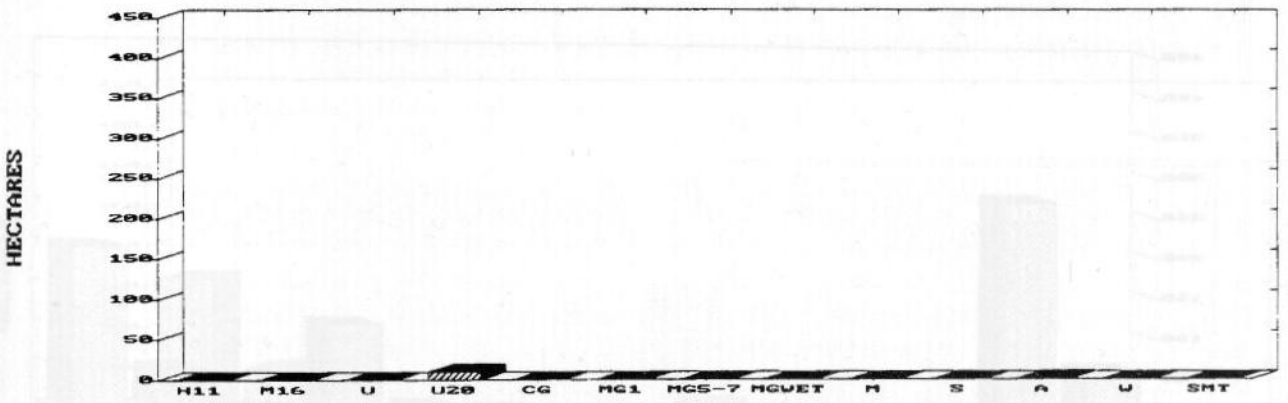
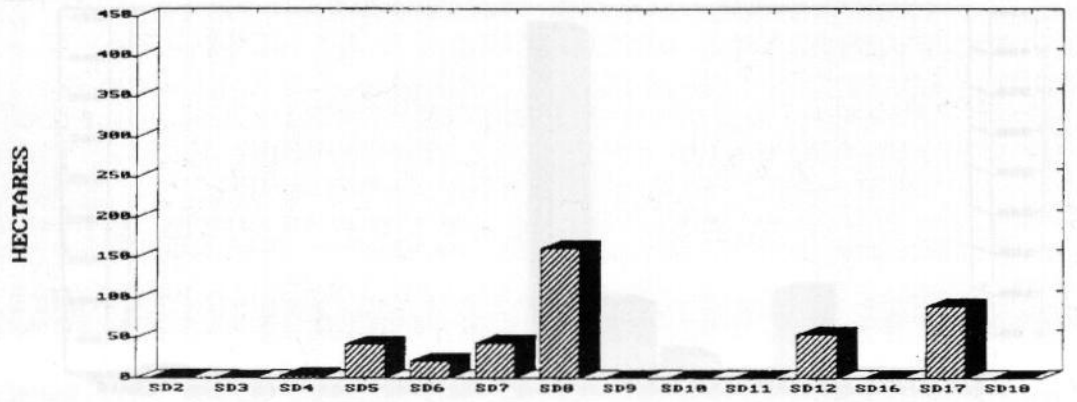


Figure 14.4 The extent of National Vegetation Classification (NVC) communities at Crossapol and Gunna, Coll (Site 8) a. Sand dune (SD) communities; b. Other NVC communities or community aggregates, plus saltmarsh transition (SMT).



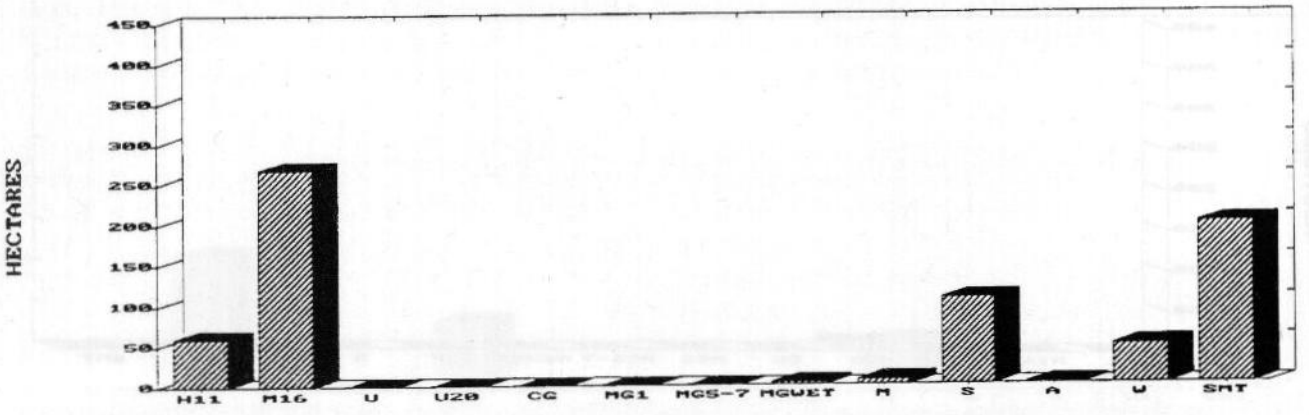
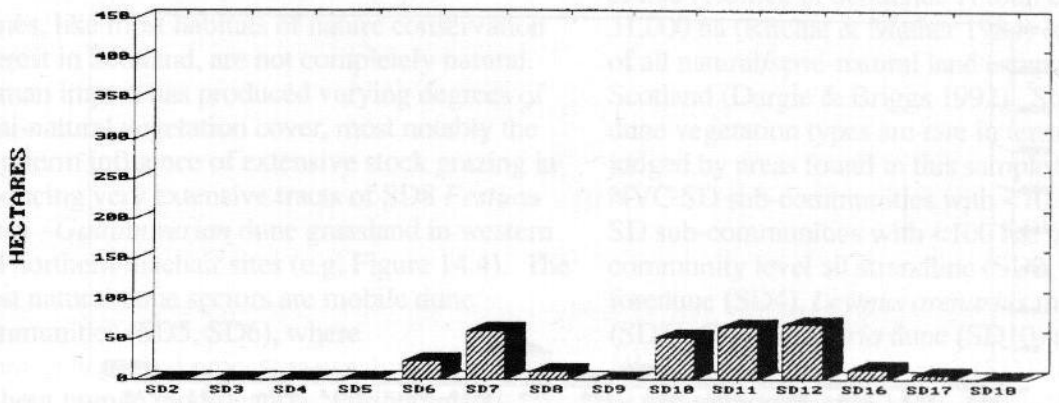


Figure 14.5 The extent of National Vegetation Classification (NVC) communities at Morrich More, Ross and Cromarty (Site 28). a. Sand dune (SD) communities; b. Other NVC communities or community aggregates, plus saltmarsh transition (SMT).



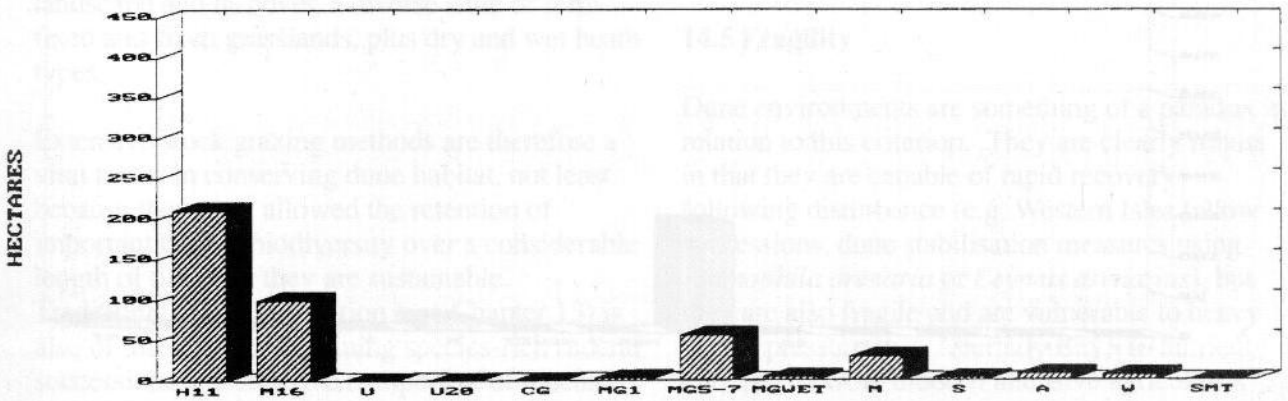
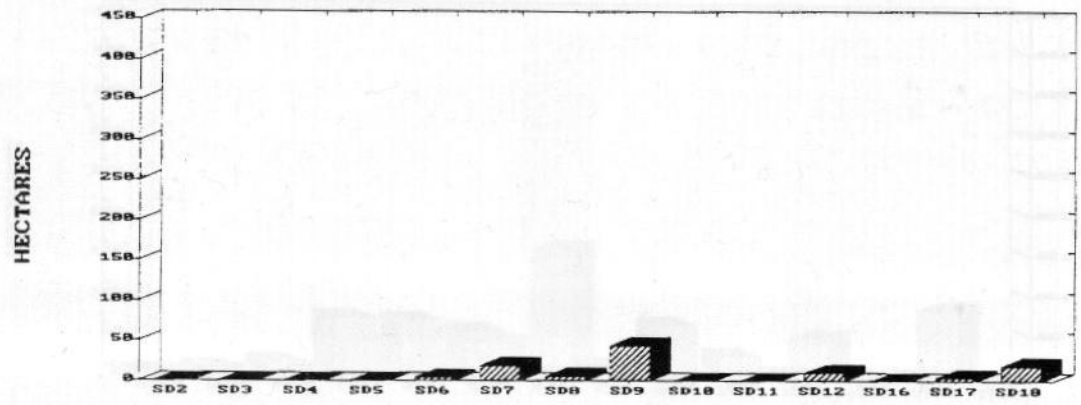


Figure 14.6 The extent of National Vegetation Classification (NVC) communities at Sands of Forvie, Gordon (Site 30). a. Sand dune (SD) communities; b. Other NVC communities or community aggregates, plus saltmarsh transition (SMT).



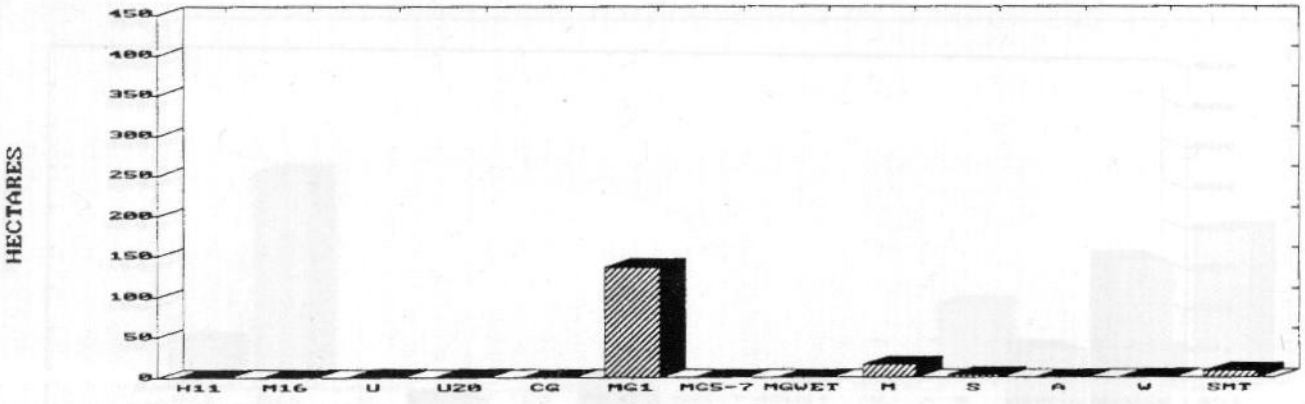


Figure 14.7 The extent of National Vegetation Classification (NVC) communities at Aberlady Bay, East Lothian (Site 34). a. Sand dune (SD) communities; b. Other NVC communities or community aggregates, plus saltmarsh transition (SMT).

14.3 Naturalness

Dunes, like most habitats of nature conservation interest in Scotland, are not completely natural. Human impact has produced varying degrees of semi-natural vegetation cover, most notably the long-term influence of extensive stock grazing in producing very extensive tracts of SD8 *Festuca rubra - Galium verum* dune grassland in western and northern machair sites (e.g. Figure 14.4). The most natural dune sectors are mobile dune communities (SD5, SD6), where geomorphological processes usually operate without human modification. Further inland geomorphology is still important as a factor in the stabilisation of vegetation cover, and in producing the more complex topography associated with secondary destabilisation and restabilisation. The interaction between stock grazing, geomorphology and dune plants has resulted in the current dune landscape and its cover, a diverse suite of semi-fixed and fixed grasslands, plus dry and wet heath types.

Extensive stock grazing methods are therefore a vital factor in conserving dune habitat, not least because they have allowed the retention of important habitat biodiversity over a considerable length of time, i.e. they are sustainable. Traditional arable cultivation (see Chapter 13) is also of interest in maintaining species-rich ruderal successions, a distinctive component of machair landscape in the Western Isles (Crawford 1989). Such practice was widespread in medieval times and rigg/furrow topography is common on some dunes which are long uncultivated (notably Sands of Forvie). This shows the ability of dune vegetation to obscure cultivated ground following succession. Traditional agriculture is thus critical in understanding the predominant semi-natural character of surveyed dunes.

14.4 Rarity

Rarity requires examination at three levels of dune nature conservation: geomorphological type, vegetation community and biological species. Sample data mean that precise information on the frequency of geomorphological types is not available. It is likely that large spit and prograding dune types will be the most uncommon types, with sites such as Sands of Forvie and Morrich More representing outstanding examples.

Dune vegetation, due to its specialised nature, is a scarce resource in Scotland. A total extent of c. 31,000 ha (Ritchie & Mather 1984) is only 0.7% of all natural/semi-natural land estimated for Scotland (Dargie & Briggs 1992). Some sand dune vegetation types are rare in terms of extent, judged by areas found in this sample survey: 7 NVC SD sub-communities with <10 ha, 19 NVC SD sub-communities with <100 ha. At NVC community level all strandline (SD2, SD3), foredune (SD4), *Leymus arenarius* mobile dune (SD5), *Carex arenaria* dune (SD10) and *Hippophae rhamnoides* scrub (SD18) are all rare or uncommon (Figure 14.2).

Rare and scarce plant species on dunes in Scotland are discussed but are few in number (see 5.3). This survey was not intended to cover dune fauna but Scottish dunes are not believed to hold major populations of rare or scarce vertebrates.

14.5 Fragility

Dune environments are something of a paradox in relation to this criterion. They are clearly robust in that they are capable of rapid recovery following disturbance (e.g. Western Isles fallow successions, dune stabilisation measures using *Ammophila arenaria* or *Leymus arenarius*), but they are also fragile and are vulnerable to heavy visitor pressure (e.g. Aberlady Bay), to nutrient enrichment from modern intensive agricultural practices (e.g. Loch of Strathbeg, Ardnave), and to loss of diversity following loss of grazing (e.g. parts of Aberlady Bay and Sands of Forvie).

14.6 Typicalness and position in an ecological/ geographical unit

These two conservation criteria are often related, since typical habitats (those which are repeated from one site to another) vary in ecology and geographical position. The sample nature of this study makes it impossible to present a list of typical types of Scottish dune (see 14.2) but there is some evidence that strong geographical patterns are present, leading to regional restriction of some vegetation types and perhaps suggesting a distinct biogeographical region covering dunes in the west and north of Scotland.

A strong feature of many NVC community and sub-community distributions is restriction to either a southwestern/eastern or western/northern pattern

of sites. Taking contiguous runs of presence in sites (allowing only a few gaps due to absence) the communities in Table 14.2 can be placed into one of these two geographical distributions.

Table 14.2 NVC communities and sub-communities showing regional geographical patterns in surveyed Scottish dunes.

Southwestern/Eastern	Western/Northern
SD6b	SD7?f
SD6c	SD7?g
SD6e	SD8c
SD7c	SD8d
SD8a	SD8e
SD8b	MG5
SD9a	MG11
MG1a	
SD12	TOTAL = 7
H11	
SD16	
SD17	
TOTAL = 12	

These community types, once classified into these two broad distributions, can be used to locate the approximate boundaries between sites for the geographical regions. A total can be calculated for each site in terms of the number of southwestern/eastern and western/northern community types present (Table 14.3). The southwestern/eastern distribution is strong from Troon southwards on the west coast and from Morrich More southwards on the east coast. The western/northern distribution is strong from Tiree and Coll north and east to Bay of Quendale in Shetland. The sites on Islay (Laggan Bay, Ardnave, Killinallan) and Dunnet Links are very mixed and suggest an overlapping boundary zone in these positions.

These patterns must be treated with caution since they are only based on a non-random sample of 34 sites. However, if the patterns are advanced as the major hypothetical spatial characteristics of Scottish dune vegetation further work can test the validity of the distributions as biogeographical regions. Two major ecological controls seem to be operating as explanatory variables: high sand carbonate inputs and a hyperoceanic climate for the western/northern distribution. These act to restrict southwestern/eastern types to more acidic sands in sheltered sites, generally with a more continental climate.

Table 14.3 Site totals for number of community and sub-community types in two geographical regions.

	SITE	WESTERN/NORTHERN DISTRIBUTION PATTERN	SOUTHWESTERN/EASTERN DISTRIBUTION PATTERN
1	TORRS WARREN	-	11
2	TURNBERRY	-	5
3	TROON	-	6
4	LAGGAN BAY	4	7
5	ARDNAVE	5	5
6	KILLINALLAN	3	4
7	HOUGH BAY & BALEVULLIN	4	1
8	CROSSAPOL & GUNNA	4	1
9	VATERSAY	5	-
10	UIDH	5	-
11	TANGUSDALE	6	-
12	BORVE	4	-
13	ALLASDALE	3	-
14	CLEAT	3	-
15	FUDHAY	4	-
16	KILPHEDER	5	-
17	HOWBEG	4	-
18	HOWMORE	4	-
19	DRIMSDALE	4	-
20	STILLIGARY	4	-
21	MIDDLEQUARTER	5	-
22	SOLLAS	7	-
23	SHEIGRA TO OLDSHOREMORE	5	-
24	AN FHARAID	4	1
25	SANDSIDE BAY	4	-
26	DUNNET LINKS	5	4
27	BAY OF QUENDALE	4	2
28	MORRICH MORE	1	5
29	LOCH OF STRATHBEG	1	8
30	SANDS OF FORVIE	-	9
31	FOVERAN	-	9
32	BARRY LINKS	-	12
33	TENTSMUIR	-	11
34	ABERLADY BAY	-	10

The calcium carbonate content of sandy soils has long been recognised as an important factor in controlling the vegetation of dune soils (Ranwell & Boar 1986). Dune systems in Scotland with high initial carbonate content (>10%) probably have little evidence of surface leaching and calcifugous vegetation is thus only encountered on the edge of blown sand in transitions to acidic habitats. No detailed investigation has been attempted here using soil pH values since only a small proportion of quadrats also have such data. Despite this limitation the broad patterns of community and sub-community distribution suggest that soil calcium carbonate is very important. Extensive acidic dune vegetation (SD11 and SD12 types) is restricted to sites known to have low carbonate levels (notably Torrs Warren and Sands of Forvie). Dune grassland at Morrich More has extensive transitions which correlate strongly with surrogate information replacing pH data (Dargie 1989). The calcium carbonate of Western Isles machair can be very high indeed and approaches a pure shell sand. The origin of this material is uncertain (W. Ritchie pers. comm.) but might be correlated with enhanced biological productivity around the offshore shelf sea front, producing large amounts of shellfish on the shallow rock platforms that lie inshore. Maerl beds (red algae) could also supply a proportion of the dune carbonate.

14.7 Recorded history and educational value

Relatively few Scottish dunes have been used for research and educational purposes, though Sands of Forvie (Landsberg 1955, Ritchie et al. 1968) and Aberlady Bay are notable exceptions. Current archaeological studies in the Western Isles are documenting a 6,000 year stratigraphic sequence at Udal, North Uist (I.A. Crawford, pers. comm.). Detailed geomorphological studies of dune history and beach sediment budget have been investigated at Morrich More (Hansom & Leafe 1990). A sand dune bibliography has been produced for Britain (Radley & Woolven 1990) and lists many classic descriptive papers. Some at least of this work could be repeated to examine change over time in Scotland. Dunes make excellent ecological classrooms where succession, competition, dispersal and survivorship can be demonstrated with unusual clarity. They are also important in teaching coastal geomorphology and a variety of interdisciplinary studies.

14.8 Potential value

This criterion is normally applied to sites proposed for habitat creation or re-creation. It is presently unimportant in relation to Scottish dunes but could feature if dune areas currently under conifer plantation were to be considered for re-instatement as dune vegetation.

14.9 Intrinsic appeal

Dunes are strongly appreciated by people for several reasons, mainly related to recreation. They adjoin bathing beaches, often provide spectacular displays of flowers, and their topography encourages a sense of space combined with privacy. There are viewpoints, sheltered hollows and warm slopes for sunbathing. Access is rarely a problem.

15. Conclusions and recommendations

15.1 Conclusions

1. This sample of Scottish dune vegetation has revealed a large number of NVC dune vegetation types, plus many communities from other NVC habitats. All vegetation types are presented in tables as area covered per site, allowing any site surveyed to be placed in its national context. The outstanding characteristics of Scottish dune vegetation are large extents of dune grassland maintained by extensive grazing, plus large areas of dune heath (wet and dry), mire and swamp. Most surveyed systems rank highly on criteria used to evaluate nature conservation importance, revealing geomorphological and habitat diversity with relatively low levels of adverse modification.

2. Many vegetation types show restriction to geographical areas, with western/northern and southwestern/eastern biogeographical regions emerging from analysis. The western/northern types probably represent hyperoceanic communities which are confined to the cool, moist and very exposed seaboard of Europe. The southwestern/eastern types probably relate more closely to the dunes of northern England, with the dune heaths of the Scottish east coast standing out as another feature of conservation importance.

3. Several vegetation types were encountered which do not fit NVC descriptions and these may warrant new community/sub-community status. The majority of vegetation records, however, fit NVC types well and in general the scheme is a sound method of describing dune vegetation at the national scale. The extension to vegetation mapping and the quantification of community extent enabled the careful comparison of sites and a search for geographical trends in Scotland.

4. Human impacts are widespread on Scottish dunes, though probably not to the extent of influence in England and Wales. Agriculture, forestry and management as golf course are the major impacts, with military training, sand extraction and other land use as much more minor factors.

5. Coastal erosion is dominant in surveyed sites, though progradation is important in a few localities. As with most British dunes, their landward limits are usually constrained by agriculture, forestry or some other form of development. Loss of the coastal margin due to erosion and an inability to migrate inland creates the process of 'coastal squeeze' (Davidson et al. 1991), with gradual to rapid loss of dune habitat. The problem is probably much less severe in Scotland, compared to England and Wales, but needs to be kept under review in important areas such as the Western Isles.

15.2 Recommendations

This survey is based on only a sample of Scottish dunes, though coverage is probably 30% of the total vegetational resource area. Any patterns found could therefore be influenced by sampling bias and, in any case, are restricted in certainty because the site total, at 34, is small. Results should therefore be regarded as a first approximation to Scottish dune vegetation types and their geographical patterns. Further work is probably required in the following areas to be more certain of findings:

1. A rigorous examination of SD6, SD7 and SD8 grasslands is required to clarify difficulties in harmonisation (Chapter 8) and the position of possible new NVC sub-communities. This work could probably be completed by using the present quadrat data set and making further visits to sites surveyed in 1987 to check vegetation mapping;

2. Objective testing is needed of the validity of proposed new NVC types and geographical patterns, probably requiring data collection from further sites.

16. Bibliography

Birse, E. L. 1980. *Plant communities of Scotland - a preliminary phytocoenonia.* Soil Survey of Scotland Bulletin No. 4. Aberdeen, Macaulay Institute for Soil Research.

Birse, E. L. 1984. *The phytocoenonia of Scotland - additions and revision.* Soil Survey of Scotland Bulletin No. 5. Aberdeen, Macaulay Institute for Soil Research.

Birse, E. L., Landsberg, S. Y. & Gimingham, C. H. 1957. *The effects of burial by sand on sand dune mosses.* Transactions, British Bryological Society 3 : 285-301.

Boorman, L. A. 1986. *A survey of sand dunes in relation to grazing.* CSD Report No. 632. Huntingdon, Nature Conservancy Council.

Burd, F. 1989. *The saltmarsh survey of Great Britain - an inventory of British saltmarshes.* Research and survey in nature conservation No. 17. Peterborough, Nature Conservancy Council.

Canfield, R. H. 1941. *Application of the line-intercept method in sampling range vegetation.* Journal of Forestry 39 : 388-394.

Crawford, I. 1989. *The machairs of the Uists - land use and vegetation.* Contract Surveys No. 64. Peterborough, Nature Conservancy Council.

Dargie, T. C. D. 1989. *Morrich More SSSI, Ross and Cromarty - Vegetation survey 1988.* CSD Contract Report No. 915. Peterborough, Nature Conservancy Council.

Dargie, T. C. D. 1991. *Isles of Scilly dune vegetation survey 1990.* CSD Contract Report No. 1179. Peterborough, Nature Conservancy Council.

Dargie, T. C. D. 1992. *A comparison of ITE soft coast vegetation types and National Vegetation Classification units on selected Scottish dune systems.* JNCC Report No. 119. Peterborough, Joint Nature Conservation Committee.

Dargie, T. C. D. & Briggs, D. J. 1992 *The state of the Scottish environment 1991.* Perth, Scottish Wildlife and Countryside Link.

Davidson N. C. et al. 1991 *Nature conservation and estuaries in Great Britain.* Peterborough, Nature Conservancy Council.

Doody J. P. Ed. 1991. *Sand dune inventory of Europe.* Peterborough, Joint Nature Conservation Committee.

Galvin S. 1990. *Coastal Ecology Branch research reports and publications 1980-1990.* Coastal Habitat Network Paper No. 4. Peterborough, Nature Conservancy Council.

Gemmell A. R., Greig-Smith P. & Gimingham, C. H. 1953 *A note on the behaviour of Ammophila arenaria (L.) Link in relation to sand dune formation.* Transactions of the Botanical Society of Edinburgh 36 : 132-136.

Hansom, J. D. & Leafe, R. N. 1990. *The geomorphology of Morrich More: development of a scientific database and management prescription.* CSD Contract Report No. 1161. Peterborough, Nature Conservancy Council.

Hill, M. O. 1979. *TWINSPAN - a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes.* Ithaca, Cornell University.

Hope-Simpson, J. F. & Jefferies, R. C. 1966. *Observations relating to vigour and debility in Marram grass (Ammophila arenaria (L.) Link).* Journal of Ecology 54 : 271-274.

Houston, J. 1983. *The conservation and management of sand dune coasts in Holland and Denmark.* London, Winston Churchill Memorial Trust. Unpublished report in 2 vols.

Landsberg, S. Y. 1955. *The morphology and vegetation of the Sands of Forvie.* Ph.D. Thesis. Aberdeen, University of Aberdeen.

Malloch, A. J. C. 1988. *VESPAN II - a computer package to handle and analyse multivariate species data and handle and display species distribution data.* Lancaster, University of Lancaster.

Malloch, A. J. C. 1990. *MATCH - a computer program to aid assignment of vegetation data to the communities and sub-communities of the National Vegetation Classification.* Lancaster, University of Lancaster.

Nature Conservancy Council 1990a. *Handbook for Phase 1 habitat survey : a technique for environmental audit.* Peterborough, Nature Conservancy Council.

Nature Conservancy Council 1990b. *On course conservation - managing golf's natural heritage.* Peterborough, Nature Conservancy Council.

Radley, G. P. & Woolven, S. C. 1990. *A sand dune bibliography.* Contract Surveys No. 122. Peterborough, Nature Conservancy Council.

Ranwell, D. S. 1959. *Newborough Warren, Anglesey. I. The dune system and dune slack habitat.* Journal of Ecology 47 : 571-601.

Ranwell, D. S. Ed. 1972. *The management of sea buckthorn Hippophae rhamnoides on selected sites in Great Britain.* Norwich, Coastal Ecology Research Station, Nature Conservancy.

Ranwell, D. S. 1972. *Ecology of salt marshes and sand dunes.* London, Chapman and Hall.

Ranwell, D. S. & Boar, R. 1986. *Coast dune management guide.* London, Institute of Terrestrial Ecology, HMSO.

Ratcliffe, D. A. 1971. *Criteria for the selection of nature reserves.* Advancement of Science, London 27 : 294-296.

Ratcliffe, D. A. Ed. 1977. *A nature conservation review.* Cambridge, Cambridge University Press. 2 vols.

Ratcliffe, D. A. 1986. *Selection of important areas for wildlife conservation in Great Britain : the Nature Conservancy Council's approach.* In : M.B. Usher Ed. *Wildlife conservation evaluation,* pp. 135-159. London, Chapman and Hall.

Ritchie, W., Smith, J. S. & Rose, N. 1978. *Beaches of north-east Scotland.* Perth, Countryside Commission for Scotland.

Ritchie, W. & Mather, A. S. 1984. *The beaches of Scotland.* Perth, Countryside Commission for Scotland.

Rodwell, J. S. Ed. 1991a. *British plant communities. Volume 1 : woodlands and scrub.* Cambridge, Cambridge University Press.

Rodwell, J. S. Ed. 1991b. *British plant communities. Volume 2 : mires and heaths.* Cambridge, Cambridge University Press.

Rodwell, J. S. Ed. in prep. *British plant communities. Volume 3 : grasslands and montane vegetation.* Cambridge, Cambridge University Press.

Rodwell, J. S. Ed. in prep. *British plant communities. Volume 4 : aquatic communities, swamps and tall herb fens.* Cambridge, Cambridge University Press.

Rodwell, J. S. Ed. in prep. *British plant communities. Volume 5 : maritime and weed communities.* Cambridge, Cambridge University Press.

Shaw, M. W., Hewett, D. G. & Pizzey, J. M. 1983. *Scottish coastal survey : a report on soft coast sites in Scotland.* NERC/NCC Contract HF3/03/61. Bangor, Institute of Terrestrial Ecology.

Sneddon, P. & Randall, R.E. 1992. *The vegetated shingle structures of Great Britain.* Peterborough, Joint Nature Conservation Committee (in press). 4 vols.

Willis, A. J. et al. 1959. *Braunton Burrows : the dune system and its vegetation.* Journal of Ecology 47 : 1-24, 249-288.

Wilson, K. 1960. *The time factor in the development of dune soils at South Haven Peninsula, Dorset.* Journal of Ecology 48 : 341-359.

Annex 1

NVC dune surveys - site reports

Site 1 *Torrs Warren, Dumfries & Galloway, 1990.* C. Doarks, S.M. Hedley, G.P. Radley & S.C. Woolven. Sand Dune Survey of Great Britain Site Report No. 94. Peterborough, Nature Conservancy Council 1990.

Site 2 *Turnberry Dunes, Ayrshire, 1989.* C. Doarks, S.M. Hedley & S.C. Woolven. Sand Dune Survey of Great Britain Site Report No. 93. Peterborough, Nature Conservancy Council 1990.

Site 3 *Troon, Ayrshire, 1990.* C. Doarks, S.M. Hedley & S.C. Woolven. Sand Dune Survey of Great Britain Site Report No. 92. Peterborough, Nature Conservancy Council 1990.

Site 4 *Laggan Bay, Islay, Argyll & Bute, 1989.* C. Doarks, S.M. Hedley, G.P. Radley & S.C. Woolven. Sand Dune Survey of Great Britain Site Report No. 97. Peterborough, Nature Conservancy Council 1990.

Site 5 *Ardnave, Islay, Argyll & Bute, 1990.* C. Doarks, S.M. Hedley, G.P. Radley & S.C. Woolven. Sand Dune Survey of Great Britain Report No. 96. Peterborough, Nature Conservancy Council 1991.

Site 6 *Killinallan, Islay, Argyll & Bute, 1990.* C. Doarks, S.M. Hedley, G.P. Radley & S.C. Woolven. Sand Dune Survey of Great Britain Site Report No. 95. Peterborough, Nature Conservancy Council 1991.

Site 7 *Hough Bay & Balevullin Machair, Tiree, Argyll & Bute, 1991.* T.C.D. Dargie. Site Report No. 42 to Joint Nature Conservation Committee. Peterborough, JNCC 1992.

Site 8 *Crossapol & Gunna Machair, Coll, Argyll & Bute, 1991.* T.C.D. Dargie. Site Report No. 43 to Joint Nature Conservation Committee. Peterborough, JNCC 1992.

Site 9 *Vatersay, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 53. Contract Surveys No. 103. Peterborough, Nature Conservancy Council 1990.

Site 10 *Uidh, Vatersay, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 54. Contract Surveys No. 105. Peterborough, Nature Conservancy Council 1990.

Site 11 *Tangusdale, Barra, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 53. Contract Surveys No. 105. Peterborough, Nature Conservancy Council 1990.

Site 12 *Borve, Barra, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 56. Contract Surveys No. 106. Peterborough, Nature Conservancy Council 1990.

Site 13 *Allasdale, Barra, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 57. Contract Surveys No. 107. Peterborough, Nature Conservancy Council 1990.

Site 14 *Cleat, Barra, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 58. Contract Surveys No. 108. Peterborough, Nature Conservancy Council 1990.

Site 15 *Fuday, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 60. Contract Surveys No. 110. Peterborough, Nature Conservancy Council 1990.

Site 16 *Kilpheder, South Uist, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 61. Contract Surveys No. 111. Peterborough, Nature Conservancy Council 1990.

Site 17 *Howbeg, South Uist, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 62. Contract Surveys No. 112. Peterborough, Nature Conservancy Council 1990.

Site 18 *Howmore, South Uist, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 63. Contract Surveys No. 113. Peterborough, Nature Conservancy Council 1990.

Site 19 *Drimsdale, South Uist, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 53. Contract Surveys No. 114. Peterborough, Nature Conservancy Council 1990.

Site 20 *Stilligarry, South Uist, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 53. Contract Surveys No. 115. Peterborough, Nature Conservancy Council 1990.

Site 21 *Middlequarter, North Uist, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 53. Contract Surveys No. 116. Peterborough, Nature Conservancy Council 1990.

Site 22 *Sollas, North Uist, Western Isles, 1988.* I. C. Crawford. Sand Survey of Great Britain Site Report No. 53. Contract Surveys No. 117. Peterborough, Nature Conservancy Council 1990.

Site 23 *Sheigra to Oldshoremore, Sutherland, 1987.* G.P. Radley, A.R. Waite & I.C. Crawford. Sand Dune Survey of Great Britain Site Report No. 14. Contract Surveys No. 39. Peterborough, Nature Conservancy Council 1989.

Site 24 *An Fharaid, Sutherland, 1987.* G.P. Radley, I.C. Crawford & A.R. Waite. Sand Dune Survey of Great Britain Site Report No. 15. Contract Surveys No. 40. Peterborough, Nature Conservancy Council 1989.

Site 25 *Sandside Bay, Caithness, 1987.* G.P. Radley, A.R. Waite & I.C. Crawford. Sand Dune Survey of Great Britain Site Report No. 16. Contract Surveys No. 41. Peterborough, Nature Conservancy Council 1989.

Site 26 *Dunnet Links, Caithness, 1987.* G.P Radley, A.R. Waite & I.C. Crawford. Sand Dune Survey of Great Britain Site Report No. 13. Contract Surveys No. 38. Peterborough, Nature Conservancy Council 1988.

Site 27 *Bay of Quendale, Shetland, 1991.*
T.C.D. Dargie. Site Report No. 41 to Joint Nature Conservation Committee. Peterborough, JNCC 1992.

Site 28 *Morrich More SSSI, Ross & Cromarty, 1988.*
T.C.D. Dargie. CSD Contract Report No. 915.
Peterborough, Peterborough, 1989.

Site 29 *Loch of Strathbeg, Banff & Buchan, 1990.* C. Doarks, C. Holder & G.P Radley. Sand Dune Survey of Great Britain Site Report No. 99. Peterborough, JNCC.

Site 30 *Sands of Forvie, Gordon, 1991.* T.C.D. Dargie. Site Report No. 45 to Joint Nature Conservation Committee. Peterborough, JNCC 1992.

Site 31 *Foveran Links, Gordon, 1990.* C. Doarks, C. Holder & G.P Radley. Sand Dune Survey of Great Britain Site Report No. 98. Peterborough, JNCC 1992.

Site 32 *A management plan and vegetation survey of Barry Links SSSI, Angus, 1987.*
S.C. Woolven. M.Sc. Conservation Dissertation. London, University College.

Site 33 *A vegetation survey of Tentsmuir and the adjoining coastal areas, 1988.* J.S. Robertson. Edinburgh, Nature Conservancy Council, South East Scotland Region 1988.

Site 34 *Aberlady Bay, East Lothian, 1991.* T.C.D. Dargie. Site No. 44 Report to Joint Nature Conservation Committee. Peterborough, JNCC 1992.