Sand Dune Vegetation Survey of Great Britain:

A national inventory

Part 1: England

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"When I have seen the hungry ocean gain
Advantage of the kingdom of the shore,
And the firm soil win of the watery main,
Increasing store with loss and loss with store,"

William Shakespeare, Sonnet No. 64.

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G.P. Radley,
Peterborough, March 1992.

Summary

This report describes the compilation of a national inventory of English coastal dunes and their vegetation between 1987 and 1990. The vegetation of 121 dune sites was described and mapped using the National Vegetation Classification. Information on the structure, land use and management of each of these sites was collected using a standard proforma.

The results highlight the enormous diversity of coastal sand dune vegetation, with more than 120 distinct types recorded from right across the spectrum of the National Vegetation Classification. They also illustrate the considerable range of variation that exists between different geographical areas. The importance of dunes as habitat for large numbers of rare plants is briefly mentioned.

The close relationship between dune vegetation and physical processes is a recurring theme in the report, as is the influence of changing patterns of land use. Recreation is clearly identified as being now the single most important and widespread use of dunes.

The discussion section highlights the importance of sand dunes as important natural areas supporting diverse wildlife, including numerous rare species, in the intensively managed English lowlands.

The report identifies four main issues in coastal dune management for nature conservation. These are:

1. the management of instability;
2. the management of recreation;
3. the management of succession;
4. the importance of naturalness.

The report concludes by describing how the results of an inventory such as this might be used to monitor future change, select sites as part of a European series and identify 'Ecological Zones'.

1. Introduction

1.1 Coastal dunes

Sand dunes are one of a series of 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 landwards 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 principle of succession with great clarity, and dunes are invaluable for ecological teaching and research.

1.2 The Nature Conservancy Council's coastal ecology research programme

This survey is one of a series of coordinated botanical surveys of major British coastal habitats. These were planned and executed by the coastal section of the former Nature Conservancy Council's (NCC) Chief Scientist Directorate as part of an integrated programme of research and survey. The other surveys in this series are the Saltmarsh Survey (Burd 1989) and the Vegetated Shingle Survey (Sneddon & Randall 1993, in prep.).

The overall aims of this research programme were:
– to establish the size, location and quality of the main terrestrial coastal habitats in Great Britain;
– to allow the impact of development proposals on sites of national importance and on the resource as a whole to be assessed;
– 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.

Full details of publications resulting from this research programme are given in Galvin (1990). Since the reorganisation of the NCC in March 1991 the programme has been continued by the country agencies and the Joint Nature Conservation Committee. This report was completed by English Nature.

1.3 The aims of the sand dune survey

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 and setting it in the context of Britain as a whole;
– a computer database to hold the results of the survey.

A full list of the site reports prepared for England is given in Chapter 7.

2. Methods

2.1 Scope of the survey

It was decided at the outset that the survey should attempt to cover all significant areas of coastal dune vegetation in England. What quickly became apparent was that different people had very different ideas on what was or was not a dune. A clear working definition was therefore needed. After some discussion it was agreed that the survey should encompass all areas of semi-natural vegetation on blown sand of geologically recent marine origin. This definition excludes the inland dunes of the Breckland and the Coversands whilst including a wide range of vegetation with only slight maritime influence found towards the inland margins of the larger coastal systems.

2.2 Preliminary work

2.2.1 Mapping units

In 1975 the Nature Conservancy Council commissioned Lancaster University to develop a National Vegetation Classification, 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 survey, and the communities and sub-communities of the National Vegetation Classification (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 were subsequently converted to the new system.

2.2.2 Locating and defining 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. These had been annotated, to show areas of major coastal habitats, by Janet Welsh in 1984 to provide information for a coastal resource database. 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. Before any site was surveyed it was reconnoitred and its limits determined by visual inspection using the definition given above. In cases where semi-natural vegetation extended beyond the limits of the blown sand, the landward boundary of the survey was determined by examining soil profiles to determine the presence or absence of blown sand.

2.2.3 Review of existing sources of information

Prior to this survey there had been no systematic vegetation survey of the dunes of England. There was, however, an enormous number of published and unpublished descriptive works on particular sites or groups of sites. It was thought that in some cases this information might render a fresh survey unnecessary. Early in the project a literature search was carried out to identify and collate relevant published information. The results of this were then published in the form of a bibliography (Radley & Woolven 1990). Much additional, unpublished, information came from site files held by NCC regional offices.

What emerged from this exercise was that certain dune systems had indeed been described in great detail, but that the methods of these surveys varied enormously. Most of the really detailed surveys of whole sites were also rather old. Experience from monitoring projects and reserve management showed that, even without direct human intervention, sites and vegetation could undergo significant changes over periods as short as ten years. It was therefore decided to use this as a cut-off point. In the event there were no sites in England where the existing surveys were both sufficiently recent and sufficiently compatible with the NVC to render fresh survey work unnecessary.

2.3 Field survey

2.3.1 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 apparently homogeneous stands. Within each stand type, typical sample areas were chosen and the vegetation recorded from inside 2 metre x 2 metre quadrats.

The NVC field manual (Rodwell 1980) 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, 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 lichens were identified and recorded using the Domin cover/abundance scale. This information was recorded on a standard field recording form along with information on aspect, soil pH, slope, bare ground, litter layer, vegetation height and grazing.

The information on grazing was collected using the 'impact' scale devised by Dr L. Boorman for his 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:

1. to note particular features or to comment on land use;

2. 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 consist 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.

2.3.2 Mapping

The larger sand dune systems pose 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. Two techniques were eventually devised which allowed vegetation boundaries on large dune systems to be drawn in the field quickly and with reasonable accuracy.

1. In a few cases detailed contour maps had already been prepared. These showed the outline of individual dunes and slacks. Vegetation boundaries could be drawn directly onto them in the field.

2. Most large dune systems are covered by vertical aerial photography. The prints were taken into the field and vegetation boundaries drawn onto 'permatrace' 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 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 onto the map or photograph, taking advantage of view-points such as high dunes, old watch towers, sea walls etc. 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 realignment. All overlays and field maps were labelled with the site name, date, recorder and, where applicable, the aerial photograph print number.

2.4 Analysis of survey data

2.4.1 Vegetation analysis

Quadrat data from each site were entered onto computer using the VESPAN II suite of programs devised by Andrew Malloch of Lancaster University (Malloch 1988). The TABLE programme was used to produce the quadrat tables, whilst the keys, tables and written descriptions provided in the various chapters of the National Vegetation Classification (NVC) (Rodwell 1991a, 1991b, 1992, in prep.), were used to allocate each quadrat to an NVC group. However, in a few cases non-NVC terms had to be 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 displayed using the TWINTAB program and then compared with the keys, tables and written descriptions provided in the various chapters of the National Vegetation Classification (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 program 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 program 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.

2.4.2 Preparation of vegetation maps

Where aerial photographs are used as the base for mapping, there is always some distortion of the image. Accurate transfer of information to a map base therefore requires the use of specialised optical equipment. Complete accuracy can be obtained using stereoplotters but these are slow and require highly skilled operators. Their level of accuracy is also greater than that with which the vegetation boundaries could be recorded. In practice sufficient accuracy can be obtained using simpler instruments. Two machines were used for the bulk of the work, a Grant Enlarger at the Department of Geography of Cambridge University and a Bausch and Lomb stereo zoom transferscope at Monks Wood Experimental Station. The latter machine can compensate for differences in scale and for distortions due to tilting. The former machine 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 superimposed 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. 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.

2.4.3 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. A standard recording form was completed for each site with a series of fields giving details of the type of dune system, land use, management, use by the public and dynamic state. An example of the recording form is given as Figure 1.

For most fields on the form, the surveyors were asked to select from a series of standardised descriptions. If the activity or attribute in question was not recorded then the field was left blank. The standardised descriptions used are listed in Table 1.

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'.

The severity of erosion by people or vehicles was assessed subjectively. Areas of dune with occasional bare paths and a few small blowouts were recorded as lightly eroded. Those with a dense, well worn path network and substantial bare areas were recorded as moderately eroded. Dunes described as severely eroded were those where there was general destabilisation over considerable areas.

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 means that the information was not recorded.

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 ness or cuspate foreland, spit, bay and hindshore. In addition, two other features of geomorphological interest were recorded: the presence of climbing dunes and tombolos.

It was decided to classify dunes according to the way in which they were currently operating, rather than try to unravel their historical development. This affected the classification of some sites in north Norfolk which developed as barrier islands (J.A. Steers in Allison & Morley 1989) but which are now at least partially joined to the mainland by reclaimed land.
These were recorded as spit dunes. Similarly, some dunes that probably developed as spits, such as those flanking the mouth of the Tees (Site report No. 38), were recorded as bay dunes. This is because they now appear to operate as such, owing to the presence of breakwaters.

Several sites were recorded as containing more than one type of dune. For example, part of the Lindisfarne dunes in Northumberland (Site report No. 20) appears to operate as a bay dune, whilst the rest act as a spit.

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.

The accurate measurement of marine erosion and of dune progradation is complex and requires repeated visits to monitor changes. 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

Full sand dune site information

Dune system no. ..... Coredata site code .....

Dune system name .....

Locational information

Country ..... Region .....

Grid references	10km squares	Administrative units
.....	.....	.....
.....	.....	.....
.....	.....	.....

Record status information

Sources of information	Dates of information
.....	.....
.....	.....

Physical attributes and status information

Area of the dune system (ha) .....

Types of dune system present	Watercourses
.....	.....
.....	.....

% age of defended coastline ..... % age of marine erosion .....

% age of accretion ..... Area of blow-outs (ha) .....

Status of site .....

.....

Human alterations and influences information

Sea defences	Mineral extraction	Dumping	Development
.....	.....	.....	.....
.....	.....	.....	.....
.....	.....	.....	.....

Stabilisation	Agricultural nature	Improvement of site area (ha)	Adjacent land use
.....	.....	.....	.....
.....	.....	.....	.....
.....	.....	.....	.....

Scrub control (Y/N) ..... Adjacent semi-natural vegn. .....

Figure 1 The standard sand dune site-recording form

Animal grazing information

	level of grazing			season				
	light	mod	heavy	win	spr	sum	aut	area grazed (ha)
Stock animals	.....	.....	.....	.....	.....	.....	.....	.....
Non-stock animals	.....	.....	.....	.....	.....	.....	.....	.....
Stock feeding	.....	.....	.....	.....	.....	.....	.....	.....

Damage to the site

Area affected by fires (ha) .....

Erosion damage	(L/W)	Vehicle damage	(L/W)
Negligible	.....	Negligible	.....
Light	.....	Light	.....
Moderate	.....	Moderate	.....
Severe	.....	Severe	.....

Golf course information

Golf course total area (ha) .....

% ages (approx.) of the total site within the golf course

Unmodified..... Modified ..... "Improved" .....

Forestry information

Conifer area (ha) ..... Broadleaf area (ha) .....

Aerial photography information

Details of aerial photographs used for mapping:
Sortie flown by
Date flown ..... Scale .....
Sortie no. ..... Print nos. .....

Figure 1 *(cont.)*

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*.

Wherever possible, confirmation of these trends was sought by reference to fixed structures. Second World War pillboxes and lines of anti-tank blocks were amongst the most useful of

Table 1 Standard descriptions used for completing the site recording form

Status

NNR	(National Nature Reserve)
LNR	(Local Nature Reserve)
SSSI	(Site of Special Scientific Interest)
NCR1	(Nature Conservation Review Site, grade 1)
NCR2	(Nature Conservation Review Site, grade 2)
NT	(National Trust property)
CTN/RSPB	(Reserve run by county trust, Royal Society for the Protection of Birds or other voluntary conservation body)
SPA	(Special Protection Area)
RAM	(Ramsar site)
ESA	(Environmentally Sensitive Area)
NSS	(Non statutory site)

Dune type

- Offshore island dune
- Prograding dunes, nesses and cuspate forelands
- Spit dune systems
- Bay dune systems
- Machair
- Climbing dunes
- Hindshore dunes

Watercourses

Freshwater	Brackish
Sandy substrate	Other substrate
<2 metres wide	2 metres to 10 metres wide
>10 metres wide	

Sea defences

Sea wall	Groynes
Beach feeding	Gabions
Brushwood	Rubble
Oil drums	Beach reprofiling

Table 1 *(cont.)*

Spoil dumping	Fences
Training wall	Boulders
Old cars	
Mineral extraction	
Active	Disused
Sand foreshore	Sand dunes
Other foreshore	Other dunes
Dumping	
Domestic refuse	Industrial waste
Fly tipping	Garden waste
Agricultural waste	Spoil
Beach cleanings	
Grazing by stock	
Cattle	Sheep
Horses	Goats
Donkeys	
Non stock grazing	
Rabbits	Deer
Hares	Geese
Agricultural improvement	
Fertiliser application	Herbicide use
Reseeding	Arable cropping
Fallow land	Irrigation
Drainage	Dunging
Development	
Caravan site	Farm buildings
Military installation	Transport installation
Beach huts	Leisure facility
Industrial development	Houses
Water storage	Water extraction
Car park	Cemetery
Boatyard	Bird hide
Other buildings	
Stabilisation works	
Fencing	Boardwalk
Marram planting	Hydroseeding
Regrading	Brushwood
Reseeding	*Hippophae* planting
Mulching	Oil drums
Old cars	
Adjacent land use	
Agriculture: arable	Agriculture: livestock
Development: urban	Industrial development
Leisure development	Forestry
Mining/quarrying	Nature reserve

these. On eroding dunes pillboxes that must have been built on the dunes could sometimes be found lying, broken, on the beach. On prograding dunes, lines of anti-tank blocks that were originally set up at the top of the beach could sometimes be found buried under sand at some distance back from the present dune front.

Sea defence works could also be used on some sites. For example, at Yarmouth in Norfolk (Site report No. 75) there is a continuous concrete promenade, complete with wave-deflecting top and steps to provide access to the beach. In the central part of the site there is now as much as 350 metres of dune in front of this wall and parts of it are almost buried under accumulated sand. Conversely, at Berrow in Somerset (Site report No. 90) the northern end of the sea wall fronting the town of Burnham on Sea was found to be 20 metres further seawards than a line of the unprotected dune front immediately adjacent to it. Sea defence works often have the additional advantage of being shown accurately on Ordnance Survey maps.

The aerial photographs used for vegetation mapping 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.

2.4.4 Organisation of survey work

The field survey work was carried out over four field seasons, 1987 to 1990. In each of these seasons a team of three surveyors carried out field surveys between late April and the end of September. In addition, three external contracts were let; P.S. Gateley Vegetation Surveys surveyed the Sefton Coast dunes in 1988 (Edmondson, Gateley & Nissenbaum 1989) and the north Devon dunes in 1990 (Gateley & Sturgess 1993, in prep.). Dr T.C.D. Dargie surveyed the Isles of Scilly dunes in 1990 (Dargie 1990).

2.4.5 Methods employed to ensure that information was collected in a consistent manner

With a project of this size, ensuring that information is collected in a consistent manner is a major concern. Fortunately this project remained under the supervision of one individual throughout and a number of measures were adopted to ensure consistency.

1. Training in survey methodology
At the start of each field season a field training course was run for the directly employed surveyors. The survey method 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.

2. 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. Identifications were spot checked by NCC's lower plants specialist. All lichen and bryophyte samples were preserved in case of later queries. In all species identification work, surveyors were encouraged to work together to ensure consistency.

3. 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 decide to adopt a procedure where for all but the smallest 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.

2.4.6 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. This proved to be a major exercise as the maps turned out to be extremely complex. The manual techniques involving the use of dot grids described in the saltmarsh survey (Burd 1989) would have proved impossibly time-consuming. Two techniques involving electronic measurement of area were therefore tried out.

The first of these involved the use of the Skye Instruments leaf area measurement and analysis system at the University of Lancaster. With this technique the map was first divided into 1 km squares and then scanned by the machine. This gave a background count of the area occupied by lines and writing. All areas occupied by the first vegetation type were then shaded using a black felt pen and the map was scanned again. By deducting the background count from the new reading the area of the first community could be obtained. The procedure was then repeated to give the area of the second community and so on until the entire area of the map had been shaded.

The second technique involved the digitising of the vegetation maps using the ARCINFO digitising package. As well as providing a digital version of all the boundaries, this also calculates the area of each 'polygon'. Providing that the vegetation occupying each polygon is recorded, these areas can be added together to provide the information on total areas.

A trial of the first technique showed that this was likely to prove extremely time-consuming. It was found that it was not possible to measure more than two sites per day. Even to achieve this rate of progress it was necessary to do an undesirable amount of amalgamation of vegetation types. The digitising work required for the second technique, though also time-consuming, could be contracted out. In addition the digitised boundaries gave the option of loading the maps onto a Geographical Information System (GIS), to take advantage in the future of the enormous analytical power this would provide. It was therefore decided to adopt the second technique. The digitising work was done on contract by AP3 Imaging Services Ltd. The lists of polygons with their areas and vegetation codes were supplied back to the NCC as printouts and as ASCII files. The latter were then edited and checked to ensure that the maps supplied had been correctly interpreted. The areas calculated by digitising were compared with those calculated by the Lancaster University machine for North Walney NNR, one of the trial sites (see Table 2). There was good general agreement between the results obtained.

2.5 Presentation of survey results

2.5.1 Site reports

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 publications. These reports each contain a summary of the methods, 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 Chapter 7.

2.5.2 Database construction

This survey generated a large volume of information that needed to be extensively resorted in order to provide the data necessary to produce the final report. A computerised database was therefore built to hold the results of the survey. The 'Advanced Revelation' database package was used from the start as this offered great flexibility in the nature of the information stored and in the methods of retrieval. However, the VESPAN package referred to above provided a ready-to-use series of programs to store and manipulate quadrat data. This and the later MATCH program were used alongside Advanced Revelation for much of the project.

Eventually an integrated database was created using Advanced Revelation. The following categories of information were stored, each in a different computer file.

1. General information on the names and locations of sand dunes, their protected status, dynamic state, geomorphological type, land use and management. Each site was identified by a unique numerical code. Much of the information in this category came from the standard recording forms described above.

2. Target notes, as described above, each labelled with a unique serial number, the site name and its code number.

3. Quadrat records, each labelled with a unique serial number, the code number of the site and containing a grid reference.

4. Area information, consisting of the area of each individual polygon and the type of vegetation that occupies it. Each record was labelled with the site code number and given a unique serial number of its own.

Linkage between these files was provided by the code numbers used to identify each dune site. These form the 'key field' in the general information file and are used in all the other files to identify which records belong to which sites. The sand dune database was also designed to link to NCC's COREDATA system by means of a series of site codes. These codes incorporated the COREDATA codes for any statutory sites which overlap with a dune site. The full structure of the sand dune database is set out in Figure 2. It should be noted that the database includes readybuilt routines to help answer the most common queries, and uses relational indexing to facilitate the sorting of information.

Considerable thought was given to ways of ensuring the consistency and accuracy of data entry into the database. In the general information file it is necessary to enter many non-quantitative items. To ensure that such data were entered in a consistent manner the fields were designed so that the operator had to choose from a standard series of options and could not enter free text. If a previously unforeseen entry had to be made this could be done only by adding a new option to the series.

In the target note file large numbers of species names had to be recorded. To avoid spelling errors and to speed entry, the NVC's dictionary of numerical species codes was incorporated into the database. Species records were then entered using the numerical codes. The machine then displayed the species name for checking. As an alternative a facility was provided which allowed the species name to be entered in condensed form and then the correct name to be selected from a shortlist on the screen. In practice most operators found it faster to enter the numerical codes.

The VESPAN package was used to enter the quadrat records and these were then imported to the database as ASCII files. VESPAN has its own routines for checking the accuracy of data entry and uses the same numerical species codes.

The area data were also imported into the database as ASCII files. Prior to entry these were edited using a word processing program to ensure accuracy and consistency of format.

The references used to compile the bibliography were left outside the Advanced Revelation database and stored using the 'Paperbase deluxe' software. They were labelled using a standardised series of keywords to allow searches for references dealing with a particular topic or geographical area.

2.6 Species nomenclature

Vascular plant names used in this report follow those in *Flora Europaea* (1983). Lichen and bryophyte names are those used in the standard National Vegetation Classification coding list.

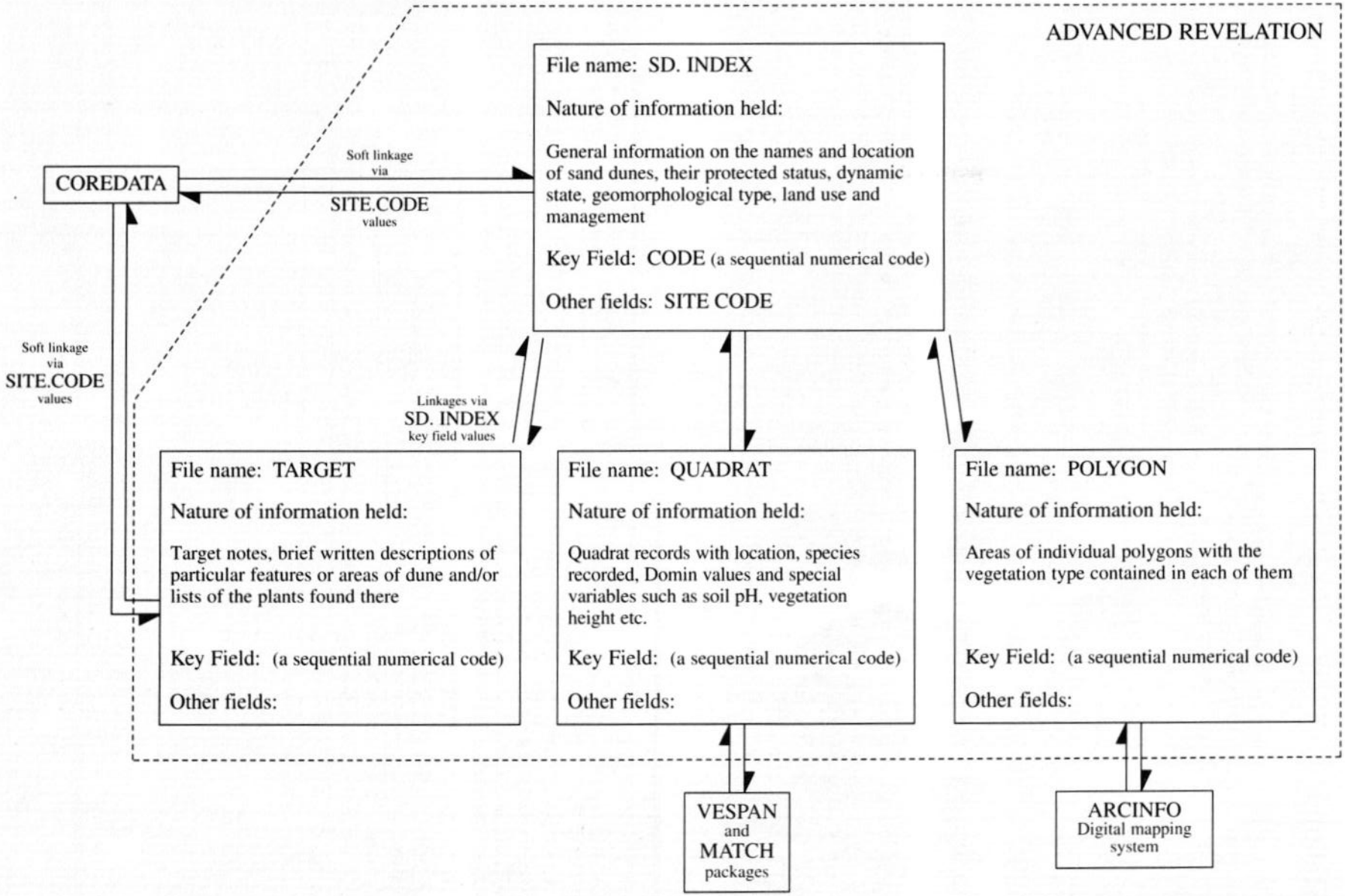

Figure 2 Structure of the sand dune database

3. Results

NB The full results, descriptions and maps for individual sites are contained in the individual site reports, a full list of which is given in Chapter 7.

3.1 Location and distribution of dune systems

Study of the 1:50,000 maps of coastal habitats prepared for the NCC by Janet Welsh in 1984 produced a list of 90 coastal dune sites in England. This list was then refined and verified by discussions with regional staff and by field survey. Some further sites were added, especially in the Isles of Scilly, and some sites were dropped because the dune element was very small. Problems of definition also arose occasionally; Janet Welsh had classified some quite extensive sections of the Suffolk coast as sand dune, but NCC's regional staff felt that they were really shingle features that had some sand on them. In the end it was decided not to include these sites. In most cases the 'site' corresponded to a whole system, but a few of the larger systems were subdivided into convenient units. In most cases the divisions were made along natural discontinuities such as the mouth of an estuary, breaks in a chain of barrier islands or rocky headlands. In one case, the dunes of the Sefton Coast, the divisions were made mainly along administrative boundaries.

A list of 121 sites was eventually chosen. It includes the overwhelming majority of coastal dunes in England, with only a few small sites omitted. These sites, with the approximate area surveyed on each, are listed in Table 2. Their distribution is shown by Figure 3. There are concentrations of dune sites in the north-east, in Lincolnshire and Norfolk, on the north coasts of Cornwall and Devon, on the Sefton Coast (Merseyside), in Cumbria and in the Isles of Scilly. Elsewhere sites are more widely scattered and there are some long stretches without any dunes, such as that between the Tees and the Humber. The total area of dune surveyed was 11,897 ha.

Table 2 Areas of dune covered by the survey

Administrative unit	Site name	Site area (ha)	Total area in county (ha)
Kent	Sandwich Bay Dunes	481	
	Romney Warren	77	558
East Sussex	Camber Sands	101	101
West Sussex	Climping Beach	16	
	Pagham Beach	2	
	East Head, West Wiltering	21	39
Hampshire	Hayling Island	93	93
Isle of Wight	St Helen's Duver	13	13
Dorset	Studland Bay	204	204
Devon (south coast)	Dawlish Warren	46	see below
Cornwall (south coast)	Par Sands	9	
	Kennack Sands	12	
	Church and Poldhu Coves Gunwalloe	46	
	Marazion	4	
	Whitesand Bay	38	see below
Isles of Scilly	Wingleton Down, St Mary's	7	
	Burnt Island, St Agnes	11	
	Porth Conger or The Cove, St Agnes	5	
	Porth Hellick Pool, St Mary's	12	
	Porth Loo and Portmelon, St Mary's	6	
	Pelistry Bay, St Mary's	10	

Table 2 *(cont.)*

Isles of Scilly *(cont.)*	Bar Point, St Mary's	12	
	Samson Flats	35	
	Appletree Banks, Tresco	47	
	Rushy Bay Dunes, Bryher	22	
	Popplestone Banks, Bryher		
	East Coast Fragments, Bryher		
	Pentle Bay, Tresco	23	
	Old Grimsby, Tresco	9	
	Gimble Porth, Tresco	11	
	Norwethel		
	St Helen's (South Coast)		
	Tean	31	
	Lower Town Dunes, St Martin's	10	
	Great Bay Dunes, St Martin's	15	
	Higher Town Dunes, St Martin's	6	
	Eastern Isles, including Little Arthur	16	288
Cornwall (north coast)	Lelant	10	
	Gwithian to Mexico	294	
	Godrevy Towans	76	
	Porthtowan Dunes		
	Penhale Sands	542	
	Holywell Dunes	70	
	Crantock Dunes	20	
	Fistral Dunes	41	
	Constantine Bay	76	
	Padstow Bay Rock Dunes	96	1334
Devon (north coast)	Northam Burrows	134	
	Instow Sands	32	
	Braunton Burrows	899	
	Croyde Bay	19	
	Woolacombe Sands and Down	46	1176
Somerset	Berrow Dunes	177	177
Avon	Weston Dunes	5	
	Sand Bay	22	27
Merseyside	Hoylake Dunes	74	
	Wirral Coast & Wallasey Golf Course	83	
	Seafort–Hightown	155	
	Altcar Firing Ranges	133	
	Cabin Hill–Lifeboat Road	237	
	Formby Point	178	
	Formby Golf Course–Woodvale Aero	303	
	Ainsdale NNR	343	
	Ainsdale LNR	111	
	Birkdale Hills	418	
	Southport Dunes	78	2113
Lancashire	Fylde Coast	57	57
Cumbria	South Walney	81	

Table 2 *(cont.)*

Cumbria *(cont.)*	North Walney	142	
	Sandscale Haws	199	
	Dunnerholme–Askham in Furness		
	Haverigg Haws	130	
	Eskmeals Dunes	227	
	Seascale-Drigg	345	
	Silloth-Maryport	322	
	Grune Point	55	1501
Northumberland	North Northumberland Coast	160	
	Lindisfarne	207	
	Ross Links & Budle Bay	348	
	Bamburgh–Seahouses	92	
	Seahouses–Beadnell	16	
	Beadnell–Newton Links	62	
	Embleton Bay	61	
	Howdiemont and Sugar Sands	9	
	Alnmouth Dunes	35	
	Alnmouth Town Dunes	5	
	Warkworth Dunes	76	
	Amble–Hauxley	25	
	Druridge Bay	135	
	Lynemouth	19	
	Lyne Sands–Newbiggin by the Sea	69	
	North Seaton	3	
	Cambois	16	
	Blyth–Seaton Sluice	37	1375
Cleveland & Durham	Hart Warren Dunes	35	
	Seaton Dunes & Common with North Gare Sands	77	
	South Gare & Coatham Sands		
	Redcar & Marske Sands	217	329
Humberside	Holderness Coast	43	
	Spurn Head	64	
	Welwick Dunes	9	
	Cleethorpes & Humberstone Dunes	25	141
Lincolnshire	North Lincs. Coast Dunes	491	
	Saltfleet Dunes	25	
	Saltfleetby and Theddlethorpe Dunes	343	
	Sutton on Sea–Skegness	96	
	Ingoldmells–Gibralter Point	280	1235
Norfolk	Hunstanton–Holme Dunes	134	
	Thornham–Brancaster	108	
	Scolt Head Island	80	
	Holkham	266	
	Blakeney–Cley	109	
	Winterton and Horsey	302	
	Caistor–Yarmouth	137	1136
Total for England			**11897**

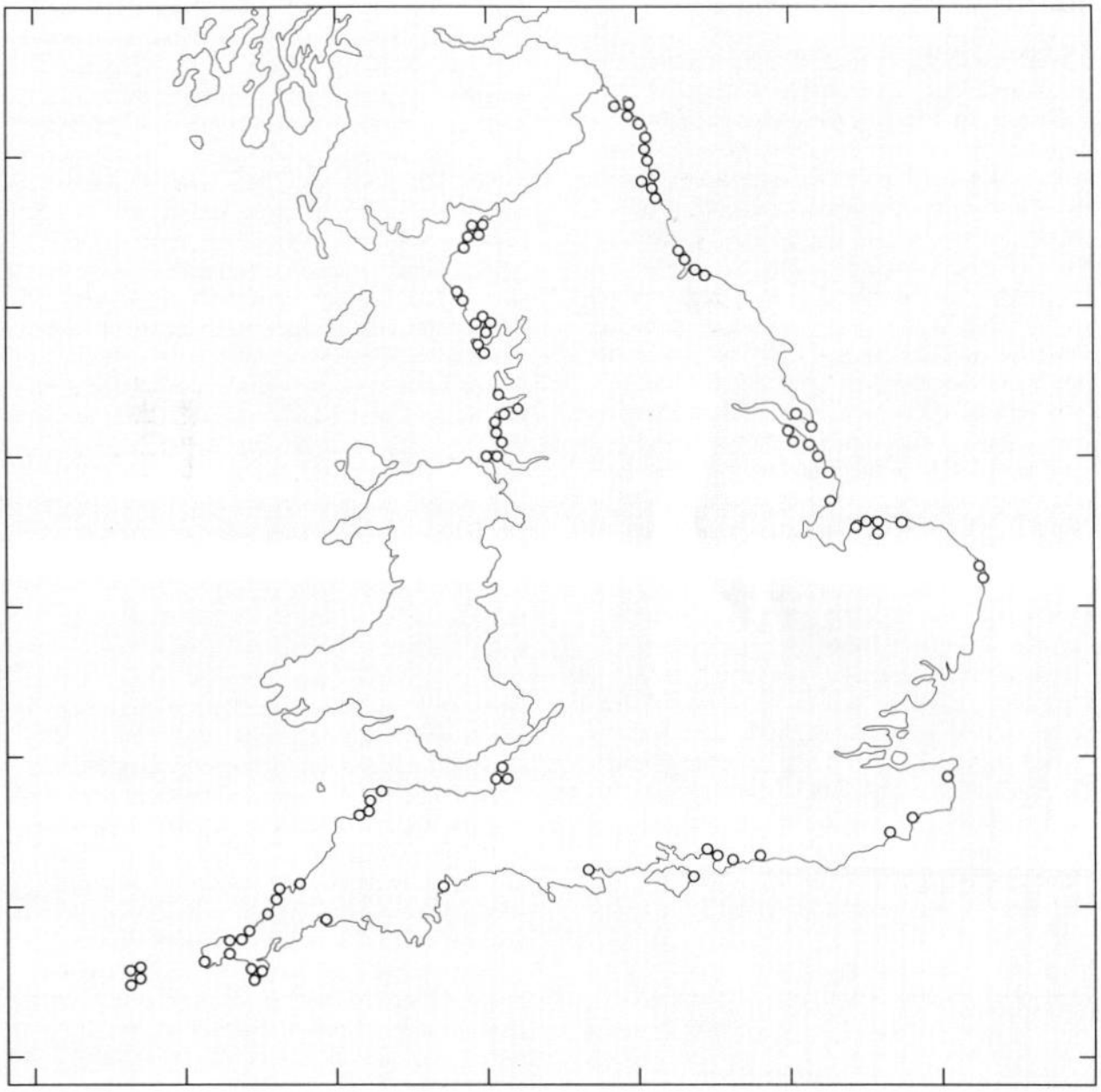

Figure 3 Dunes in England covered by the sand dune survey. Symbols refer to sand dune sites within 5 km squares. The number of symbols is less than the number of sites as two or more closely spaced sites may be represented by one symbol.

3.2 Geomorphological structure

The number of sites from which each type of geomorphological structure was recorded is shown in Table 3. Bay dunes were the most common with 67 records. They typically form where a limited supply of sand is trapped within the shelter of two headlands and consist of a single, narrow band of dunes. The distribution of these (Figure 4) shows that they are largely confined to the north and west, with no records from the south and east coasts between Par in Cornwall and Skegness in Lincolnshire. In the north and west they are generally distributed, with a particularly high concentration along the Northumberland coast. Here they make up a large proportion of the total length of coastline and include the Druridge Bay dunes (Site report No. 32), which extend continuously for some 10 km.

Spit dunes form as sandy promontories at the mouths of estuaries, often forming a fan-like series of dune ridges and intervening slacks, with the handle of the fan tied to the mainland. These were the next most abundant type and were recorded from 35 sites. They are more generally distributed (Figure 5) than bay dunes, some of the largest examples being in Cumbria. There is a particularly clearly developed pair of spits flanking the estuaries of the Irt, Mite and Esk at Ravenglass (Site reports No. 9 and 19).

The largest dunes of the English coast are the hindshore systems. These are comparatively scarce and are found only on westerly facing coasts where there is a combination of abundant sediment supply, a shallow offshore zone and exposure to strong onshore winds. Large quantities of sand can be driven landwards in huge arcs or ridges which continue to erode and move until eventually stabilised at a considerable distance from the sea. The passage of these waves of sand often leaves behind areas that have been eroded down to the water table and this type of dune frequently contains extensive dune slacks. The distribution of the thirteen sites where hindshore systems were recorded is shown in Figure 6. These thirteen records represent only five separate systems; eight are subdivisions of the Sefton Coast, Merseyside (CSD Report No. 917), the largest single dune system in the country. Two more are subdivisions of the St Ives Bay dunes in north Cornwall (Site reports No. 8 and 11). The other three systems are Braunton Burrows in north Devon (Site report No.138), Penhale (Site report No. 4) and Holywell Dunes (Site report No. 5), both in north Cornwall.

Table 3 Numbers of sites containing examples of each geomorphological type of dune system in England

Geomorphological type	Number of sites
Bay dunes	67
Spit dunes	35
Hindshore dunes	13
Nesses and cuspate foreland dunes	6
Offshore island dunes	6
Climbing dunes	18
Tombolos	2

Offshore island dunes usually rest on ridges of coarse, freely draining deposits of sand or shingle formed under high energy conditions. They are frequently long and thin and often tend to grow in the dominant direction of longshore drift. Extensive areas of saltmarsh and mudflat may form on their landward sides. They are another scarce type, though with a very different distribution to that of the hindshore systems. They were recorded from only six sites, all in Lincolnshire and north Norfolk (Figure 7). Scolt Head Island in Norfolk (Site report No. 71) is the largest and most clearly developed example. The number of offshore island dunes has been reduced by land reclamation, as has already been mentioned, but against these losses must be set the formation and stabilisation of smaller new examples at Holkham, Norfolk (Site report No. 72), Saltfleetby, Lincolnshire, and the North Lincolnshire Coast (Site report No. 40), as these systems prograde.

Nesses and cuspate forelands build out from an open coast where there is a super-abundance of sediment or where an area receives longshore drift from two directions at once. Such dunes sometimes grow as a series of low and relatively narrow ridges with sections of the former beach isolated in between and developing into slacks.

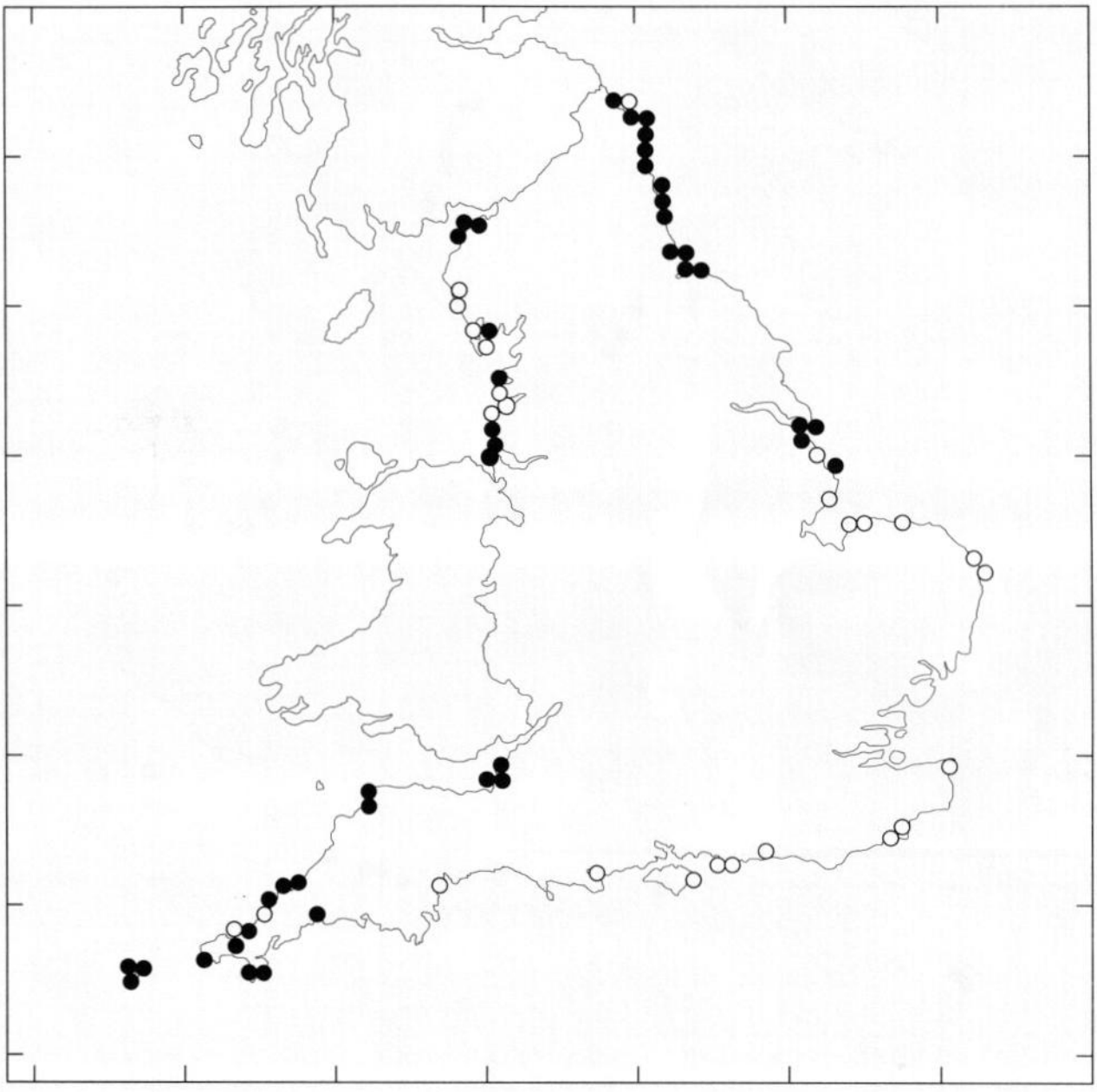

Figure 4 Distribution of bay dunes in England. Symbols refer to 10 km squares.
○ Bay dunes absent
● Bay dunes present

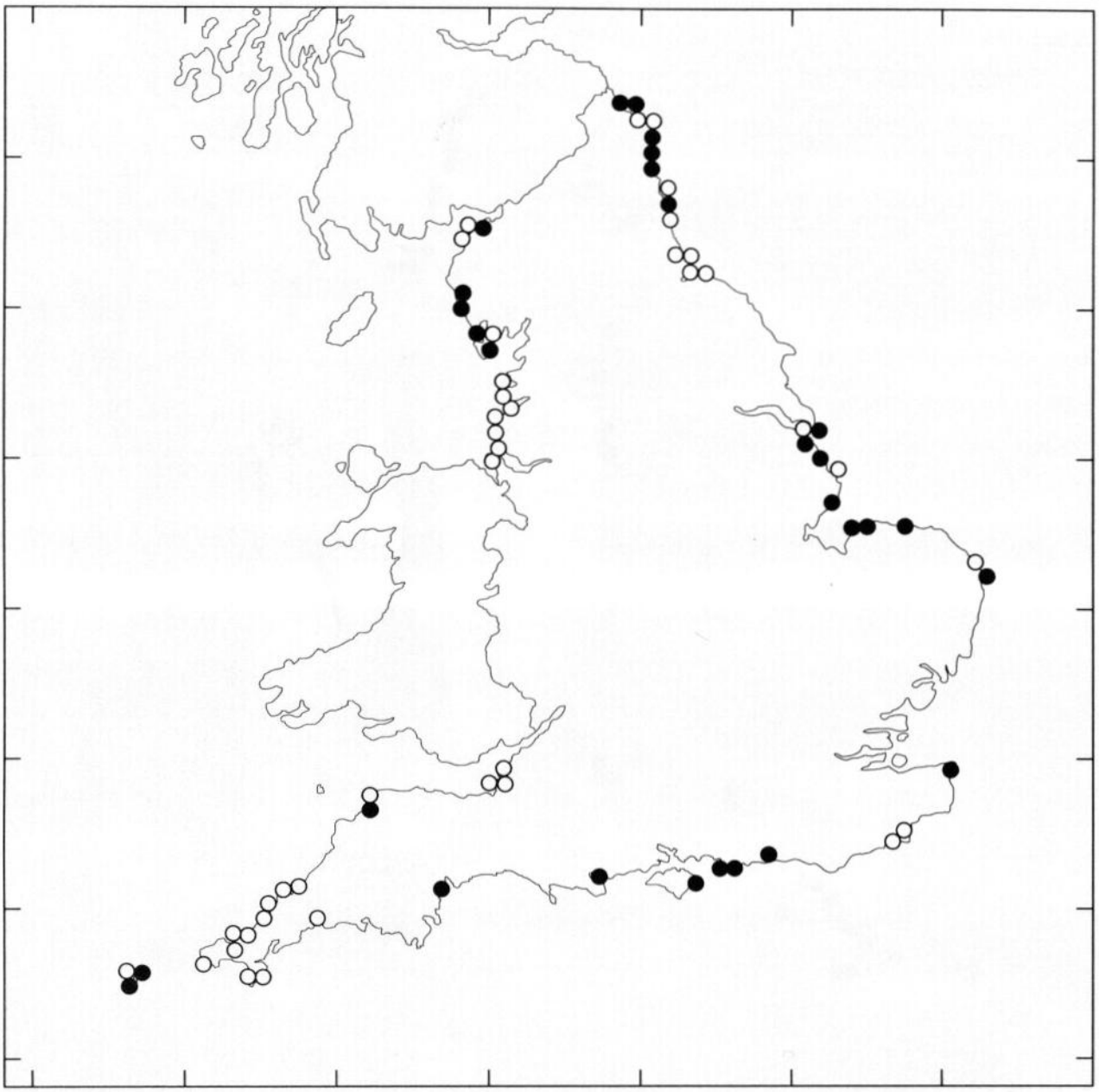

Figure 5 Distribution of spit dunes in England. Symbols refer to 10 km squares.
○ Spit dunes absent
● Spit dunes present

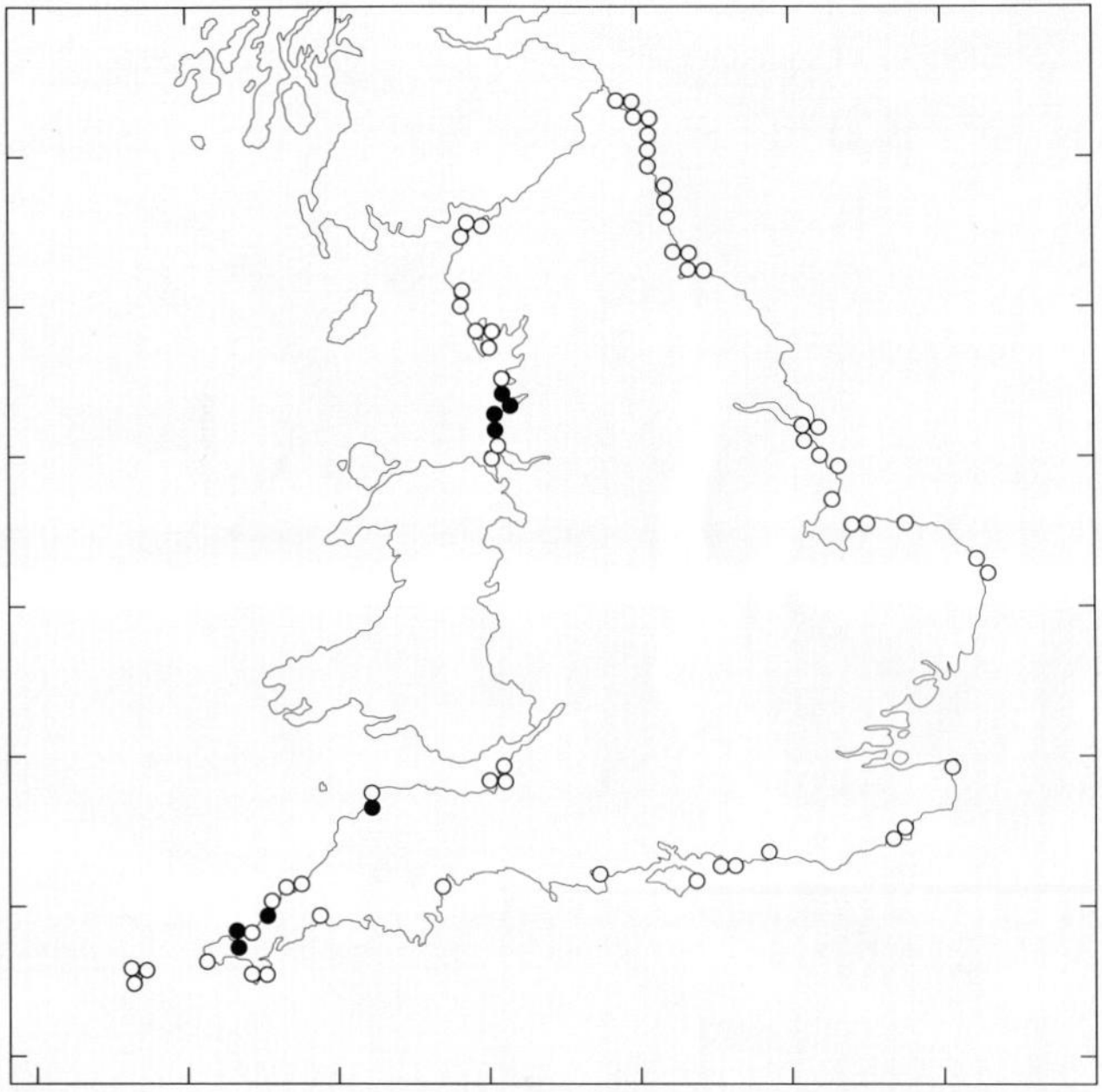

Figure 6 Distribution of hindshore dunes in England. Symbols refer to 10 km squares.
○ Hindshore dunes absent
● Hindshore dunes present

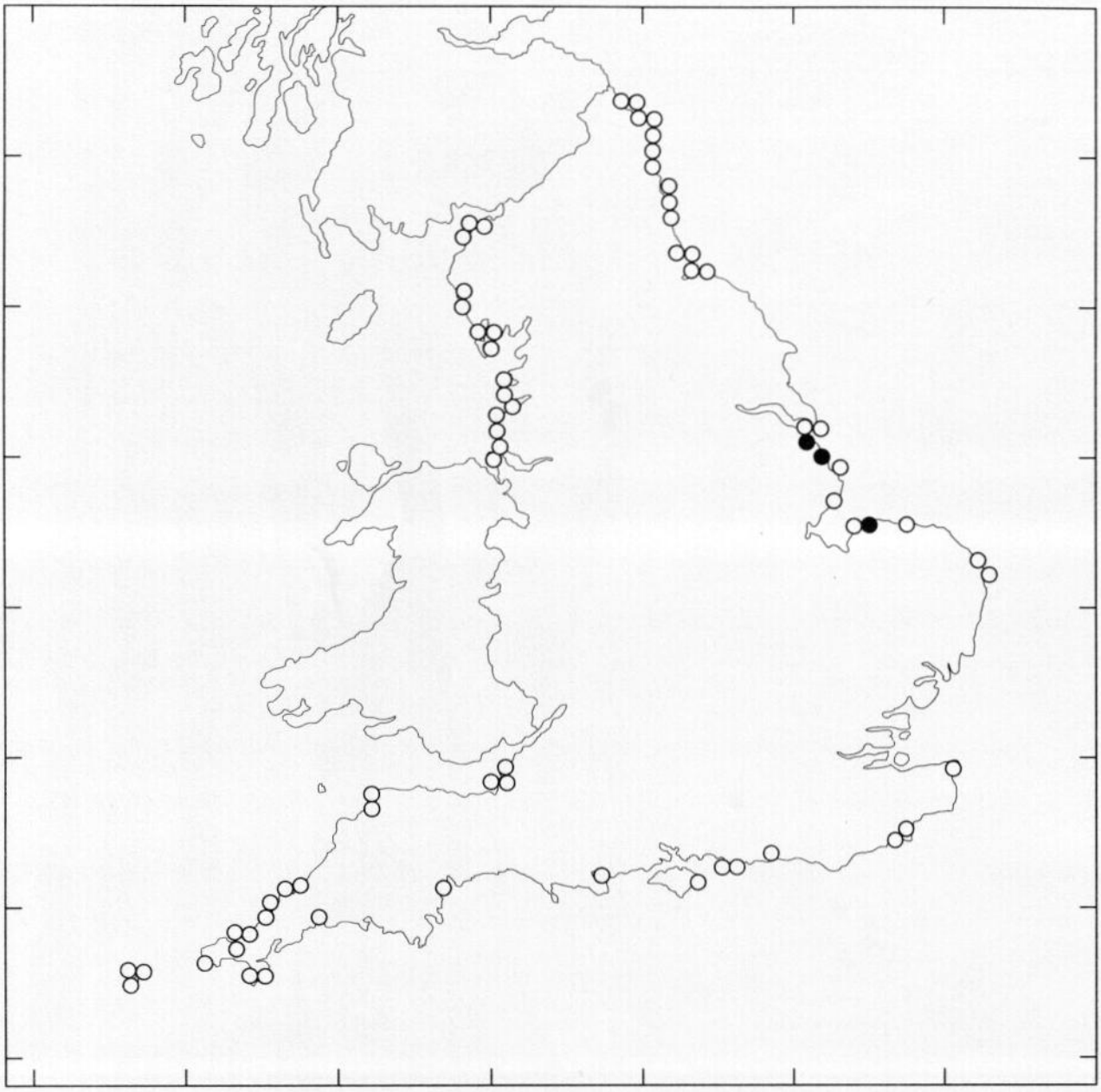

Figure 7 Distribution of offshore island dunes in England. Symbols refer to 10 km squares.
○ Other
● Offshore island dunes

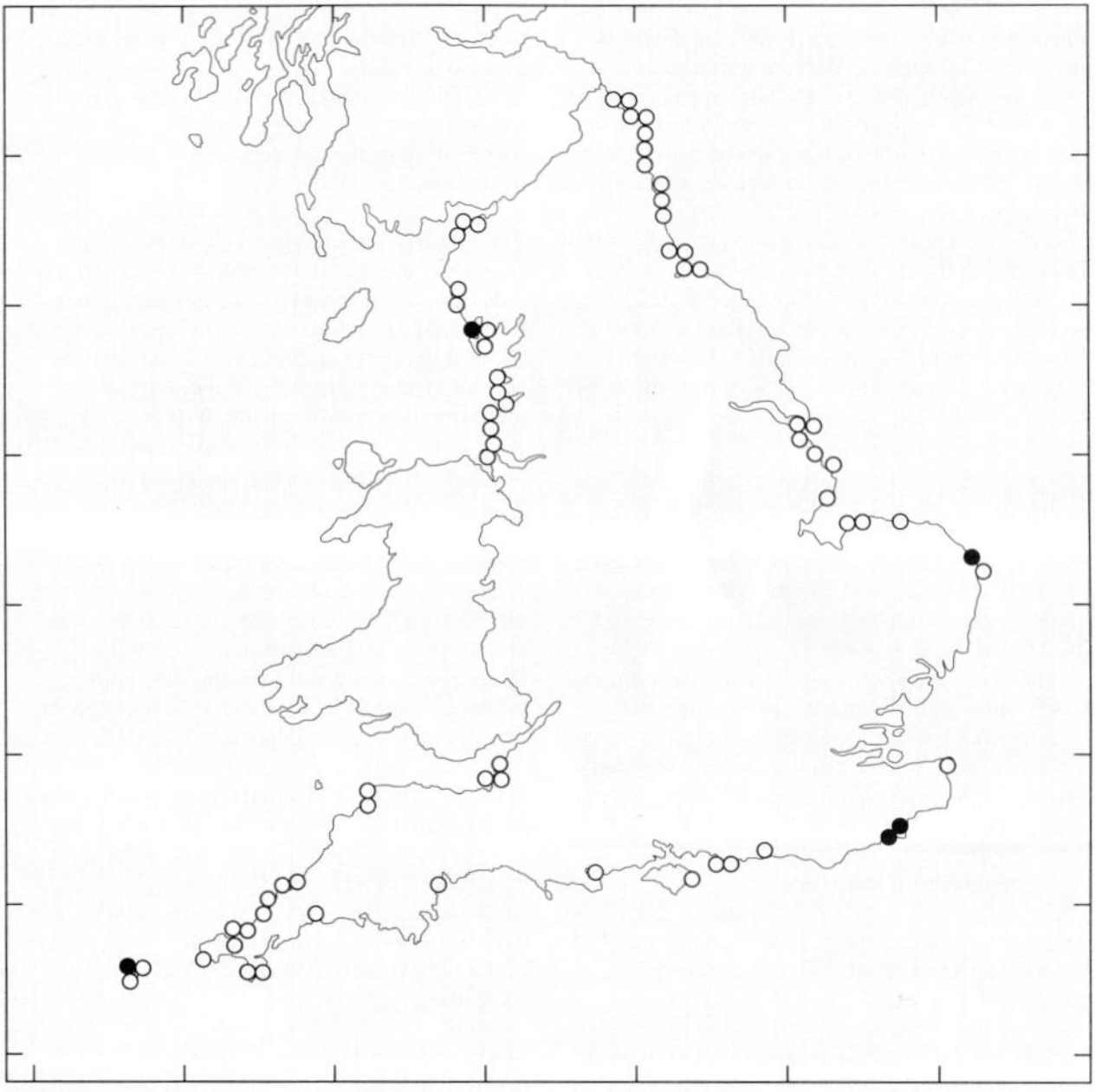

Figure 8 Distribution of ness and cuspate foreland dunes in England.
Symbols refer to 10 km squares.
○ Ness and cuspate foreland dunes absent
● Ness and cuspate foreland dunes present

They were also recorded from only six sites, but these are widely scattered (Figure 8). There is the classic example at Winterton in east Norfolk (Site report No. 74), though there appeared to be very little accretion at this site at the time of the survey. In the southeast there are two dune areas, Romney Warren (Site report No. 77) and Camber Sands (Site report No. 78) which were so classified because they occupy small parts of the Dungeness shingle structure. On the west coast there is Sandscale Haws (Site report No. 2), a well developed example in the Duddon Estuary, Cumbria. Finally, in the Isles of Scilly there is a very small system on the island of Samson (CSD Report No. 1179).

Unlike the types described above, climbing dunes can occur in a variety of situations, wherever there is higher ground adjacent to a dune system and sufficient wind energy to drive the sand up the slope. Climbing dunes were recorded from eighteen sites and are quite widely distributed in the more hilly areas, with the greatest concentrations in Cornwall and northern Northumberland (Figure 9). Tombolos form when a neck of sand is deposited between two pieces of land. They were very scarce with only two recorded, both in the Isles of Scilly.

3.3 Retreat and progradation at the beach/dune interface

The results of this survey have been summarised by dividing the 121 sites visited into five categories.

1. Sites with net marine erosion: those where the percentage of the shoreline recorded as either actively eroding or protected from erosion only by sea defences was at least 10% greater than the percentage recorded as prograding.
2. Sites with net progradation: those where the percentage of the shoreline recorded as prograding was at least 10% greater than that recorded as either eroding or protected from erosion only by sea defences.
3. Sites in approximate equilibrium: those where the percentage of the shoreline in the two categories defined above differed by less than 10%.
4. Sites of uncertain status: those where less than 10% of the shoreline could be put into either of the above categories. These may well be in approximate equilibrium but it is also possible that they are undergoing either gradual retreat or gradual advance.
5. Relict sites: dunes of coastal origin now isolated from coastal processes by land reclamation or the development of other formations.

The numbers falling into each of these five categories are shown in Table 4. Dunes with net erosion were the most numerous, accounting for 67 of the 121 sites, compared with 21 sites that showed net progradation and 12 that were in approximate equilibrium. The distribution of these three categories of site is shown in Figures 10, 11 and 12 respectively. Examination of these distribution maps confirms the general preponderance of eroding sites, but also highlights some local variations. The predominance of eroding sites is particularly marked in Northumberland, where no sites were recorded as prograding. There was a localised area of considerable accretion in south Humberside and north Lincolnshire, whilst on the north Norfolk coast there appears to be an approximate overall balance.

It is also interesting to look at the Sefton coast, Merseyside (CSD Report No. 917). This one system showed a complex pattern of local erosion and progradation. Of the eight subdivisions, five showed net erosion and three net progradation. Similar patterns could be seen in the field on some other sites with long shorelines.

There were seventeen sites where it was not possible to estimate the balance between erosion

Table 4 Summary of the dynamic status of English dune systems as recorded by the sand dune survey 1987-1990.

Dynamic status	Number of sites
Net marine erosion	67
Net progradation	21
Approximate equilibrium	12
Uncertain	17
Relict	4

Note: For full definitions of these terms see text (Section 3.3).

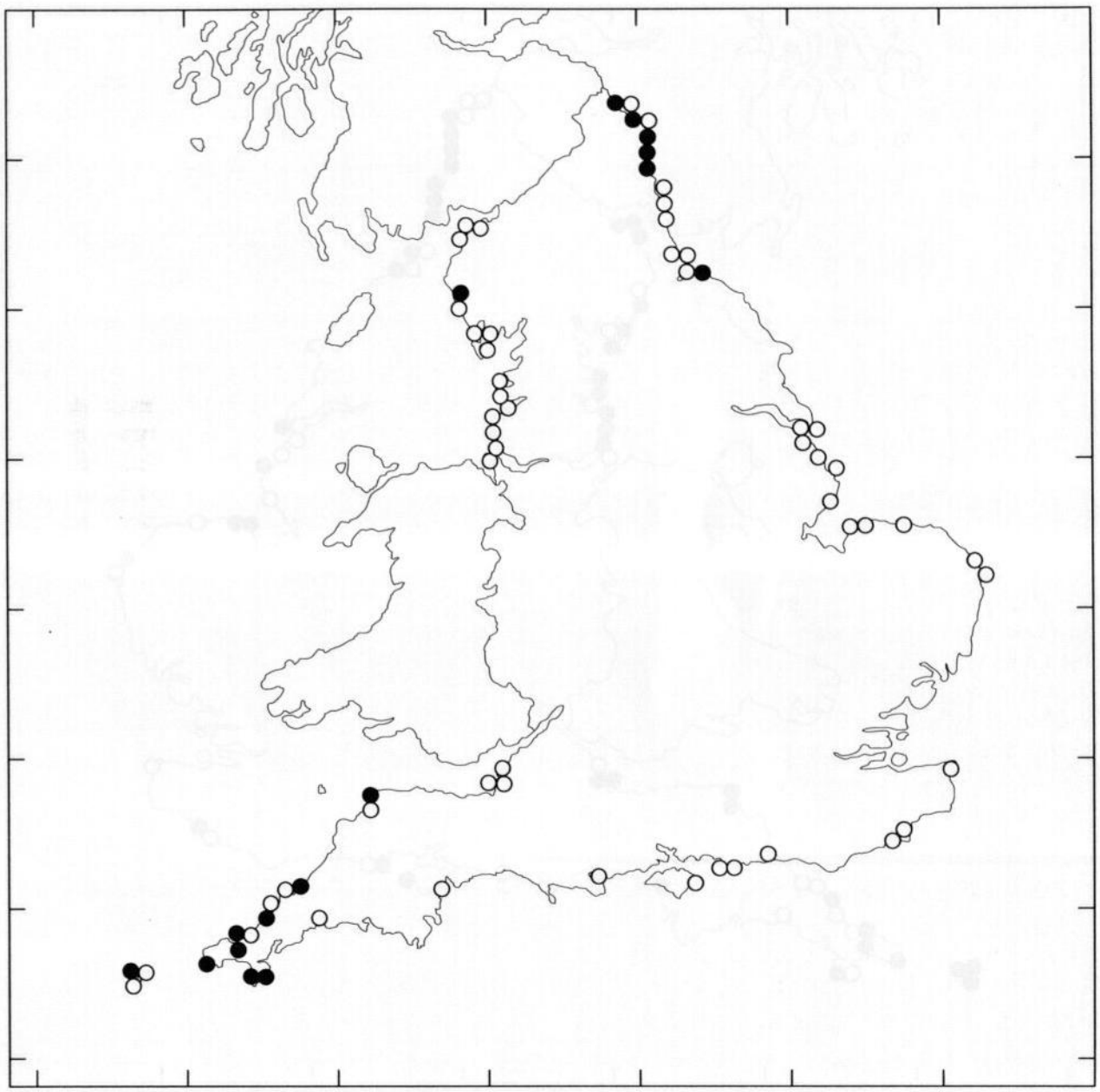

Figure 9 Distribution of climbing dunes in England. Symbols refer to 10 km squares.
○ Climbing dunes absent
● Climbing dunes present

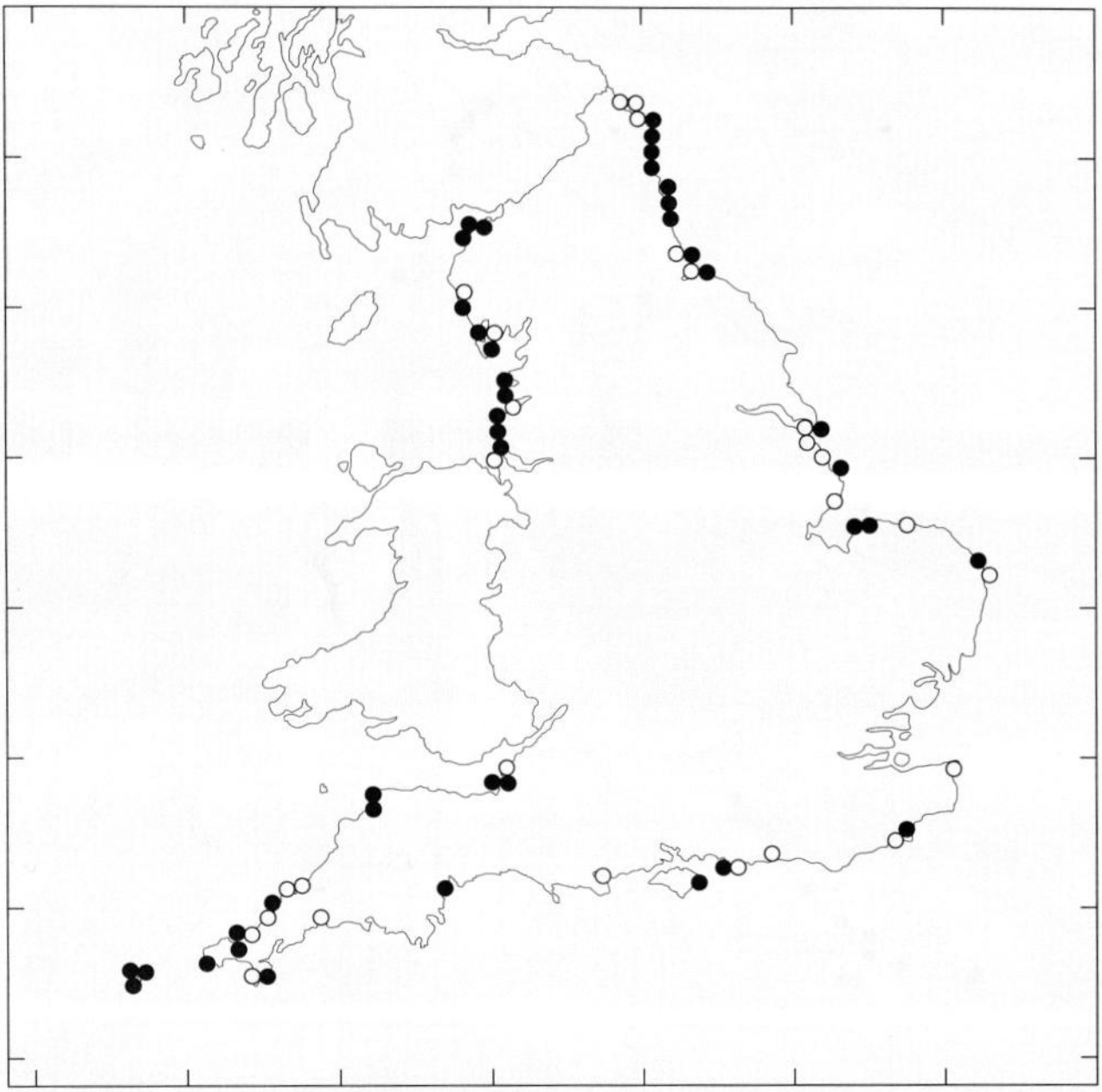

Figure 10 Distribution in England of dunes which appear to show net marine erosion. Symbols refer to 10 km squares.

○ Others

● Retreating dunes

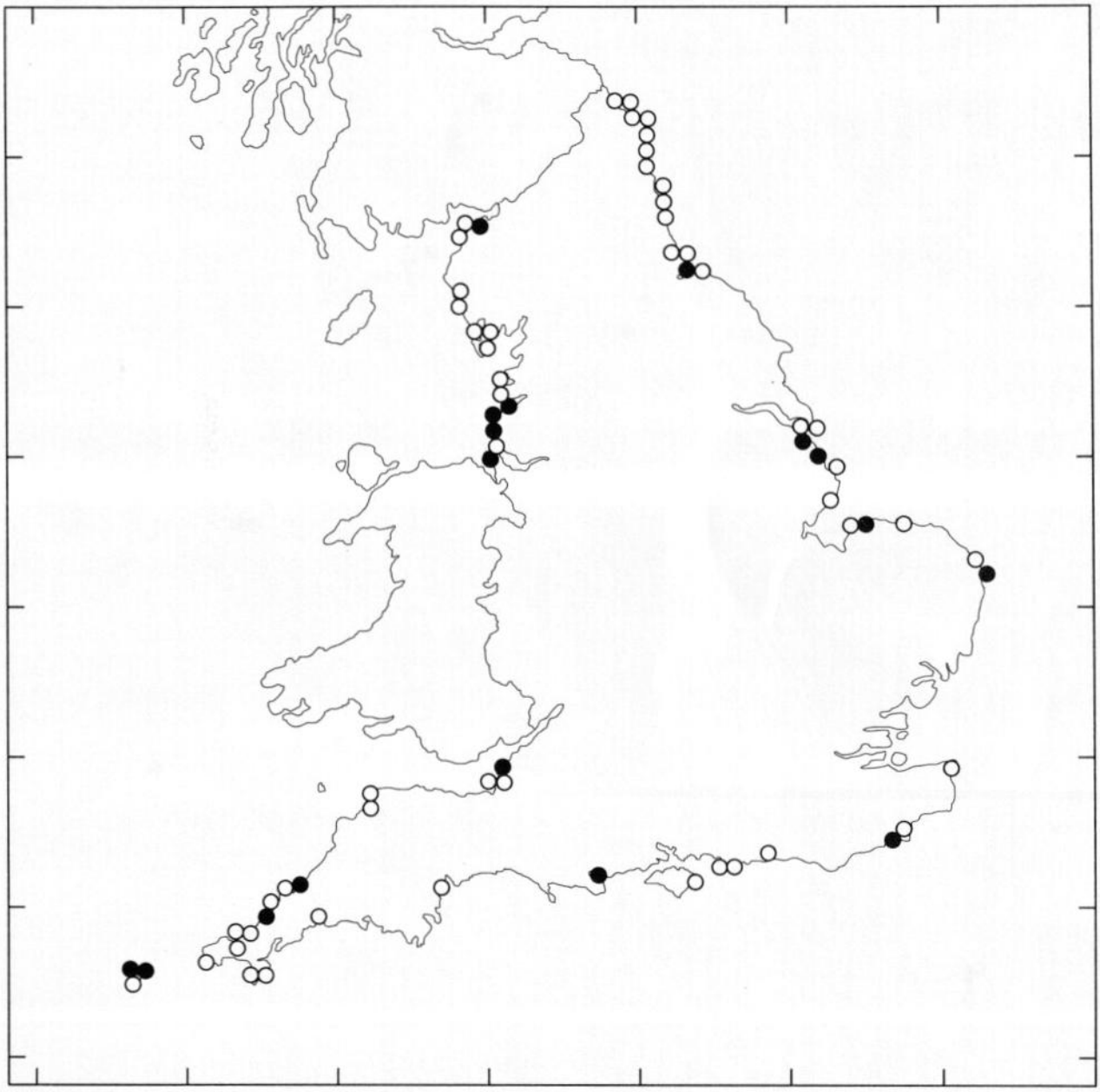

Figure 11 Distribution in England of dunes which appear to show net progradation. Symbols refer to 10 km squares.

- ○ Others
- ● Prograding dunes

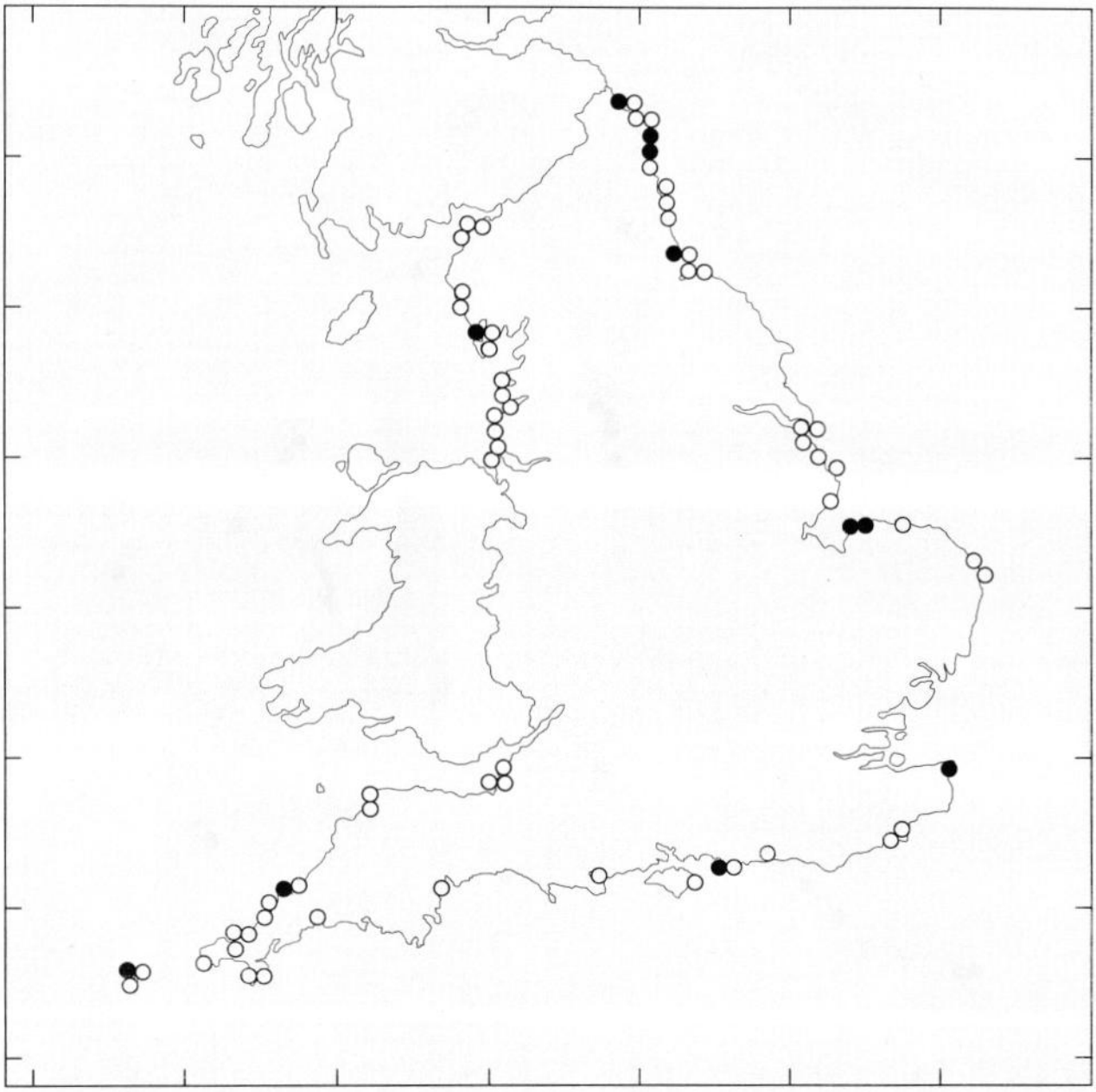

Figure 12 Distribution in England of dunes where marine erosion and progradation appear to be in approximate equilibrium. Symbols refer to 10 km squares.

○ Others

● In equilibrium

and progradation and a further four 'relict' sites. The distribution of these two classes is shown in Figures 13 and 14 respectively. Probably the clearest example of a relict system is Saltfleet Dunes in Lincolnshire (Site report No. 91). This site consists of the remnants of a sizeable dune ridge that runs parallel to the North Lincolnshire Coast Dunes (Site report No. 40). It is now separated from the present coastline by a broad strip of low-lying land, used mainly for agriculture, that probably developed as saltmarsh, but which is now protected at its seaward edge by an artificial bank.

This summary of erosion and accretion is based on very crude data and considerably simplifies the complexities occurring within individual sites. Some indication of these can be seen in the case of Druridge Bay in Northumberland (Site report No. 32). At the time of the survey there was quite rapid erosion at both ends of this long bay dune system, but in the central part there was evidence of cyclical change. Along one stretch of the dune front at the time of the survey there was a line of Second World War anti-tank blocks that appeared to have been buried under several metres of sand by advancing dunes. They had then been partially re-exposed in an eroding dune face, and at the time of the survey they were partially reburied by freshly accumulated sand. This suggests that there may be cyclical change both seasonally and over longer periods.

Despite such complexities, the overall conclusion that there are considerably more sites that are retreating than are advancing is consistent with the findings of other authors (Bird 1985; May 1985).

3.4 The impact of human activities

3.4.1 Interpretation and limitations of the data

The ways in which information on the impact of human activities on dunes was collected are fully described in Chapter 2. The most serious limitation of these data is that they are 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 these 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 estimate subjectively the level of an activity. This was the case for grazing, erosion and vehicle damage. In these fields an effort was made to achieve consistency by relying mainly on the judgement of one individual, the project leader G.P. Radley.

Despite these limitations the information collected on human activities does have the advantage of having been collected from all significant dune areas in England within the period 1987 to 1990. 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 not readily available from other sources.

3.4.2 Agriculture

The dunes of England have probably been shaped and moulded by agriculture for most of their existence. The characteristic semi-natural vegetation of most stable dunes is grassland or heathland which has developed as a result of grazing of the indigenous vegetation by sheep, rabbits and cattle. In the absence of such grazing, most areas of stable dune would probably have developed into some form of woodland. Dune woodlands are common in The Netherlands (Houston 1983), where the tradition of pastoral management of dunes is much less widespread.

During this survey grazing by domestic stock was recorded from only 34 out of 121 dune sites. There are clear regional variations. As can be seen from Figure 15, the greatest concentrations of stock-grazed dunes were in the north and west, where livestock farming is generally strongest. In the south and east stock grazing was

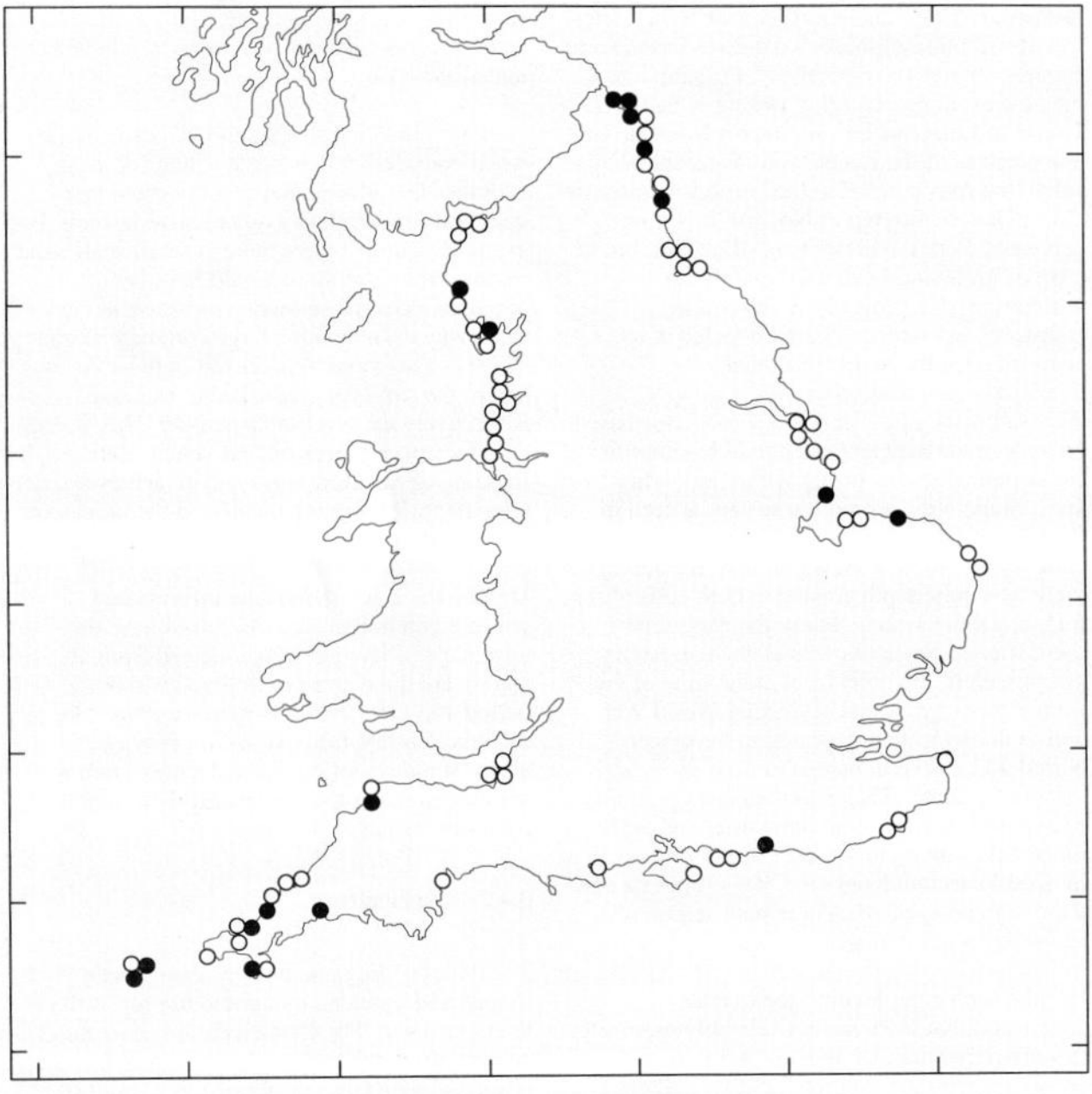

Figure 13 Distribution of dunes in England whose erosional status is uncertain.
Symbols refer to 10 km squares.
○ Others
● Status uncertain

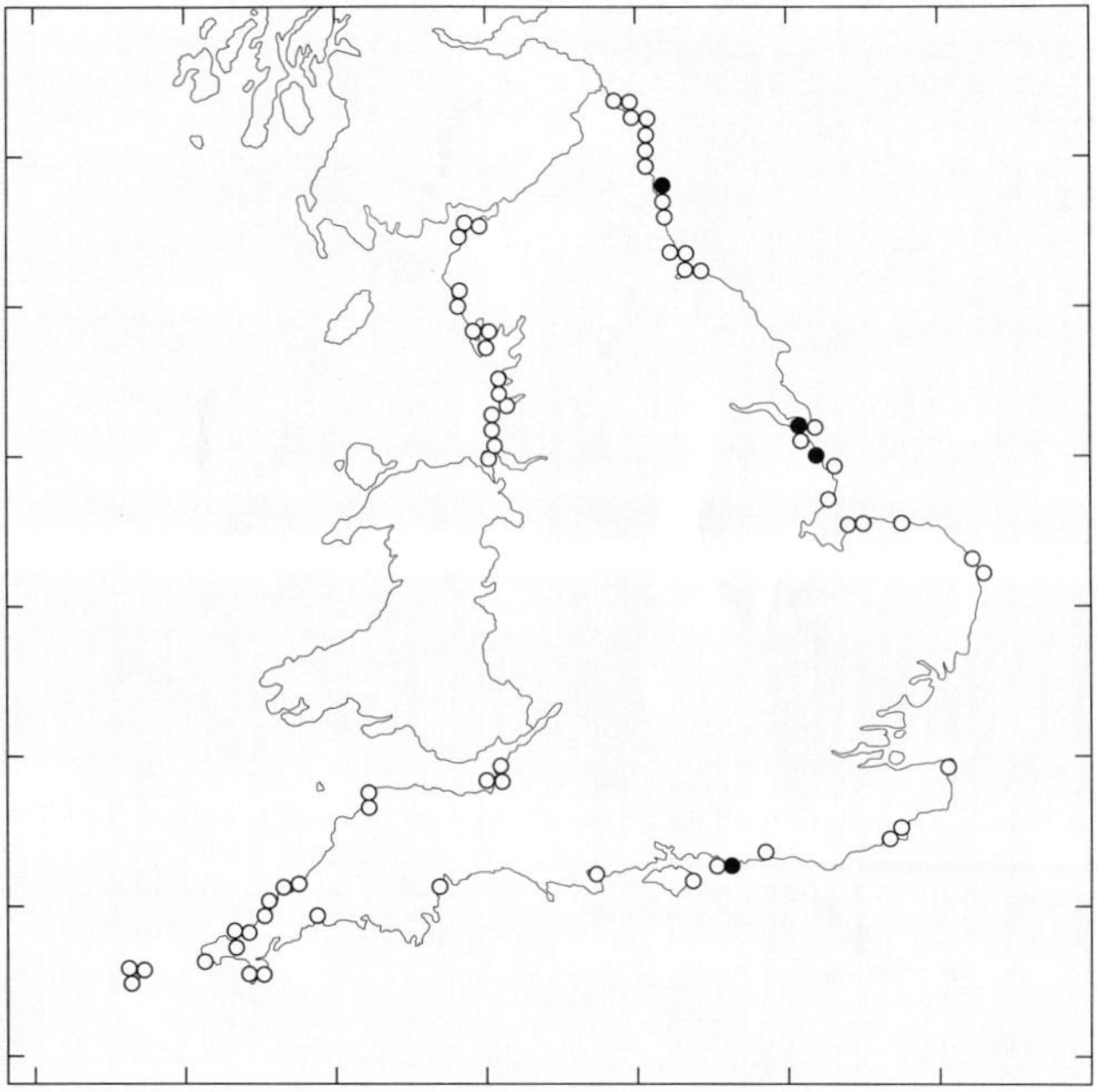

Figure 14 Distribution in England of relict dunes, removed from current coastal processes. Symbols refer to 10 km squares.

○ Others

● Relict

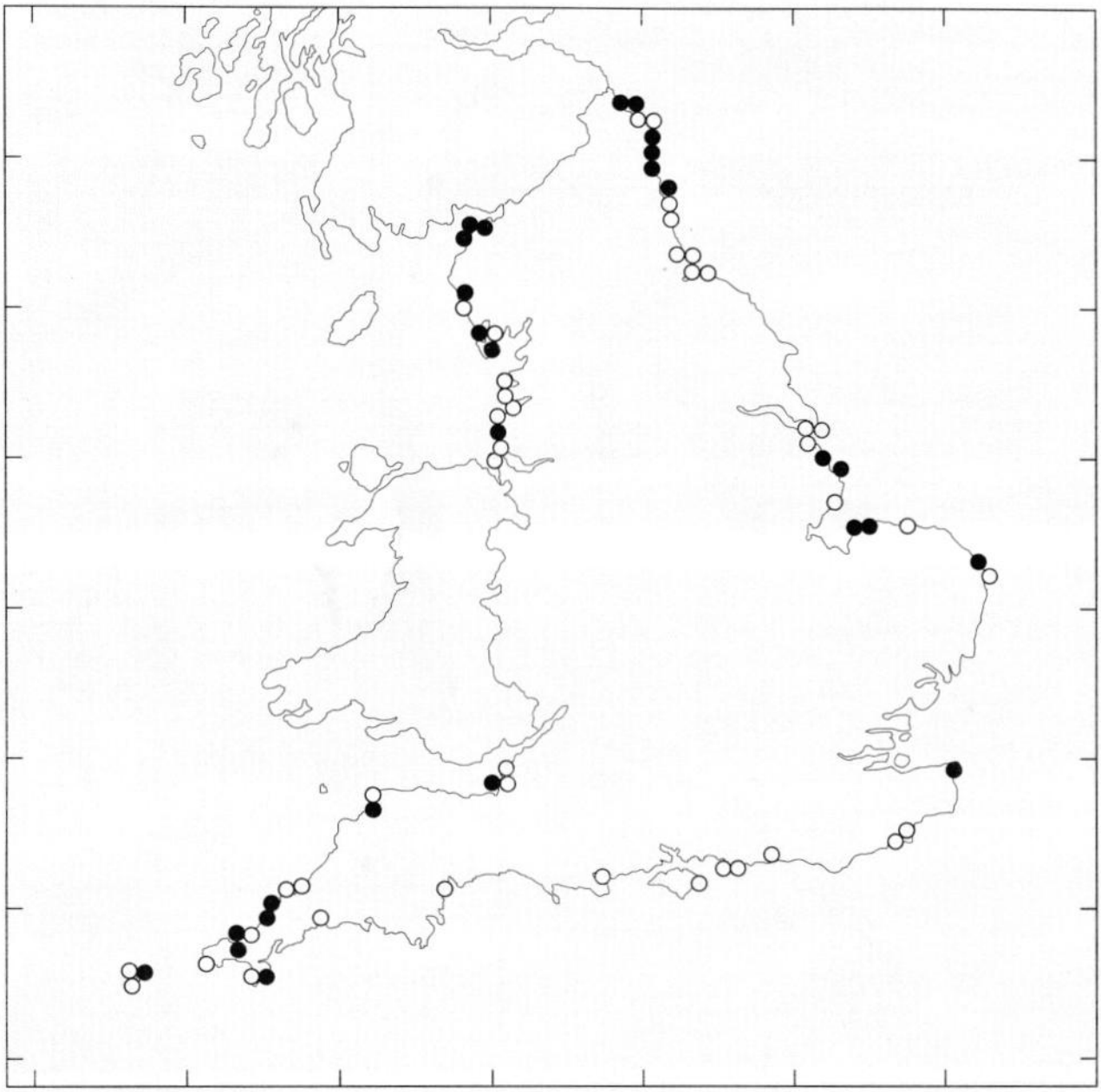

Figure 15 Distribution in England of dunes where grazing by domestic livestock was noted. Symbols refer to 10 km squares.

○ Not grazed

● Stock-grazed

rarely seen. Even where it was recorded, it was often from only limited areas and sometimes represented horse grazing rather than agricultural livestock. Even in the north and west not all dunes were grazed. Figure 15 shows some sizeable gaps, mainly around the major urban centres of Merseyside, Cleveland and Newcastle.

It is possible that stock grazing was missed on a few sites during this survey. However, the signs of recent stock grazing – fencing, dung, water supplies, mineral licks etc. – are relatively easy to spot, so it is unlikely that this activity has been seriously under-recorded.

One reason for the comparative scarcity of stock grazing in the south and east is the displacement of agriculture by leisure activities. Henderson (1986) chronicles an example of this process at Sandwich Bay in Kent, where sheep grazing has been replaced as the major land use by golf course development. Similar changes have doubtless taken place on many other dunes, including some in the north and west. Such changes cannot, however, explain the whole picture. In many cases lack of grazing appears to reflect inland farming systems that concentrate on arable production. The lack of any other pasture or livestock enterprises within the farm units means that is difficult to make economic use of areas of rough grazing such as sand dunes.

Where grazing management has survived, it has often undergone great changes. A widespread farming system, especially in north-east England, involves the use of dunes as winter holding grounds for large numbers of intensively fed cattle. This form of management results in massive inputs of nutrients and organic material to the dune soils which completely alter the dune vegetation. The results of this practice can be seen particularly clearly at Ross Links (Site report No. 21) and Druridge Bay (Site report No. 32), both in Northumberland. Evidence of winter stock feeding was recorded from eighteen out of the 121 sites visited. The distribution of these sites is shown in Figure 16.

Agricultural improvements such as reseeding, ploughing, fertilising, drainage, irrigation and the use of herbicides were recorded from 27 out of the 121 dunes surveyed. Figure 17 shows that most of these sites were in the north and west, and many appeared to be associated with sites where there was a continuing use of the dunes for pasture. It must, however, be stressed that this by no means represents the total extent to which agricultural improvement has affected dunes. The areas chosen for survey were those which appeared to support semi-natural vegetation. Land that had been turned into arable fields or grass leys would not normally have been included, unless the conversion had taken place since the date of the aerial photographs or unless it affected a pocket within surviving semi-natural dune. The historical loss of dune vegetation to intensive agriculture is likely to have been very significant, but it cannot be estimated from these data.

Rabbits are no longer kept commercially in warrens in England, but this practice was formerly widespread. Rabbits spread from these warrens and became widely established as wild animals (Sheail 1971). The introduction of the disease myxomatosis drastically reduced the wild populations in the 1950s, but since then they have staged a partial recovery. Rabbits were recorded from 81 out of the 121 dunes surveyed and Figure 18 shows that they were found around all parts of the English coast. It is likely that the presence of rabbits was under-recorded during this survey but even so it is clear that the rabbit is the most widespread grazing animal on dunes in England. The level of rabbit activity only rarely reached very high levels. One site where it did was Blakeney Point, Norfolk (Site report No. 73). The factors controlling rabbit numbers are not at all clear, though some work has been done at Lindisfarne (Garson 1985) and in The Netherlands (Wallage Drees 1988). The Norfolk dunes illustrate the complexities, for whilst Blakeney had a high level of rabbit activity, the nearby Holkham dunes (Site report No. 72) and the structurally similar Scolt Head Island (Site report No. 71) both had only low levels of activity at the time of the survey.

3.4.3 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 a number of indirect indicators of the level of recreational activity were used.

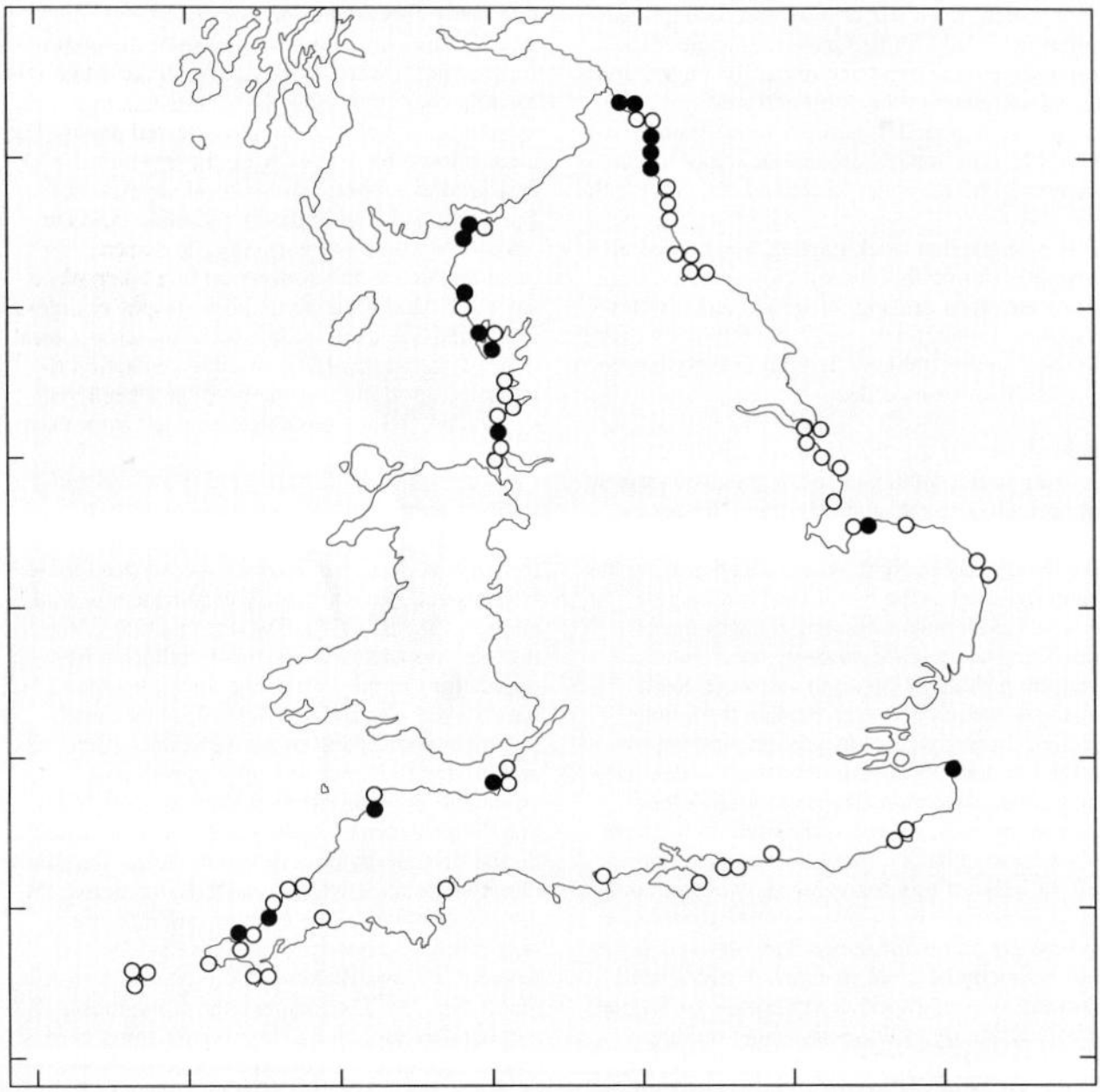

Figure 16 Distribution in England of dunes where stock-feeding was recorded. Symbols refer to 10 km squares.
○ No stock-feeding
● Stock-feeding

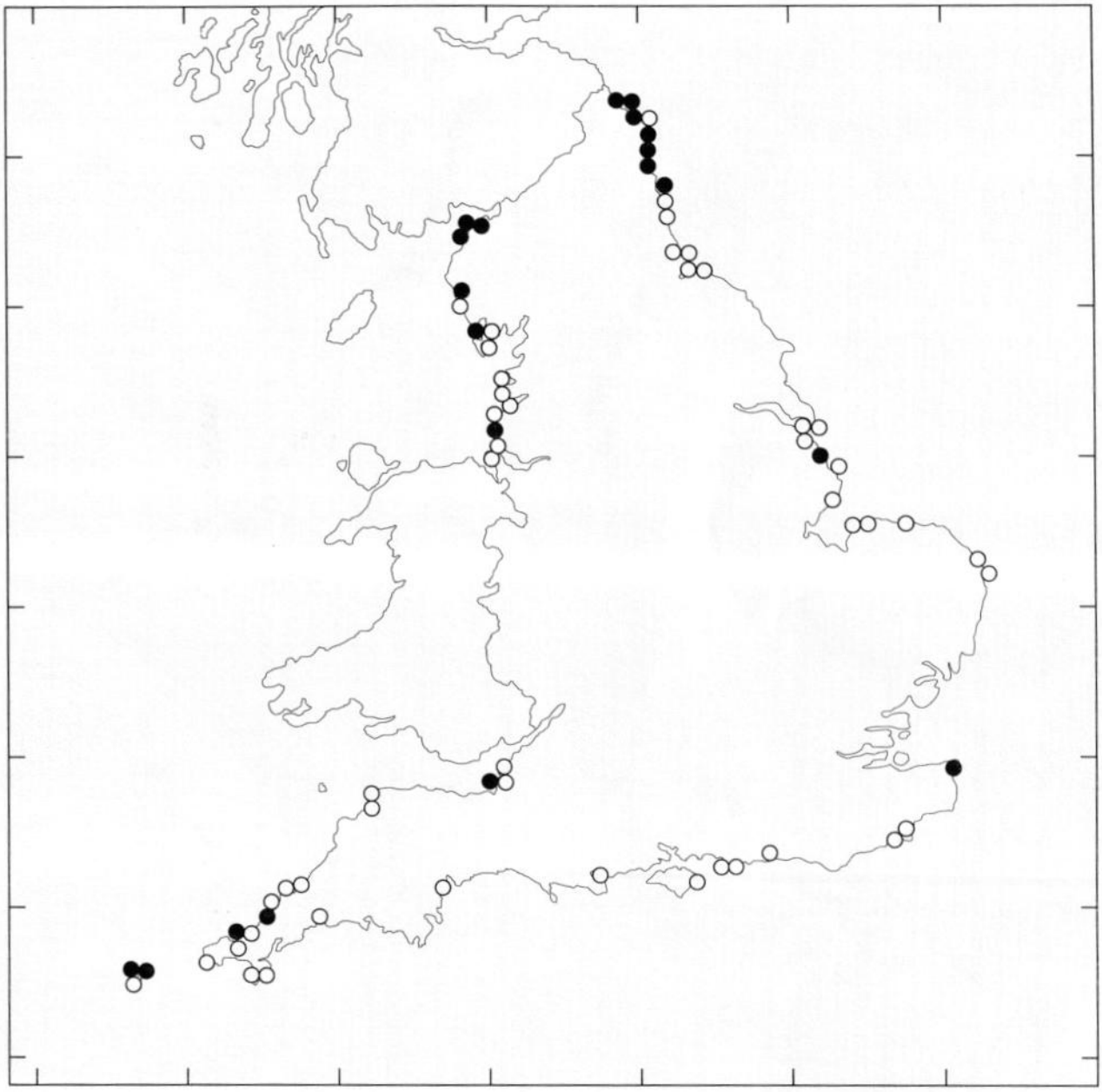

Figure 17 Distribution in England of dunes where agricultural improvements were recorded. Symbols refer to 10 km squares.
○ No improvement
● Improvement

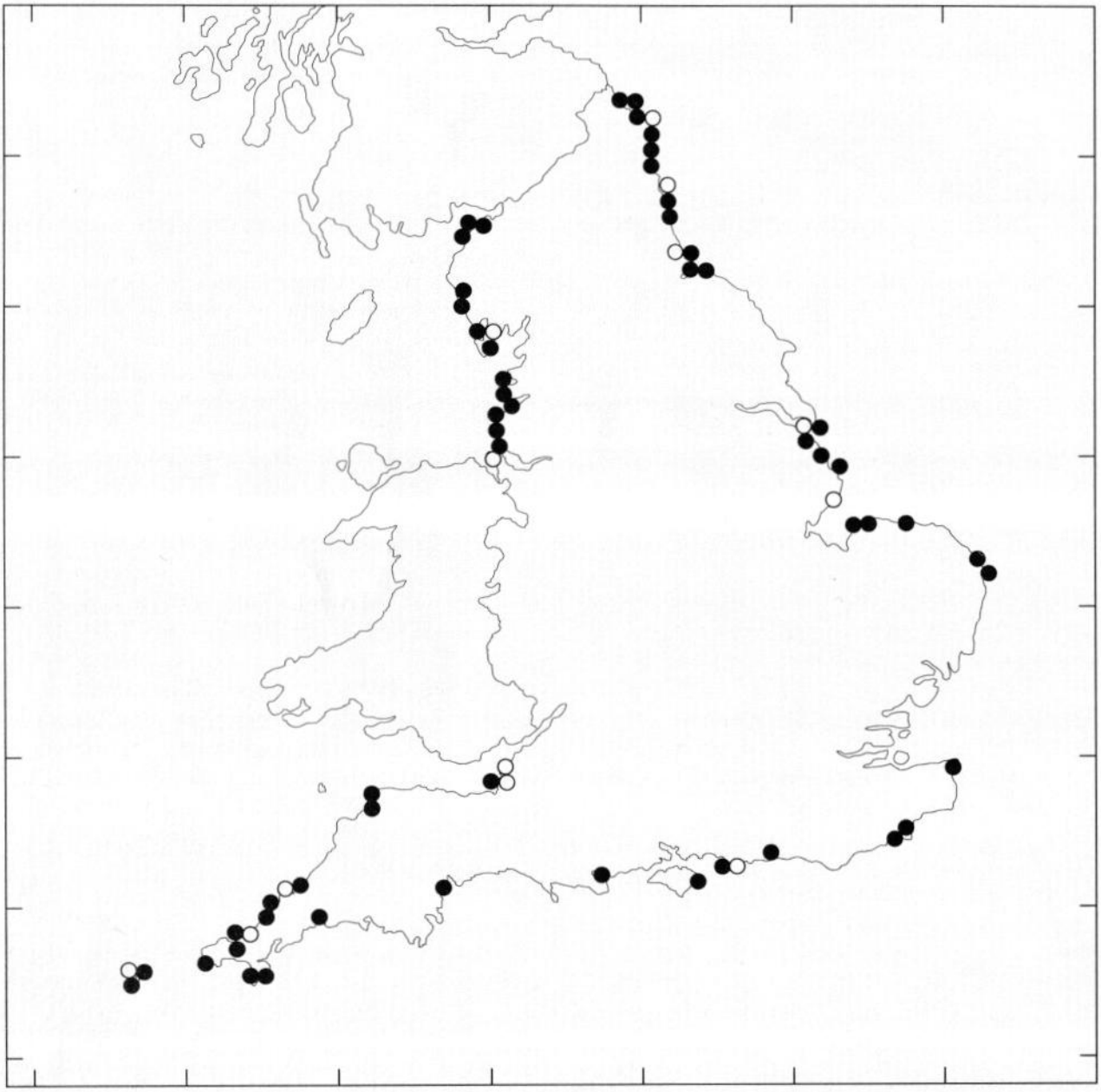

Figure 18 Distribution in England of dunes where rabbit grazing was recorded. Symbols refer to 10 km squares.
○ None recorded
● Recorded

Several authors have documented the effects of visitors, which can include a proliferation of path networks and widespread erosion (Liddle & Greig-Smith 1975a, 1975b; Boorman & Fuller 1977; Richards & Stead 1978). An attempt was therefore made during the present survey to categorise subjectively the degree of erosion damage as a measure of recreational use. Moderate or severe erosion was recorded from at least part of 81 out of the 121 sites surveyed and Figure 19 shows that these sites were widely distributed. Eight out of the 121 sites were recorded as having widespread, severe erosion. Figure 20 shows that these are concentrated around major centres of population and in Cornwall.

The impact of recreation on dunes is greatest in the vicinity of fixed facilities such as caravan sites, beach huts, and particularly car parks (Williams & Randerson 1989). Sixty-three out of the 121 dunes surveyed contained at least one such facility and Figure 21 shows that these are distributed throughout the country. A similar pattern emerges for leisure developments adjacent to dunes. These were recorded from 53 out of the 121 sites and were again widely distributed (Figure 22).

The use of offroad vehicles is a form of recreation that can cause considerable erosion. Examples of sites where the effects were obvious at the time of the survey include the South Gare section of the Tees Bay dunes (Site report No. 38) and Newbiggin dunes in Northumberland (Site report No. 35). Moderate or severe vehicle damage was recorded from 23 of the 121 dunes surveyed and Figure 23 shows that these were widely distributed.

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 1989) and many features of modern golf courses have their origin in the natural topography of links grassland. Golf courses were recorded on 32 of the 121 sites surveyed and Figure 24 shows that these were widely distributed. Golf courses only rarely result in the total destruction of semi-natural vegetation but the modern game does seem to require the greens and tees to be converted to a completely artificial sward, whilst the fairways are normally also highly modified. The least modified dune vegetation is usually found in the areas of rough.

There is enormous variation in the relative areas of unmodifed rough, modified semi-natural and artificial sward within the course boundaries. For this survey the recorders were asked to estimate the percentages of the total area of the course that fell into these three categories. Figure 25 shows the variation in the percentage of artificial sward recorded from within golf courses on dunes in England. A typical value is in the range 41–60%. The variation in the recorded percentage of unmodified dune vegetation is shown in Figure 26. On eight out of the 30 courses for which figures were available, more than 40% of the course area was unmodified rough, but on twelve out of the 30 courses it occupied 20% or less.

This range of variation can be illustrated by comparing the Royal St George Golf Club on the Sandwich Bay dunes in Kent (Site report No. 76) with some of the smaller courses such as the Trevose Head Golf and Country Club on the Constantine Bay dunes in Cornwall (Site report No. 10).

Looking at the range and diversity of recreational activities on dunes in England there can be no question that recreation is a major form of land use, and one that now affects far more sites than stock grazing. Rather than pick out sites that are heavily affected, it is probably easier to highlight some that are not. These include Scolt Head Island, Norfolk (Site report No. 71), an offshore island with limited access; Drigg Dunes, Cumbria (Site report No. 9), which is adjacent to the Sellafield nuclear reprocessing plant; and those sites used by the Ministry of Defence (MoD). Of these last, Penhale Dunes, Cornwall (Site report No. 4), is of special interest as the area occupied by the MoD, the northern half of the site, offers a sharp contrast with the remainder of the site. Within the MoD boundary the dunes are largely undisturbed; outside it there is a large holiday camp and a golf course. Much of the remaining undeveloped area outside the MoD boundary shows considerable erosion.

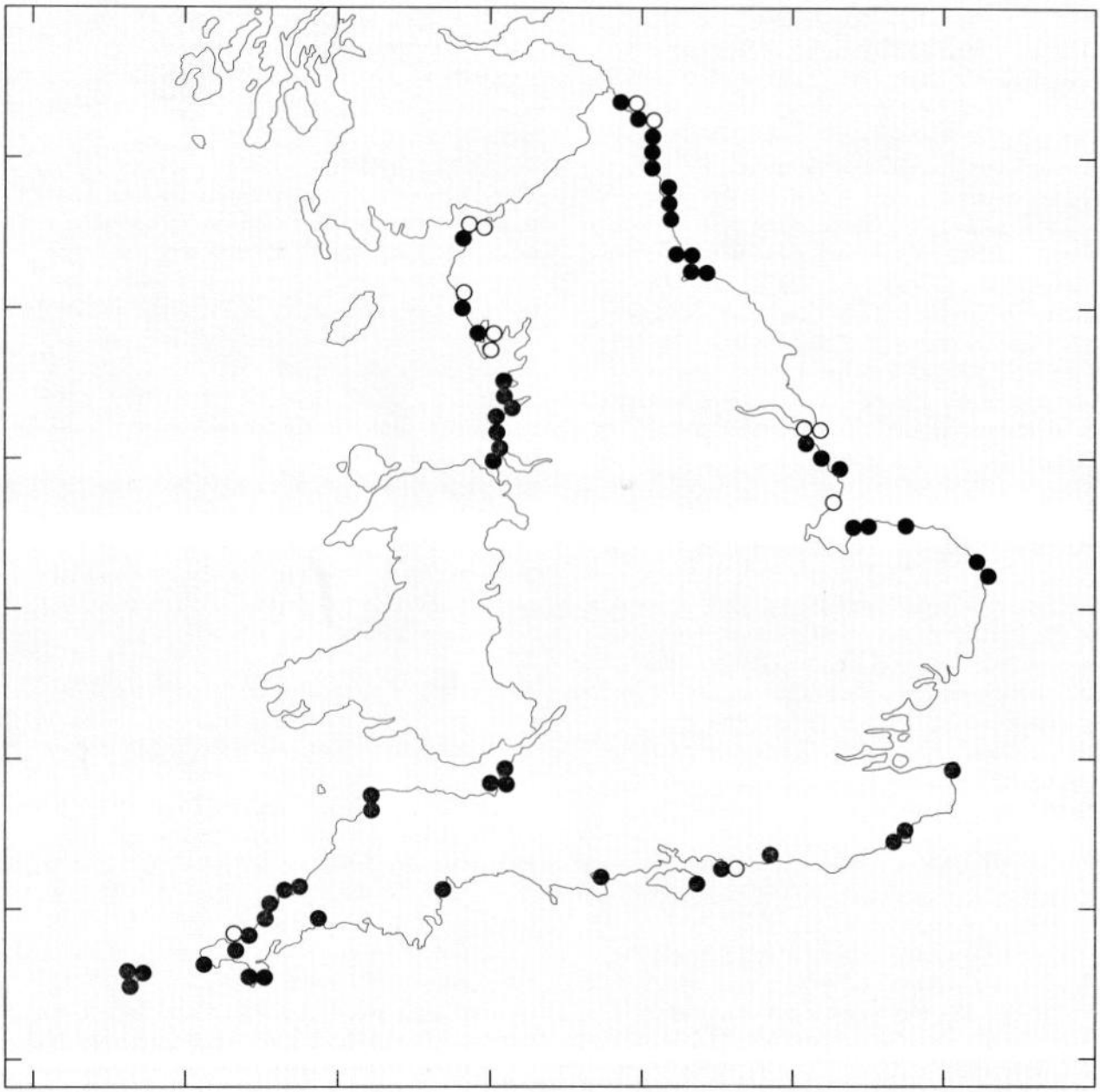

Figure 19 Distribution in England of dunes where moderate or severe erosion due to trampling was recorded for at least part of the site. Symbols refer to 10 km squares.

○ Little or no erosion

● Moderate or severe erosion

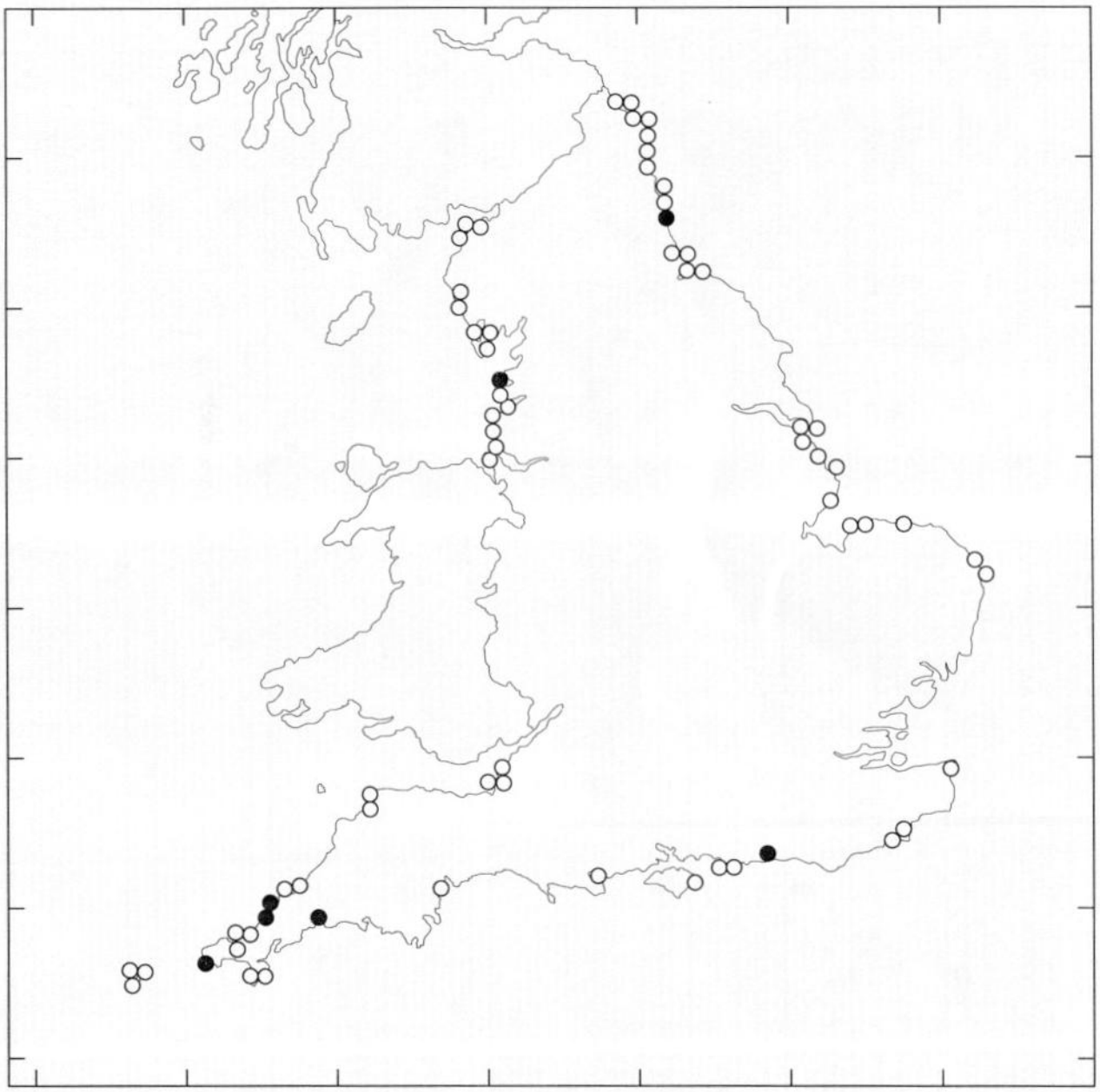

Figure 20 Distribution in England of dunes where severe erosion and widespread erosion due to trampling was recorded. Symbols refer to 10 km squares.
○ Less severe erosion
● Severe and widespread erosion

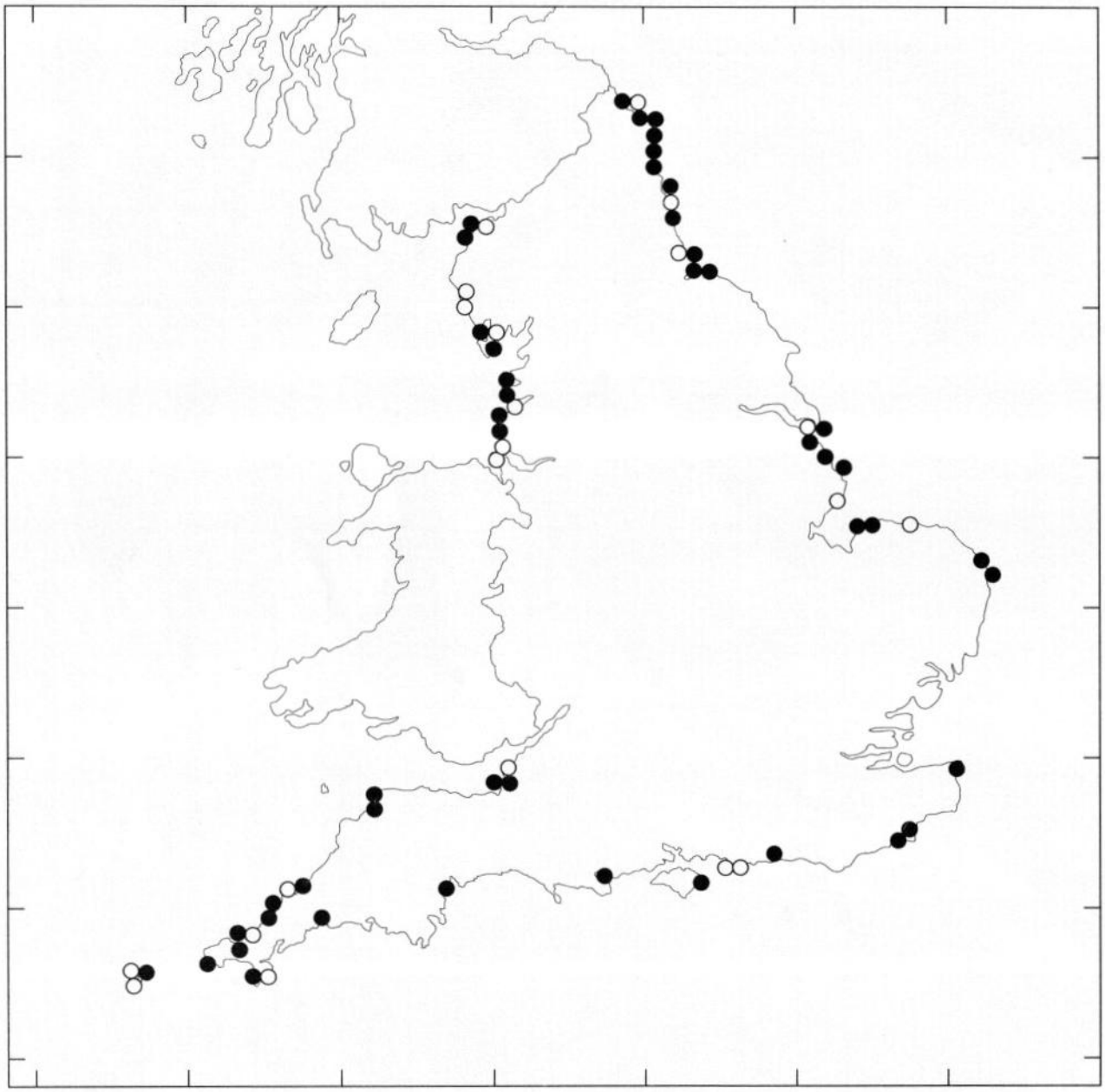

Figure 21 Distribution in England of dunes where leisure facilities were recorded on the site. Symbols refer to 10 km squares.
○ No facilities
● Facilities

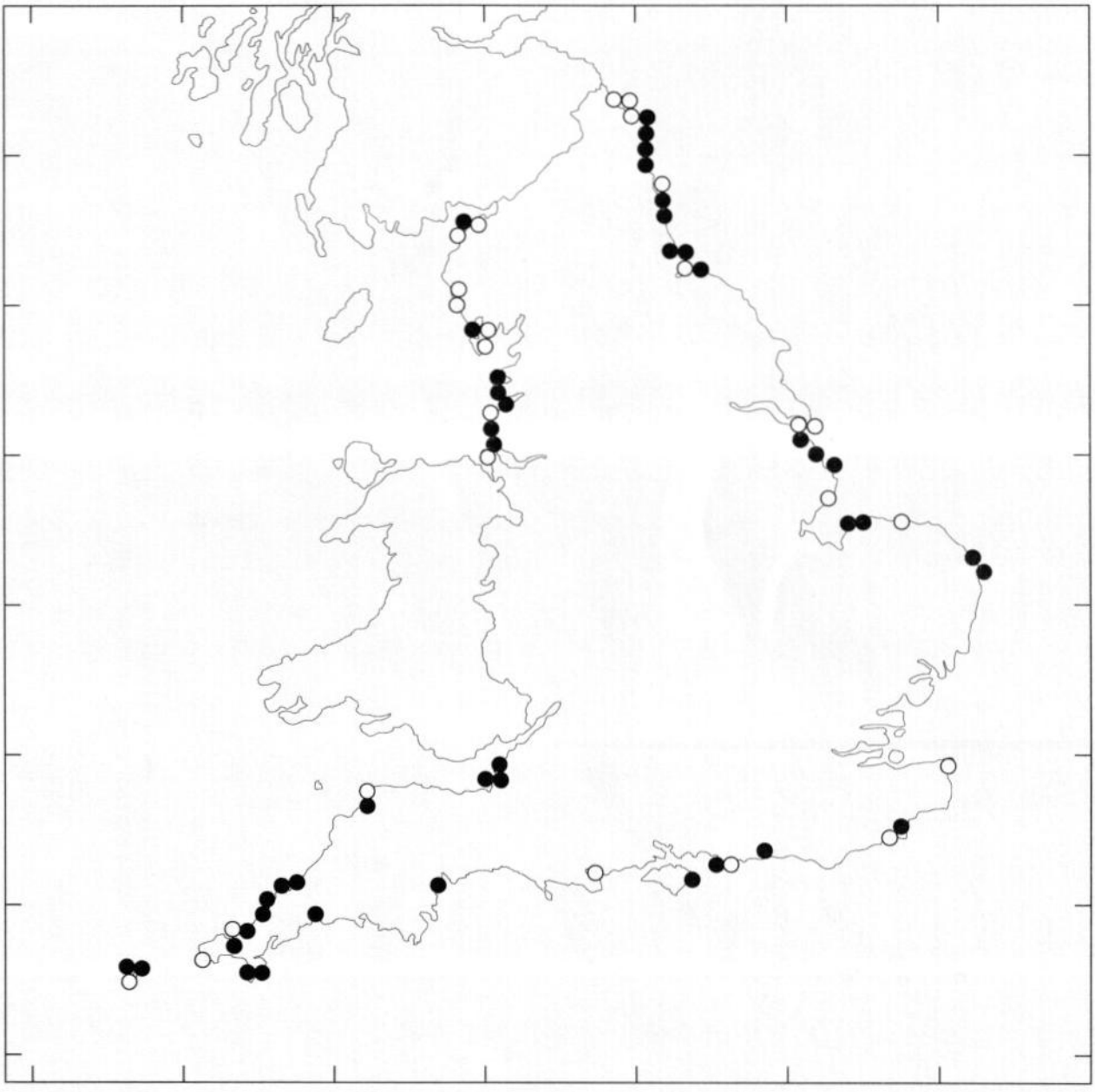

Figure 22 Distribution in England of dunes where leisure-related developments were recorded adjacent to the site. Symbols refer to 10 km squares.
○ No development
● Development

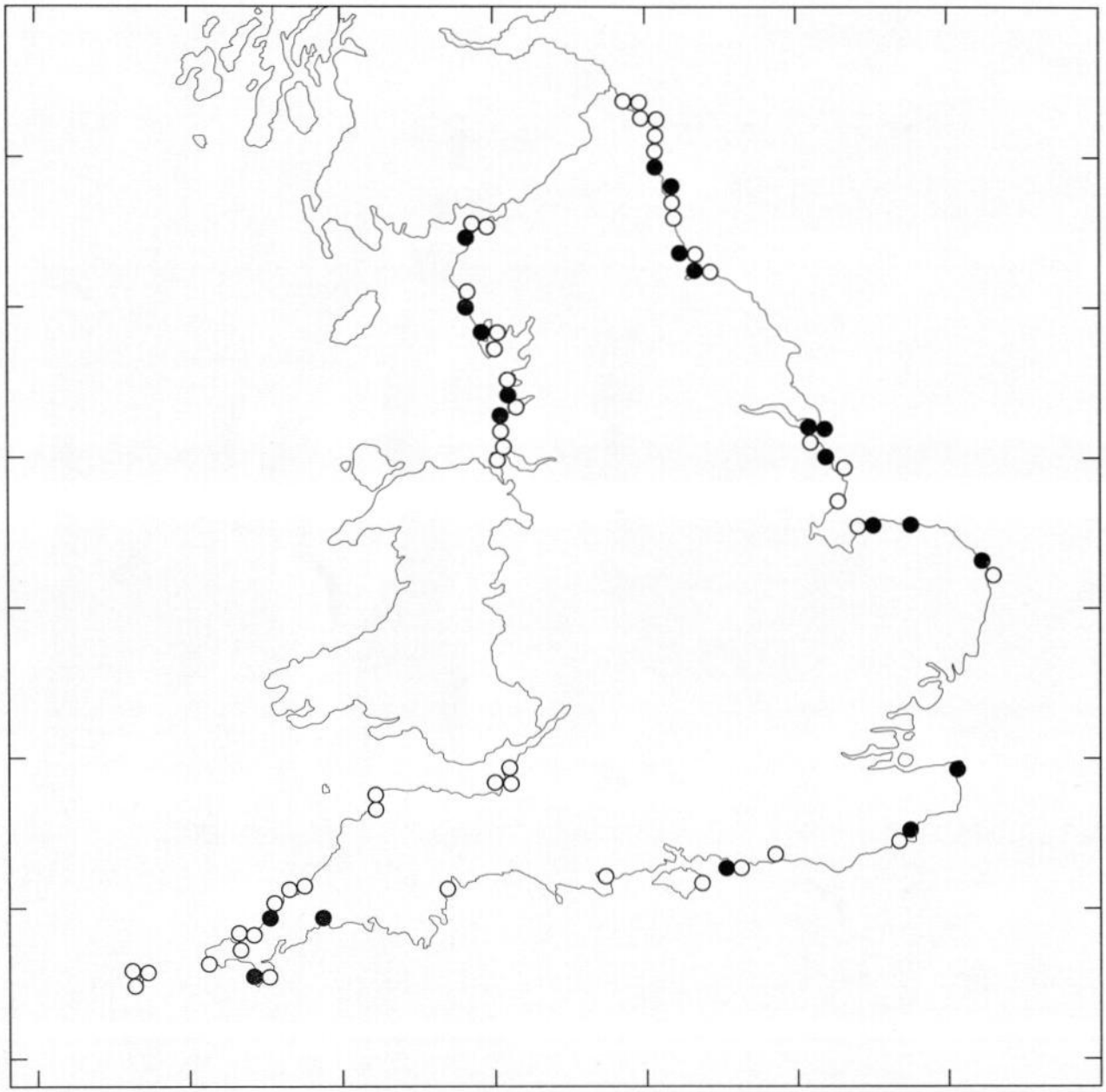

Figure 23 Distribution within England of dunes from which moderate or severe vehicle damage was recorded. Symbols refer to 10 km squares.
○ Little/no damage
● Moderate/severe damage

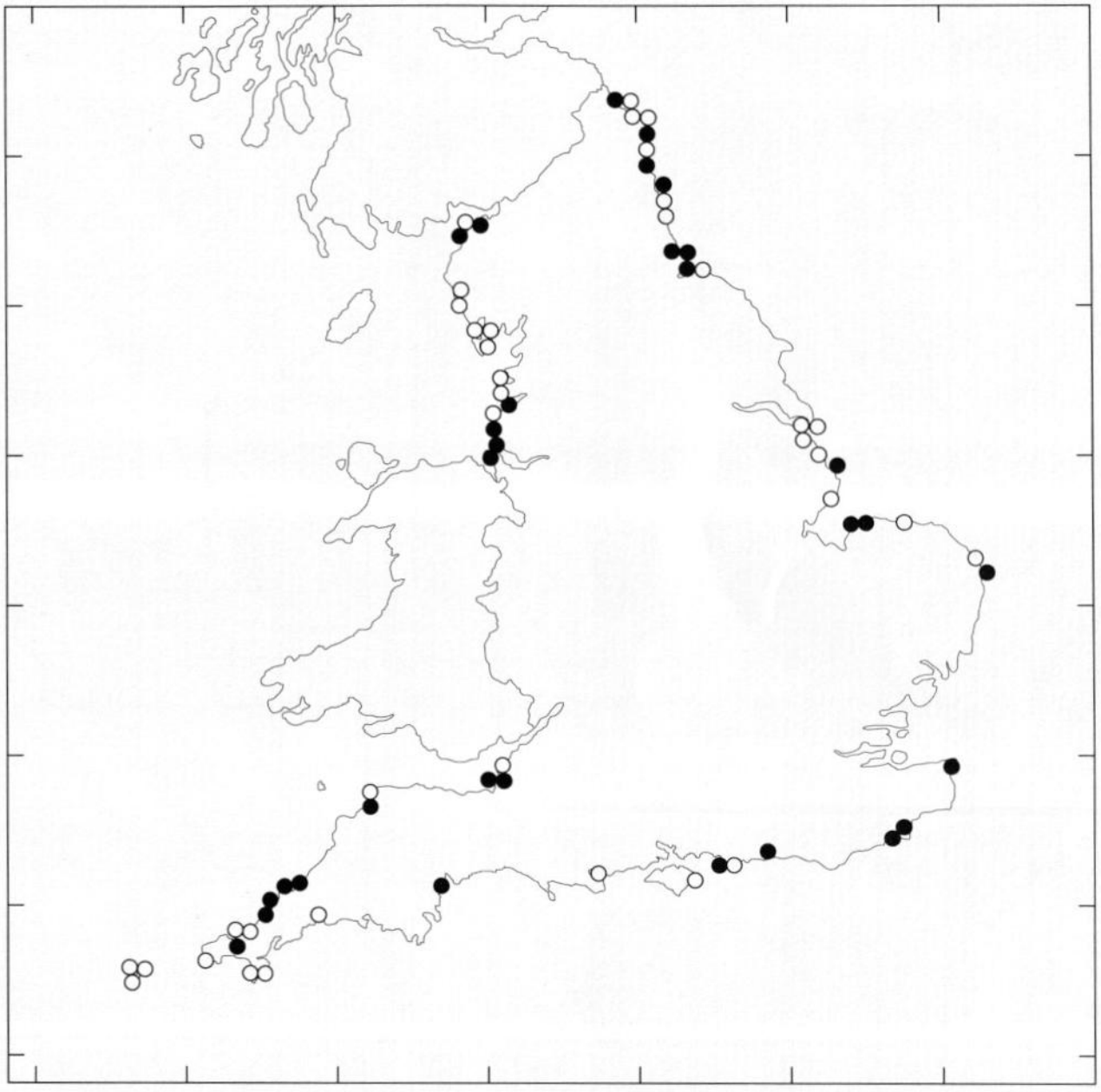

Figure 24 Distribution within England of dunes recorded as golf courses.
Symbols refer to 10 km squares.
○ No golf courses
● Golf course(s)

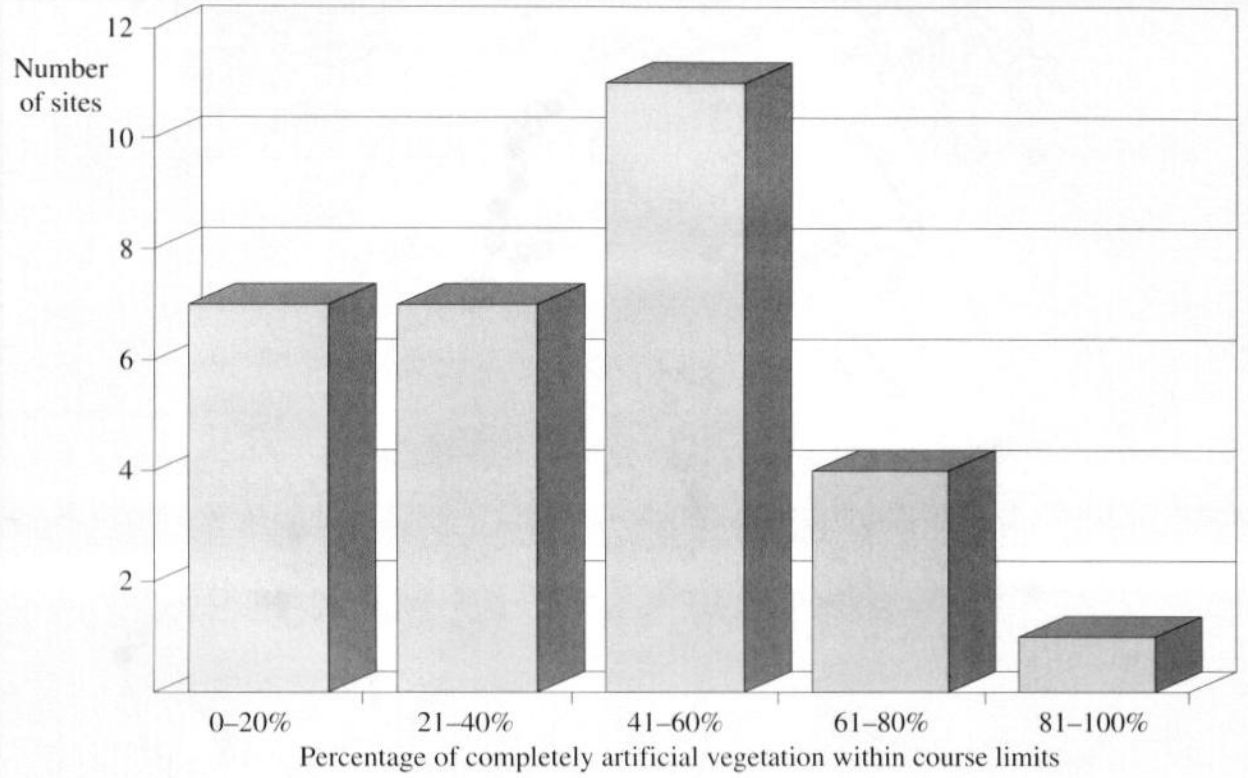

Figure 25 Variation in the percentage of completely artificial vegetation recorded from within the limits of golf courses on sand dunes in England

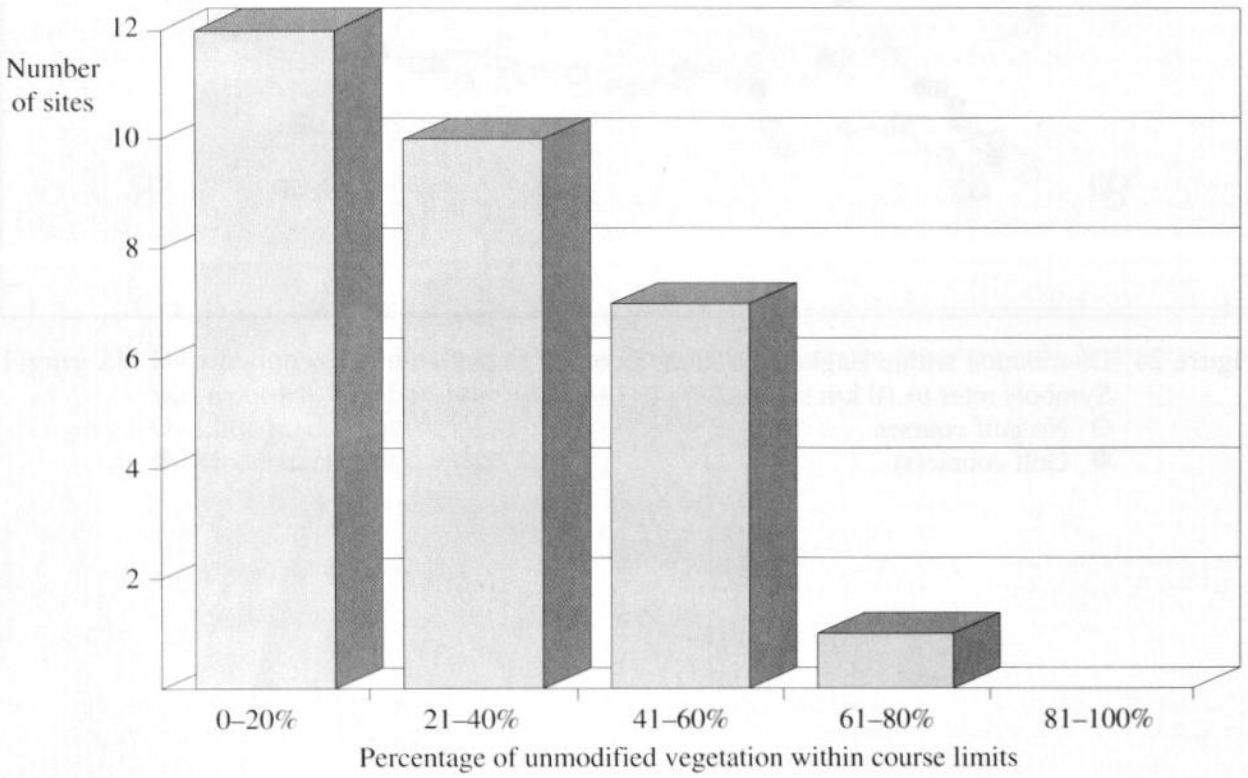

Figure 26 Variation in the percentage of unmodified vegetation recorded from within the limits of golf courses on sand dunes in England

3.4.4 Urban and industrial development

The densely populated nature of the coast of England is reflected in the fact that 61 out the 121 dune sites surveyed had some form of urban development adjacent to them. The nature and impact of this varies enormously from site to site, from the scattered bungalows of the era before planning control to the large-scale estate development that has occupied some sites near large conurbations. The Sefton Coast, Merseyside (CSD Report No. 917), shows one of the clearest examples of large-scale housing development on dunes from the Victorian period right through to the time of the survey. Other examples of substantial residential development within dunes include the Fylde Coast dunes in Lancashire, Berrow Dunes in Somerset (Site report No. 90) and Sandwich Bay, Kent (Site report No. 76). It is also likely that this survey underestimated the impact of urban development, since sites that had been completely developed would not have been covered by the survey.

Industrial development has affected dunes in three distinct ways: by the direct development of dunes for industry, by the dumping of industrial waste on dunes and by the extraction of sand and other minerals. There are also the less quantifiable impacts of emissions and discharges, but these were not looked at in this survey.

Industrial developments were recorded from within or adjacent to sixteen of the 121 dune sites surveyed. Figure 27 shows that these sites are concentrated mainly in the industrial regions of north-east England and on the Cumbrian coast. A similar pattern can be seen in Figure 28, which shows the distribution of the eleven sites where industrial waste tipping on dunes was recorded. More detailed examination of these records reveals that there are clear regional differences in the nature of the waste that has been dumped. In Northumberland it is colliery spoil, in Cleveland furnace slag and chemical waste. Cumbria has waste from the shipbuilding and cellophane industries as well as mine spoil and furnace slag, whilst Merseyside has tobacco waste dumps.

The extraction of sand from dunes and from the intertidal areas has been a source of concern to those responsible for coast protection as well as nature conservationists for many years. Despite this, the practice continues and active mineral extraction was recorded from fifteen out of the 121 sites visited. Figure 29 shows that these are mainly in the north and west of the country. Some of these extractions are small-scale, but substantial and continuing extraction of sand was recorded from within the dunes at Gwithian to Mexico Towans, Cornwall (Site report No. 8) and from the foreshore at Southport, Merseyside (CSD Report No. 917), Tees Bay, Cleveland (Site report No. 38), Druridge Bay, Northumberland (Site report No. 32) and the Taw/Torridge estuary, Devon.

3.4.5 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. During this survey sea defences were recorded in two ways: the presence and type of defence works were noted and then the percentage of the 'active' shoreline that was defended was measured from the 1:10,000 map. In interpreting these data it is worth pointing out that it is possible for a site with defence works recorded from it to have a zero value for percentage of defended coastline. This may happen because the defences have been breached, because they have been left behind by accretion or because they take the form of banks to prevent inland flooding and are therefore positioned well back from the shoreline.

Some form of sea defence was recorded from 52 of the 121 sites surveyed. The distribution of these sites is given in Figure 30. It is worth noting that there are major concentrations of undefended dunes in Cumbria, Northumberland and north Cornwall, with the defended dunes concentrated, as expected, in the more heavily populated and lower-lying sections of the coast. The remaining undefended dunes in these areas are consequently of particular interest. Good examples include Scolt Head Island (Site report No. 71) and Blakeney Point (Site report No. 73) in Norfolk and Studland (Site report No. 84) in Dorset.

Many of the sites that are defended have more

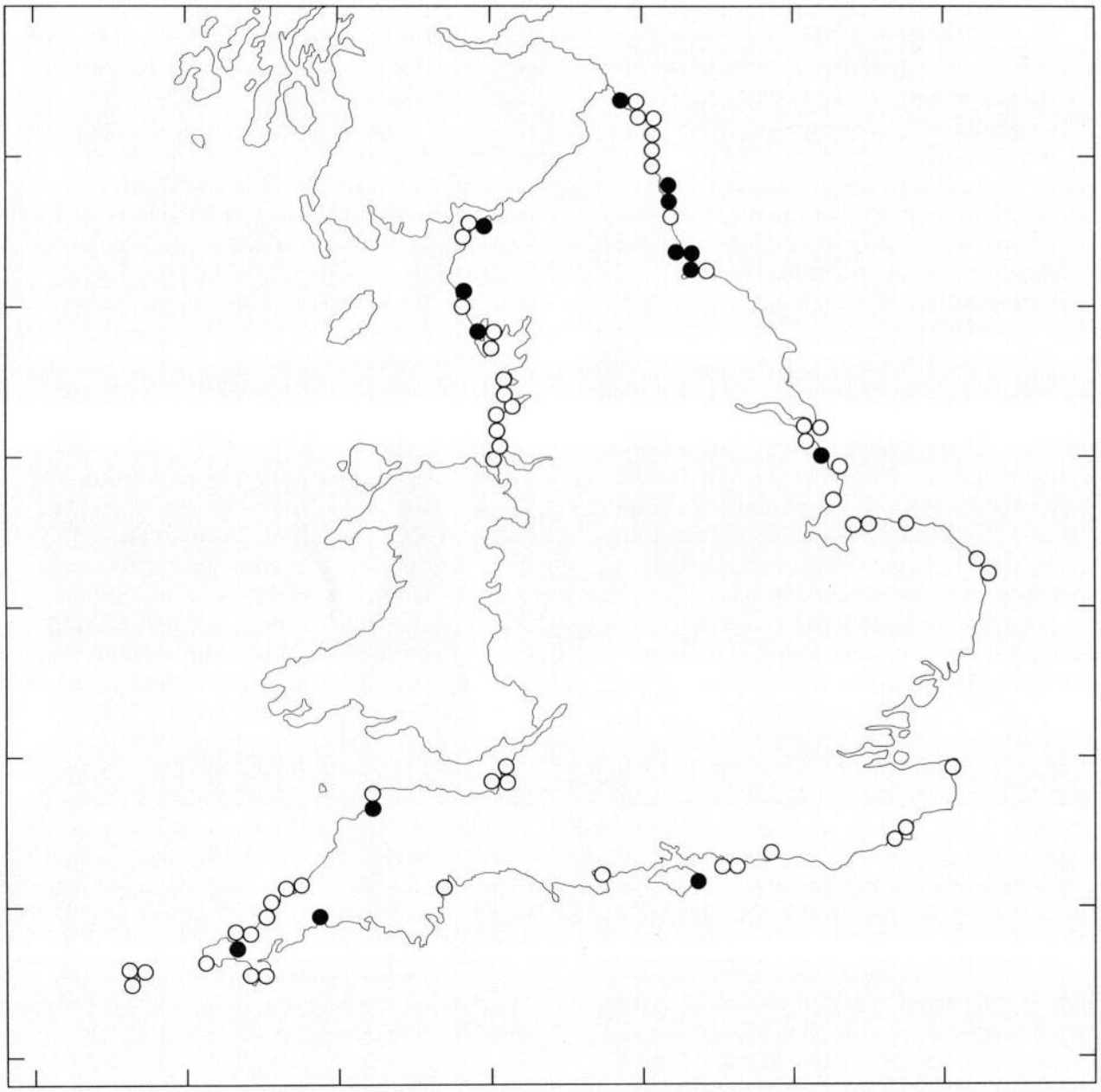

Figure 27 Distribution within England of dunes where industrial developments were recorded within or adjacent to the site. Symbols refer to 10 km squares.
○ No development
● Development

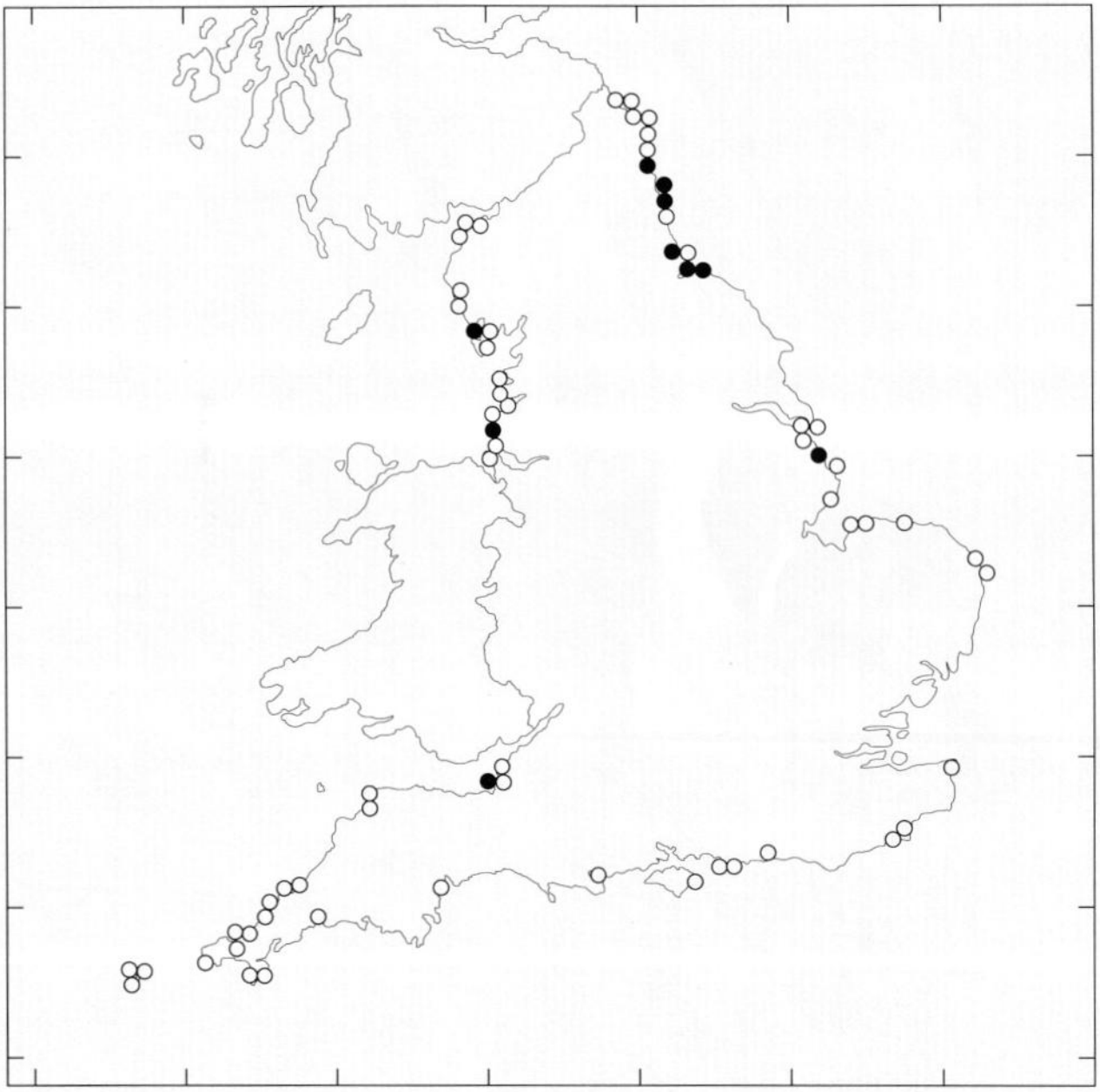

Figure 28 Distribution within England of dunes where the dumping of industrial waste was recorded. Symbols refer to 10 km squares.
○ No dumping recorded
● Dumping recorded

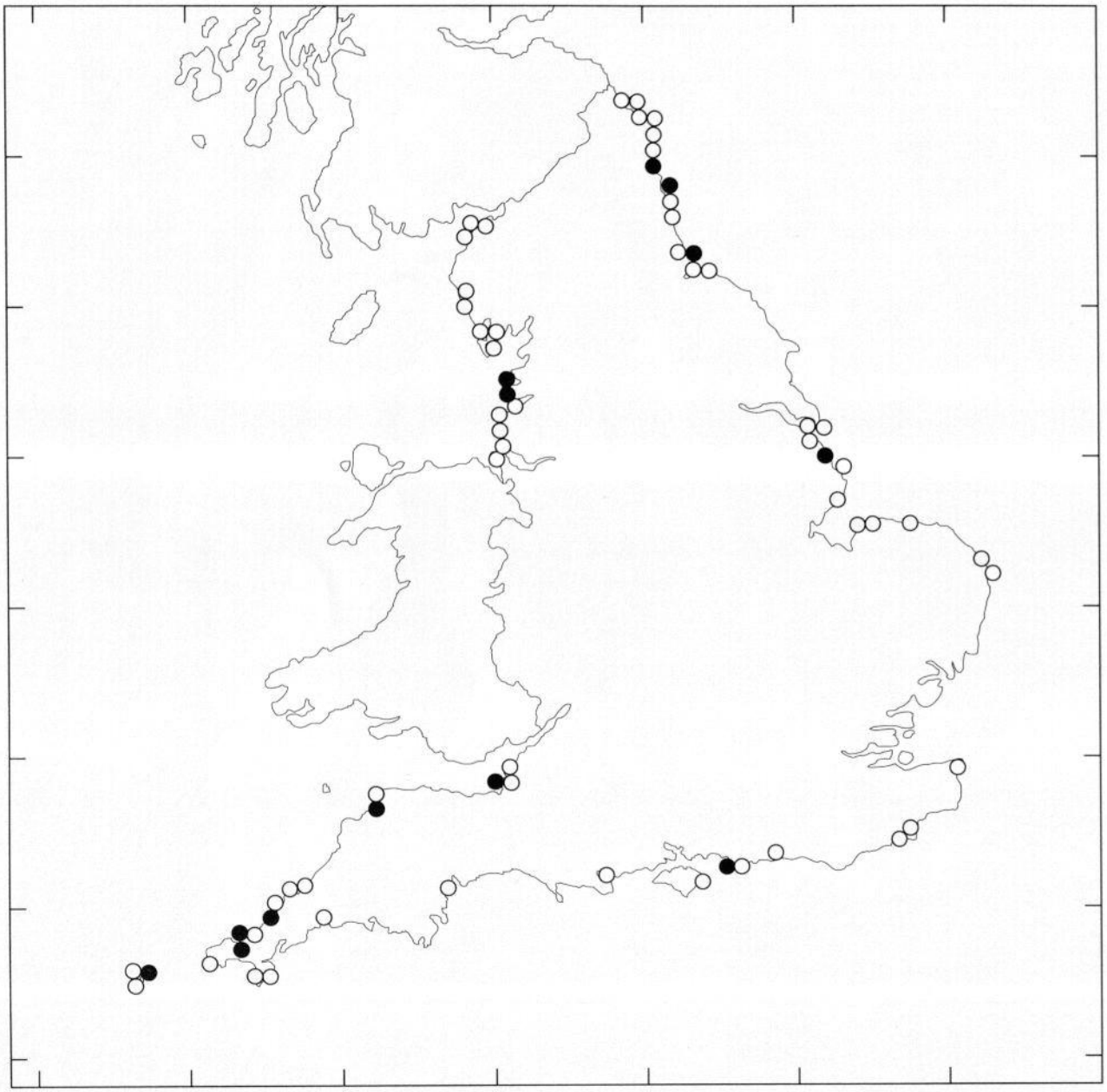

Figure 29 Distribution within England of dunes where active mineral extraction was recorded. Symbols refer to 10 km squares.

○ None active

● Active extraction

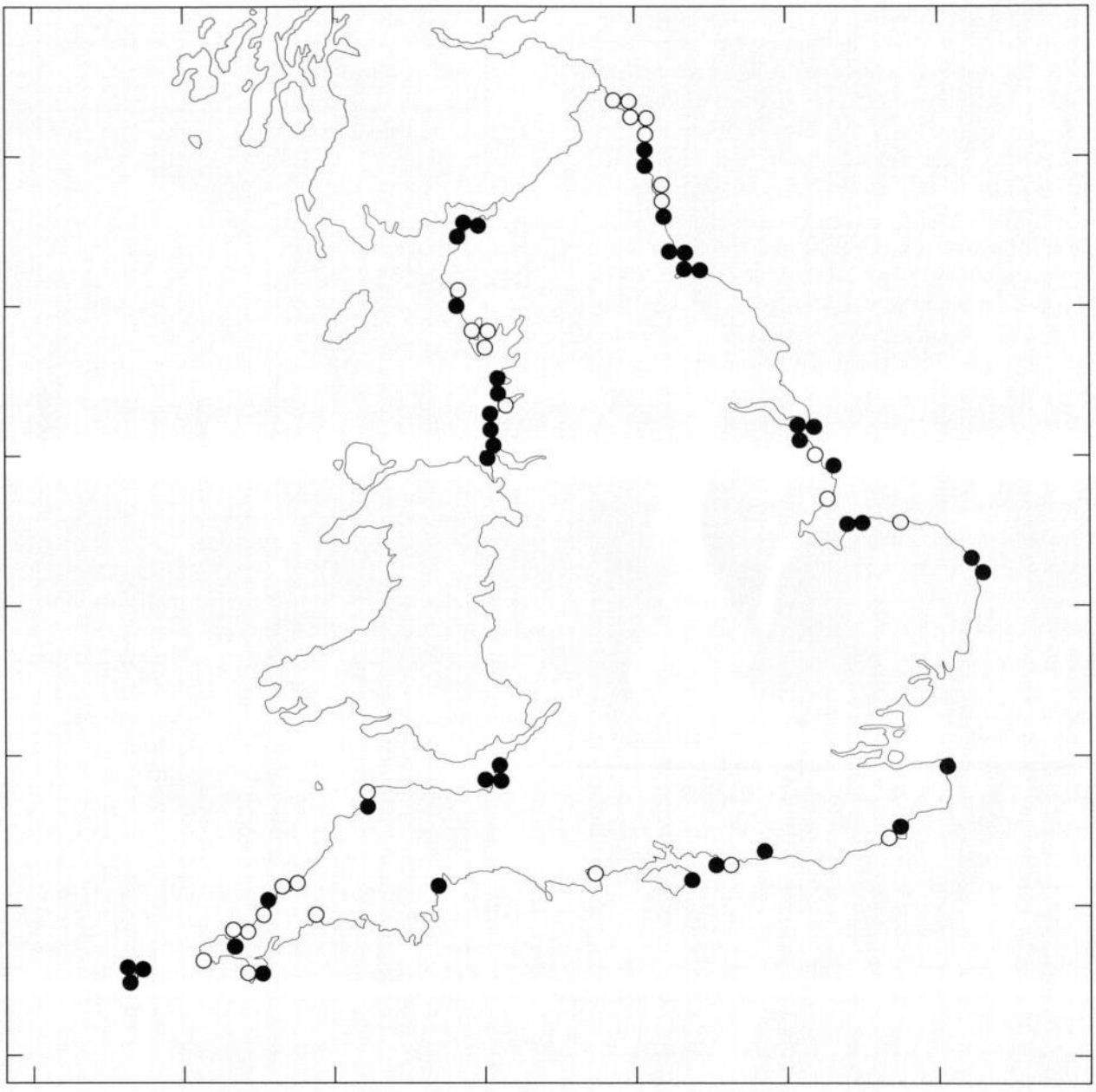

Figure 30 Distribution within England of dunes where some form of sea defence was recorded. Symbols refer to 10 km squares.
○ Not recorded
● Recorded

than one type of defence work. The figures are given in Table 5. Traditional, 'hard' defences were the most common; sea walls were recorded from 33 sites, groyne systems from thirteen and gabions from ten. Of the other techniques encountered, the most common was beach reprofiling, which was recorded from seven sites. Piles (steel or wooden structures driven into the ground), boulders, rubble, brushwood, sand fences and spoil were all recorded occasionally, and on one site, the southern end of the Sefton Coast, Merseyside (CSD Report No. 917), the dunes had been protected by a training wall. It is possible that some 'soft' defence works were under-recorded as they may not have been obvious to casual inspection.

The percentage of protected coastline from those sites where some form of sea defence was recorded is given in Figure 31. Of the 52 sites, 23 had less than 20% of their shoreline protected, but eleven had more than 80% protected.

Stabilisation work within dunes to combat wear and erosion damage was recorded from 62 of the 121 sites surveyed. The distribution of these is given in Figure 32. As with sea defence works, the techniques employed were also recorded and the data on these are given in Table 6. Sand fencing and marram *Ammophila arenaria*

Table 5 Numbers of dune sites in England where different forms of sea defence were recorded.

Type of defence work	Number of sites
Sea wall	33
Groynes	13
Gabions	10
Beach reprofiling	7
Brushwood	6
Boulders	4
Rubble	4
Fences	4
Piles	2
Spoil dumping	2
Training wall	1

Table 6 Numbers of dune sites in England from which different forms of dune stabilisation work were recorded.

Type of stabilisation work	Number of sites
Fencing	55
Marram planting	38
Boardwalks	29
Regrading	9
Brushwood	7
Sea buckthorn planting	4
Reseeding	2
Mulching	1
Hydroseeding	1

planting were the techniques most frequently encountered. Boardwalks were also widely used, being found on 29 sites. Other techniques recorded included regrading, reseeding, mulching, the use of brushwood fences and the planting of sea buckthorn *Hippophae rhamnoides*. Large-scale programmes of stabilisation employing a suite of different techniques were seen on a number of sites, notably Gwithian to Mexico Towans (Site report No. 8), Penhale Dunes (Site report No. 4) and Holywell Dunes (Site report No. 5), all in north Cornwall. A feature common to these schemes was the considerable effort that had gone into informing the public of the reasons for the work.

3.4.6 Forestry

The Sefton Coast Dunes, Merseyside, and the Holkham Dunes, Norfolk, both had sizeable areas afforested in the late 19th/early 20th century (Monro 1908; Carey & Oliver 1918). Dunes in England have, however, been largely unaffected by the large-scale, state-financed afforestation that has been carried out on many of the larger dune systems in Wales and Scotland. Most other afforestation in England has been small-scale, usually to provide shelter belts or ornamental plantings. An exception to this is the Eskmeals Dunes in Cumbria (Site report No.19), where the Ministry of Defence has established some substantial plantations.

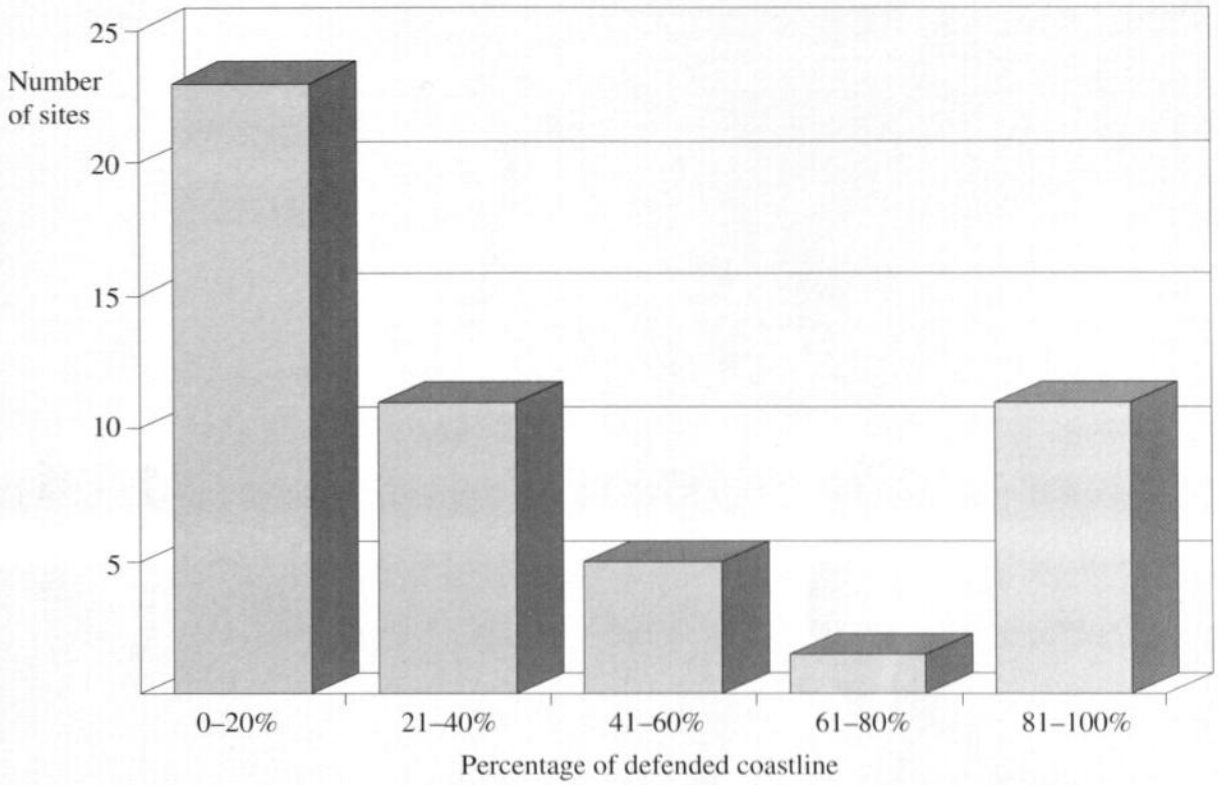

Figure 31 Variation in the percentage of defended coastline on dunes with some form of sea defence in England

Some form of afforestation was recorded from 22 out of the 121 sites surveyed. Figure 33 shows the distribution of these sites, with the area of the symbol proportional to the area afforested. This emphasises the small scale of most afforestation on English dunes, with the exception of the early schemes in Norfolk and Merseyside.

3.4.7 Waste disposal

The disposal of industrial waste on dunes has already been mentioned. The dumping of domestic refuse also affects several dunes. It was recorded from nine of the 121 sites visited, with one of the largest active dumps being on Northam Burrows, Devon. This dump has been established on an extensive area of dune-to-saltmarsh transition. A proposal to start dumping domestic refuse on the Bar Point dunes, St Mary's, Isles of Scilly (CSD Report No. 1179), was under consideration at the time of the survey.

As well as organised dumps, fly tipping and the disposal of garden refuse are widespread. One or other of these practices was recorded from 28 of the 121 sites visited, though this is almost certainly an underestimate. Figure 34 shows that the sites where it was recorded are concentrated in regions with a relatively dense population nearby. Dunes are also sometimes used as convenient dumping grounds for agricultural waste, especially on those sites where the farmers no longer keep livestock. The practice was recorded from eight of the 121 dunes surveyed.

3.4.8 Military usage

The coastal zone of England has long been of military importance. This form of land use reached a peak during the Second World War when almost every dune system had some form of defence installation and many of the larger sites were intensively used for battle training, often resulting in widespread erosion (Doody 1989). During the present survey, military installations were recorded from 28 of the 121 dunes visited (Figure 35). On most of these the

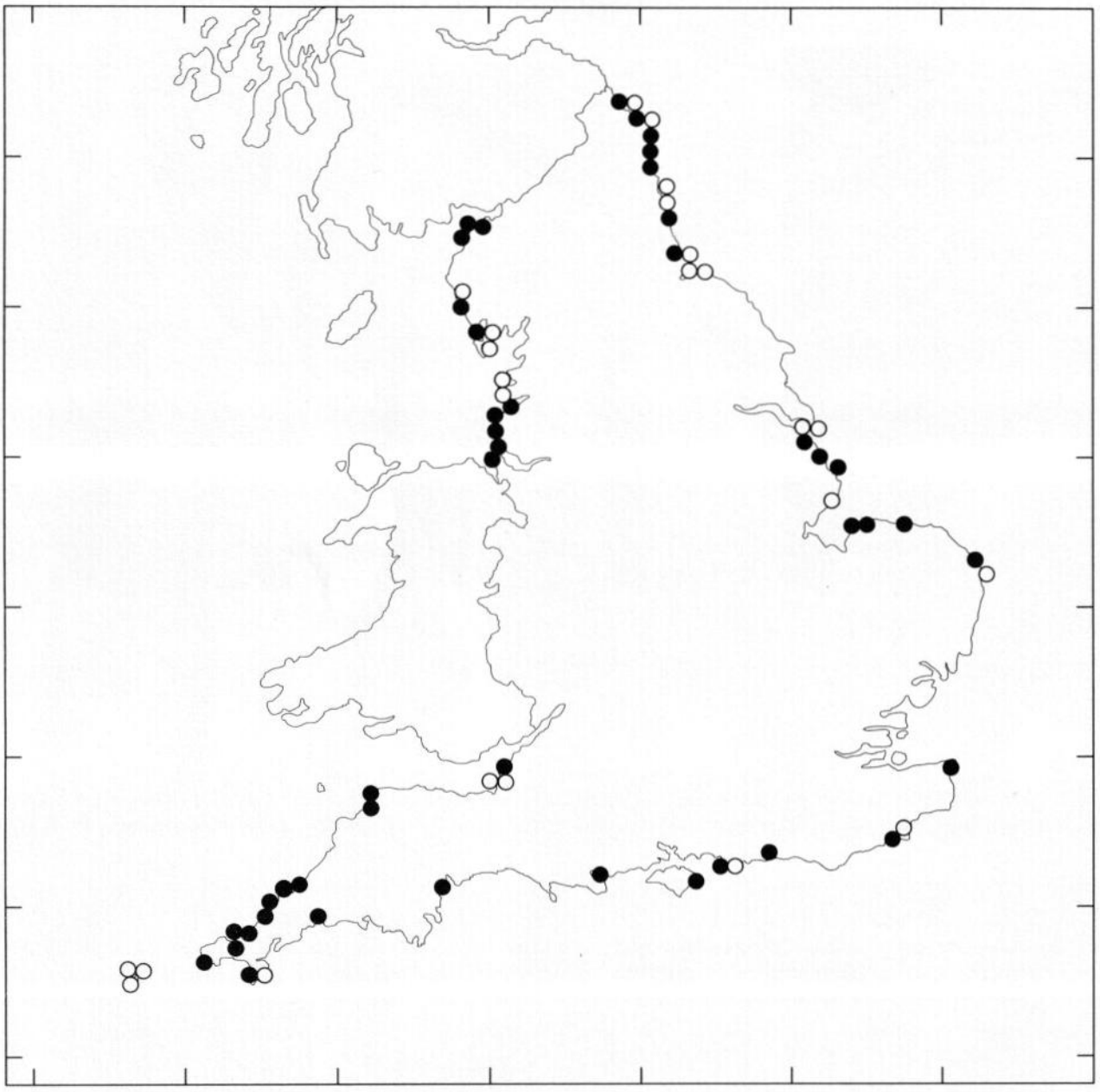

Figure 32 Distribution within England of dunes where stabilisation work was recorded. Symbols refer to 10 km squares.
○ No work carried out
● Work carried out

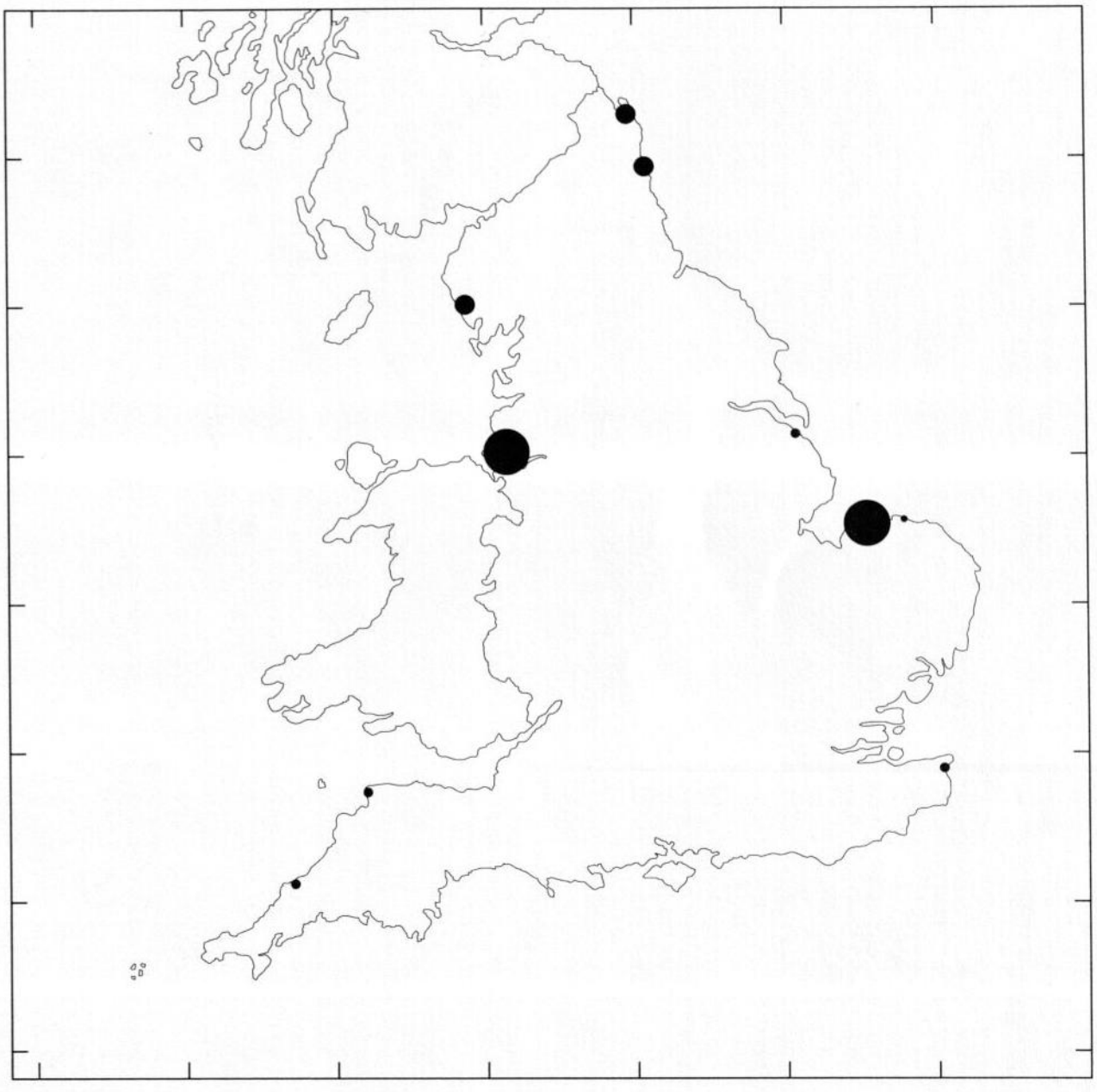

Figure 33 Afforested areas of dune in England. Area of symbol is proportional to area afforested.

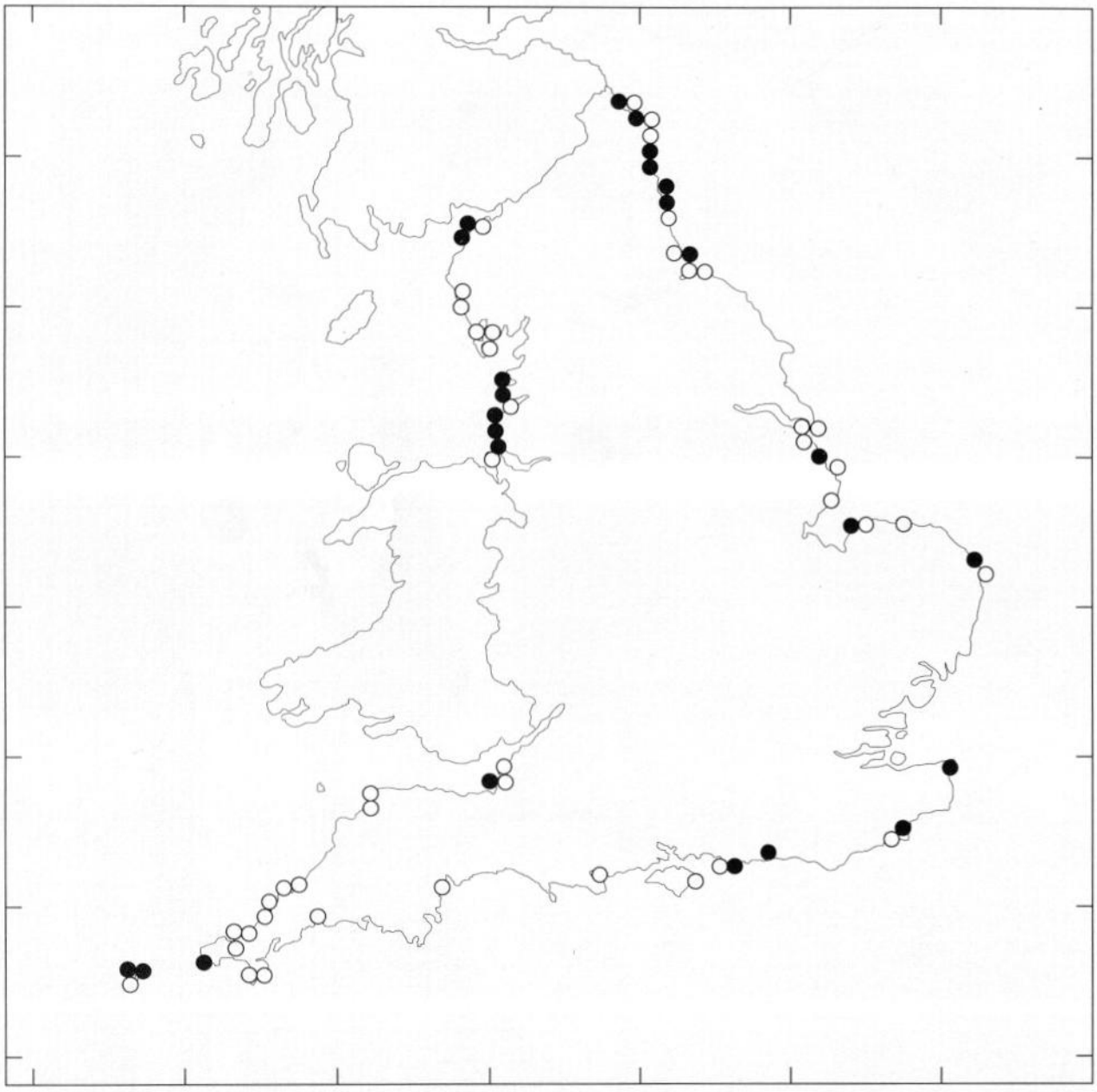

Figure 34 Distribution of dunes within England where fly tipping was recorded. Symbols refer to 10 km squares.
○ None recorded
● Fly tipping recorded

installations were disused. Pillboxes and anti-tank blocks were by far the most common, and the number of sites where these were recorded is almost certainly an underestimate of their true frequency.

Present-day military activities affect only a few sites. The nature of the impact varies enormously with the nature of the usage. On infantry training areas such as Penhale, Cornwall (Site report No. 4), the impact can be very slight, as has already been mentioned. On sites where there are fixed installations, such as Eskmeals in Cumbria (Site report No. 19), the impact is greater, though even here there are substantial tracts of undisturbed dune.

3.4.9 Nature conservation and statutory protection

The management of land for nature conservation is a comparatively recent phenomenon. Nevertheless it has had a substantial impact on dunes in England. Nature conservation was recorded as a land use from 61 of the 121 sites visited (Figure 36). In some cases the area involved represented only a part of the site, on occasions a very small part. However, on 40 sites it was the primary, though not necessarily the only, land use over the whole area. Conservation management has not only reduced the impact of some other activities but has also in many instances directly affected the course of natural succession through programmes of scrub clearance and through the reintroduction of grazing.

The number of sites that are wholly or partly managed for nature conservation in each of the former English regions of NCC is given in Figure 37, along with the total number of sites. The dunes of East Anglia (EA) and the East Midlands (EM) have the highest proportion under conservation management. Of the three regions with the largest number of sites, the south-west has the highest proportion of sites wholly managed for nature conservation. This is largely due to the number of small dune sites in the Isles of Scilly that are managed by the Isles of Scilly Environmental Trust.

Figure 38 provides information on the number of sand dune sites managed by different conservation bodies. The National Trust and English Nature both hold considerable numbers of sites, but it is the other voluntary bodies, the Royal Society for the Protection of Birds and the County Trusts that manage the greatest number. This figure is again somewhat influenced by the Isles of Scilly archipelago. Local Nature Reserves (LNRs) also make a significant contribution, especially in the north-west of England.

The influence of nature conservation on the use and management of dunes is not confined to nature reserves. The main statutory instrument of site protection for nature conservation in England, as in the rest of Great Britain, is the designation of Sites of Special Scientific Interest (SSSI) under the 1981 Wildlife & Countryside Act. SSSIs are notified to their owners and occupiers, to local planning authorities and to other public bodies and utilities. Any changes in land use that might adversely affect the interest of these sites are then subject to prior consultation with English Nature, who are also consulted over any planning applications. The ownership of land is not affected, nor are other forms of land use necessarily precluded.

Of the 121 dune sites visited, 79 were at least partly designated as SSSIs and in 56 cases the whole site, or almost the whole site, was designated. Figure 39 shows the numbers of sites divided by former NCC region; a consistent pattern emerges. In those regions where dunes are scarce, a very high proportion are SSSIs, whilst in those where dunes are more abundant, the proportion is lower. This is the pattern that would be expected from the guidance given in the SSSI selection guidelines (Nature Conservancy Council 1989). One aspect of the figures that is of interest is the different proportion of part-site designations in the different regions. On the face of it this suggests that interpretation of the guidelines on boundary definition may have varied.

3.5 The vegetation of English sand dunes

3.5.1 Introduction

The vegetation of sand dunes is shaped by a combination of physical, biotic and human factors. Within even a small dune system there

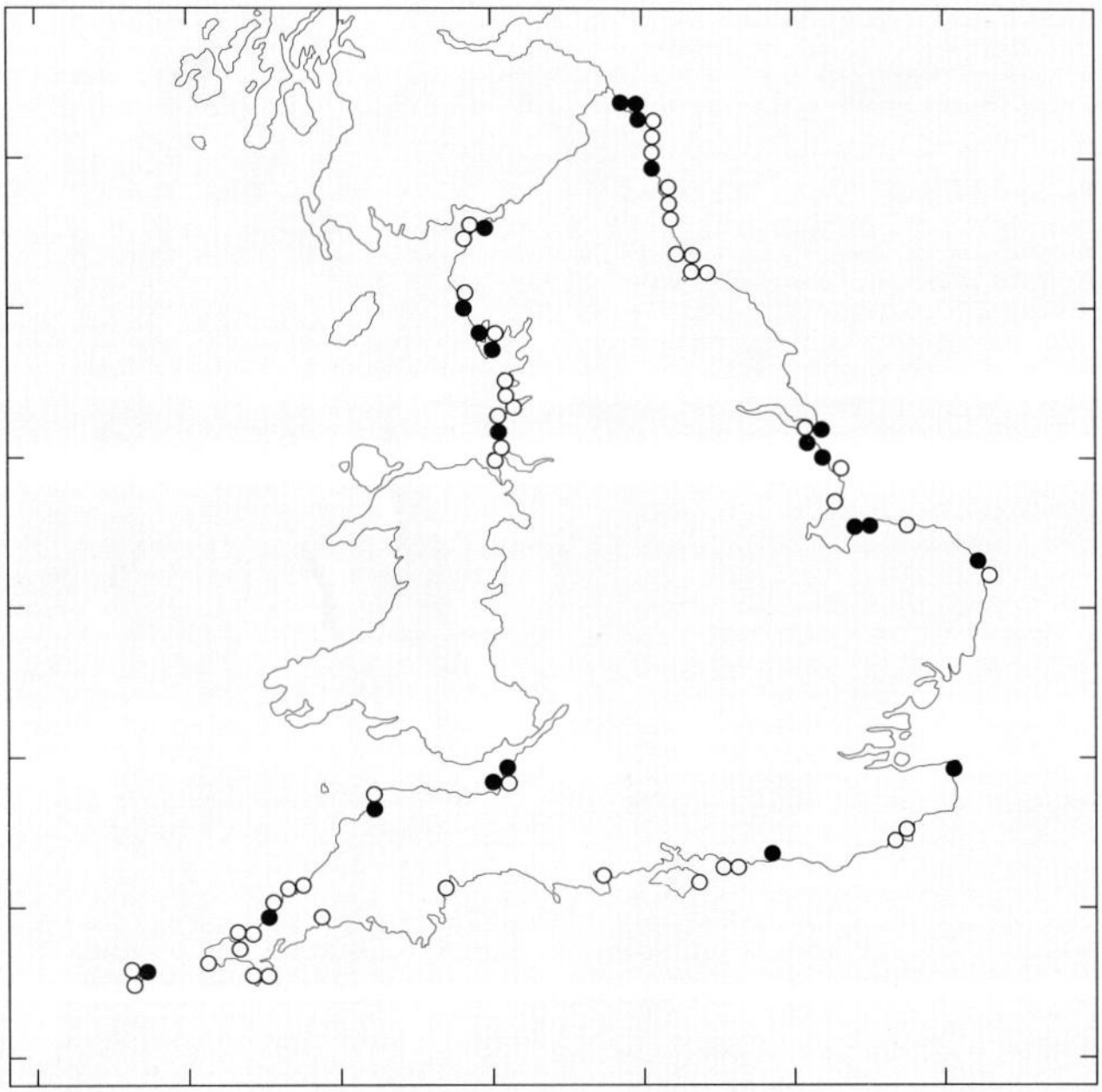

Figure 35 Distribution of dunes within England on which military structures (used or disused) were recorded. Symbols refer to 10 km squares.
○ None recorded
● Military structures recorded

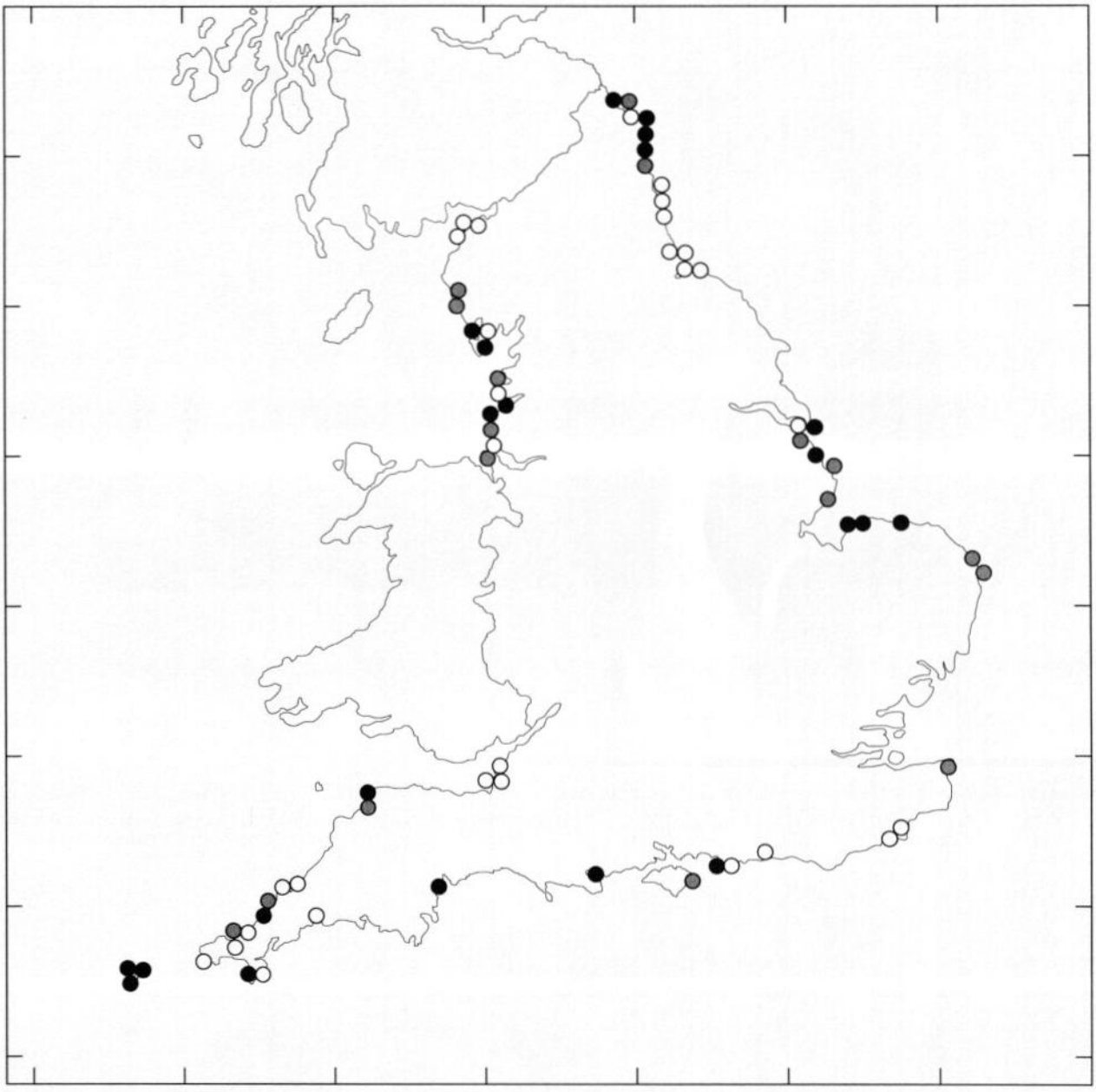

Figure 36 Distribution of dunes within England managed wholly or partly as nature reserves. Symbols refer to 10 km squares.

- ○ No area NR
- ● Area partly NR
- ● Area totally NR

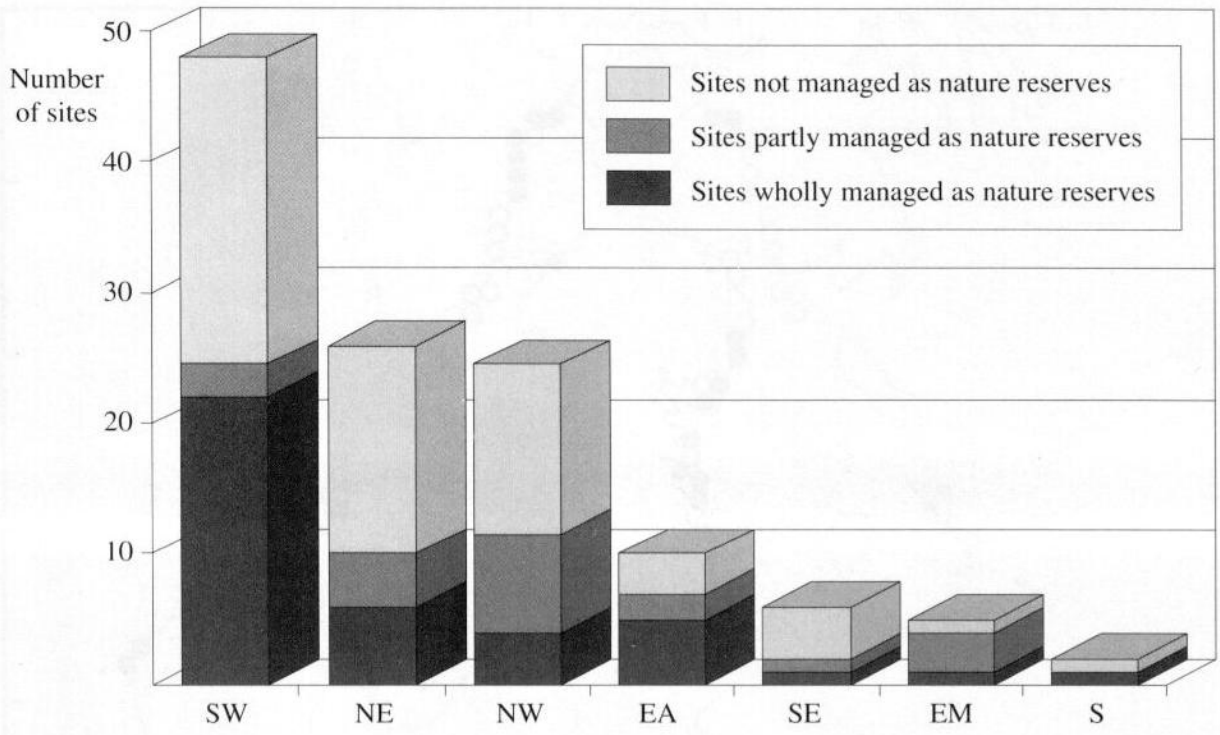

Figure 37 Numbers of sand dune sites in each NCC region with information on the extent of nature reserves

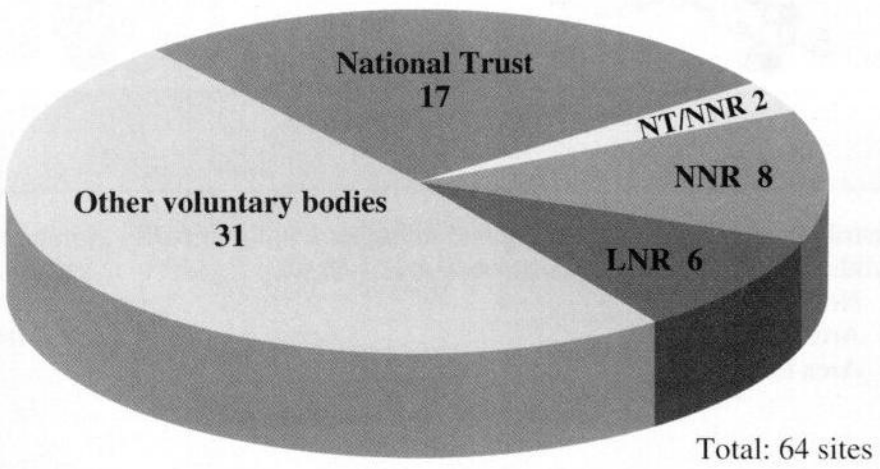

Figure 38 Numbers of sand dune sites managed by conservation bodies

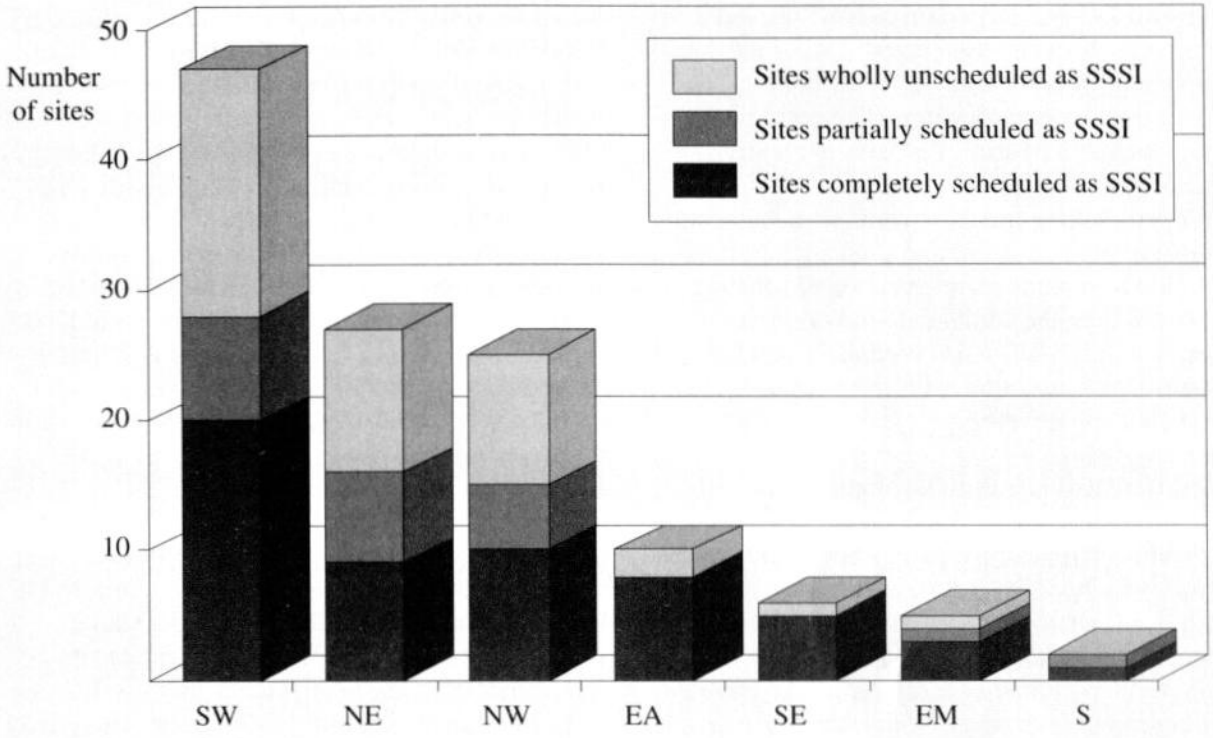

Figure 39 Numbers of sand dune sites in each former NCC region with information on the extent of SSSI designation

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 England there are three main species, all grasses, which do this: sand couch *Elymus farctus*, lyme-grass *Leymus arenarius* and marram *Ammophila arenaria*. Sand couch has only a modest ability to withstand burial, but its comparative tolerance of salt water (Gimingham 1964; Chapman 1976) means that it often initiates dune formation. Lyme-grass is a bigger plant, with a greater ability to grow up through fresh sand. It is, however, predominantly a northern species and in English dunes it normally plays only a subsidiary role. Marram is the main dune-building species. It can keep pace with up to 1 metre of fresh sand deposition per year as well as producing far-spreading horizontal rhizomes (Gemmel *et al.* 1953; Greig-Smith 1961; 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.

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. 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 and annual and perennial herbs start to appear in greater numbers, and these are then joined by sand-binding mosses such as *Ceratodon purpureus* and *Tortula ruralis* ssp. *ruraliformis* (Birse *et al.* 1957) and by lichens. These further stabilise the surface and 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 were, historically, grazed. 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, 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 dune system's fresh water table. This can happen either because of a blowout or where the water table rises up towards an existing surface as the dune system extends. Under these conditions dune slacks develop, often characterised by a marked annual fluctuation in water level. 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 metres 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 that of similar inland areas.

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, as has happened extensively on dunes in England, then the succession enters a new phase. Existing dune grassland swards change their composition and appearance, becoming rank and less species-rich. Simultaneously woody species start to invade (Hodgkin 1981) and scrub develops. In time this scrub will develop into woodland.

One scrub species, sea buckthorn *Hippophae rhamnoides*, is especially associated with sand dunes and is widely distributed on English systems. 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 as yet very rare in England, but it is found in the rather similar dunes of the Dutch coast and appears to be developing in older stands of scrub at some English sites.

Primary succession on ungrazed dunes has not been investigated in the same detail in this country, but during this survey sea buckthorn has frequently been observed invading foredune vegetation a few metres from the tideline. It seems that in at least some areas this species can colonise almost as rapidly as marram. There may never, under these circumstances, be a dune grassland stage.

In practice vegetation seldom follows the orderly succession outlined above. Areas of dune frequently become destabilised and then gradually revegetate. Sometimes the original sequence is repeated, but sometimes a distinctly different succession occurs. Sand sedge *Carex arenaria* plays a key role in this. This plant has little ability to survive burial but does have a rapidly growing, monopodial rhizome which enables it rapidly to colonise areas of exposed sand and to initiate stabilisation.

3.5.2 An outline of the treatment of dune vegetation by the National Vegetation Classification

The National Vegetation Classification (NVC) was commissioned by the Nature Conservancy Council in order to provide a common language for the description of vegetation for use by all those involved in wildlife conservation in Britain. Although it has links with Continental phytosociological classifications, it recognises that vegetation varies along a whole series of continua. Its aim is 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 habitat. 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 7 lists the communities and sub-communities covered by the sand dune chapter and those communities from other chapters that are most frequently encountered on dunes. The dune chapter encompasses strandline, mobile dunes, semi-fixed dunes, dune grasslands, slacks and dune scrub. The mobile dunes are divided into three communities, SD4, SD5 and SD6, according to which major sand-binding grass 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 possesses 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 five communities: SD13, SD14, SD15, SD16 and SD17. Each of these is in turn divided into sub-communities. All these types represent different combinations of physical factors, such as soil pH and water regime, with successional change. SD13 and SD14 represent the earlier stages of successional development.

The only scrub included within the dune chapter is that dominated by sea buckthorn SD18. This is

Table 7 List of National Vegetation Classification types commonly found on sand dunes in England, grouped by habitat

Strandline

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

Mobile dunes

SD4	*Elymus farctus* ssp. *boreali-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.

Table 7 *(cont.)*

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.

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* dune 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.
MG1b *Arrhenatherum elatius* coarse grassland, *Urtica dioica* sub-community.
MG1c *Arrhenatherum elatius* coarse grassland, *Filipendula ulmaria* sub-community.
MG1d *Arrhenatherum elatius* coarse grassland, *Pastinaca sativa* sub-community.
MG1e *Arrhenatherum elatius* coarse grassland, *Centaurea nigra* sub-community.
MG5a *Cynosurus cristatus-Centaurea nigra* meadow, *Lathyrus pratensis* sub-community.
MG5b *Cynosurus cristatus-Centaurea nigra* 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, *Lolium perenne-Plantago lanceolata* verges and lawns.
MG10a *Holcus lanatus-Juncus effusus* rush pasture, Typical sub-community.
MG11a *Festuca rubra-Agrostis stolonifera-Potentilla anserina* inundation grassland, *Lolium perenne* sub-community.

Calcicolous grassland

CG1e *Festuca ovina-Carlina vulgaris* grassland, *Koeleria macrantha* sub-community.
CG6a *Avenula pubescens* grassland, *Dactylis glomerata-Briza media* sub-community.
CG7 *Festuca ovina-Hieracium pilosella-Thymus praecox* grassland, undifferentiated.

Acidic grassland

U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland, undifferentiated.
U2a *Deschampsia flexuosa* grassland, *Festuca ovina-Agrostis capillaris* sub-community.
U6c *Juncus squarrosus-Festuca ovina* grassland, *Vaccinium myrtillus* sub-community.
U6d *Juncus squarrosus-Festuca ovina* grassland, *Agrostis capillaris-Luzula multiflora* sub-community.
U20 *Pteridium aquilinum-Galium saxatile* community, undifferentiated.

Table 7 *(cont.)*

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.

Heathland

H1d *Calluna vulgaris-Festuca ovina* heath, *Carex arenaria* sub-community.
H6 *Erica vagans-Ulex europaeus* heath, undifferentiated.
H10 *Calluna vulgaris-Erica cinerea* heath, undifferentiated.
H11b *Calluna vulgaris-Carex arenaria* dune heath, *Erica cinerea* sub-community.
H11c *Calluna vulgaris-Carex arenaria* dune heath, *Hypnum cupressiforme* sub-community.

Wet heaths and mires

M15d *Scirpus cespitosus-Erica tetralix* wet heath, *Vaccinium myrtillus* sub-community.
M16a *Erica tetralix-Sphagnum compactum* wet heath, Typical sub-community.
M16c *Erica tetralix-Sphagnum compactum* wet heath, *Rhynchospora alba-Drosera intermedia* sub-community.
M16e *Erica tetralix-Sphagnum compactum* wet heath, impoverished stands lacking Sphagna.
M23a *Juncus effusus/acutiflorus-Galium palustre* rush pasture, *Juncus acutiflorus* sub-community.
M23b *Juncus effusus/acutiflorus-Galium palustre* rush pasture, *Juncus effusus* sub-community.

Dune slacks

SD13a *Salix repens-Bryum pseudotriquetrum* dune slack, *Poa annua-Hydrocotyle vulgaris* sub-community.
SD13b *Salix repens-Bryum pseudotriquetrum* dune slack, *Holcus lanatus-Festuca rubra* sub-community.
SD14a *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.
SD15a *Salix repens-Calliergon cuspidatum* dune slack, *Carex nigra* sub-community.
SD15b *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 *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.

Table 7 *(cont.)*

SD17d *Potentilla anserina-Carex nigra* dune slack, *Hydrocotyle vulgaris-Ranunculus flammula* sub-community.

Fens and swamps

S4a *Phragmites australis* swamp, *Phragmites australis* sub-community.
S4d *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.
S21c *Scirpus maritimus* swamp, *Potentilla anserina* sub-community.
S25 *Phragmites australis-Eupatorium cannabinum* fen, undifferentiated.
S26b *Phragmites australis-Urtica dioica* tall-herb fen, *Arrhenatherum elatius* sub-community.
S28b *Phalaris arundinacea* fen, *Epilobium hirsutum-Urtica dioica* sub-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.
W4a *Betula pubescens-Molinia caerulea* woodland, *Dryopteris dilatata-Rubus fruticosus* sub-community.
W4b *Betula pubescens-Molinia caerulea* woodland, *Juncus effusus* sub-community.
W4c *Betula pubescens-Molinia caerulea* woodland, *Sphagnum* sub-community.
W16a *Quercus* spp.-*Betula* spp.-*Deschampsia flexuosa* woodland, *Quercus robur* sub-community.
W21 *Crataegus monogyna-Hedera helix* scrub, undifferentiated.
W22 *Prunus spinosa-Rubus fruticosus* agg. scrub, undifferentiated.
W23 *Ulex europaeus-Rubus fruticosus* agg. scrub, undifferentiated.
W24 *Rubus fruticosus* agg.-*Holcus lanatus* underscrub, undifferentiated.
W24a *Rubus fruticosus* agg.-*Holcus lanatus* underscrub, *Cirsium arvense-Cirsium vulgare* sub-community.
W25 *Pteridium aquilinum-Rubus fruticosus* agg. underscrub, undifferentiated.
W25a *Pteridium aquilinum-Rubus fruticosus* agg. underscrub, *Hyacinthoides non-scripta* sub-community.

Transitions to other habitats

MC5 *Armeria maritima-Cerastium diffusum* ssp. *diffusum*, maritime therophyte community.
MC8 *Festuca rubra-Armeria maritima* maritime grassland, undifferentiated.
MC8d *Festuca rubra-Armeria maritima* maritime grassland, *Holcus lanatus* sub-community.
SM16 *Festuca rubra* saltmarsh, undifferentiated.
SM21a *Suaeda vera-Limonium binervosum* saltmarsh, Typical sub-community.
SM24 *Elymus pycnanthus* saltmarsh.
SM25a *Suaeda vera* drift line, *Elymus pycnanthus* sub-community.
SM25b *Suaeda vera* drift line, *Halimione portulacoides* sub-community.
SD1a *Rumex crispus-Glaucium flavum* shingle community, Typical sub-community.
SD1b *Rumex crispus-Glaucium flavum* shingle community, *Lathyrus pratensis* sub-community.

divided into two sub-communities according to the stage in the succession that it has reached.

Vegetation in which sand sedge is dominant is recognised as a distinct community, SD10. It is also a component of a rather specialised 'grey dune' community in which lichens dominate the sward, SD11.

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, not all of which occur in England. Several 'inland' heath communities 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. Some samples can be referred to the uplands and acidic grasslands chapter (U20), but on the more base-rich soils most are closer to the community in the woodlands chapter (W25). The scrub on dry dunes, apart from that dominated by sea buckthorn, can mostly be referred to the scrub section of the woodlands chapter (W21 to W24). That which develops in dune slacks is normally dominated by 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 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 on the landward sides of spit and barrier island systems, and there are some communities (SM24 and SM25) that are particularly characteristic of the transition zone.

Vegetation that is intermediate between mobile dune and vegetated shingle (SD1) can be found where sand has blown over a shingle base. 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 vegetation that fall outside its orbit. These are described individually later on.

3.5.3 Descriptions of individual vegetation types and their distributions

3.5.3.1 Strandlines

The distributions and areas of the two types of strandline vegetation are summarised in Table 8.

SD2 *Honkenya peploides-Cakile maritima* community

This community is the characteristic pioneer vegetation of sand and fine shingle strandlines on the less exposed beach tops around the British coast. Sea sandwort *Honkenya peploides* may persist through the winter and tolerate occasional saltwater inundation. In the summer it is joined by sea rocket *Cakile maritima* and other nitrophilous annuals which exploit the organic detritus deposited by the sea during the winter and spring. The extent and distribution of this community can vary greatly from year to year as it exists in a state of perpetual instability. The present survey showed SD2 strandline to be generally distributed around the coasts of England, with particular concentrations in Cumbria, Norfolk and the Isles of Scilly. By its very nature this community does not tend to occupy large areas and a total of only 43 ha was recorded.

SD3 *Matricaria maritima-Galium aparine* strandline

This type of strandline vegetation is characteristic of sheltered, sandy shingle beaches in cooler and wetter parts of Britain. It is relatively abundant in parts of Scotland but in England was recorded only in Merseyside and Northumberland. The nutrients released from the decaying detritus allow nitrophilous plants to

Table 8 Strandline vegetation types (SD2, SD3) in surveyed English dune systems. Areas in hectares.

County	SD2	SD3
Kent	2.04	
East Sussex	0.01	
West Sussex		
Isle of Wight	0.08	
Hampshire		
Dorset		
Devon	2.44	
Cornwall	0.05	
Isles of Scilly	5.85	
Somerset		
Avon	0.58	
Merseyside	2.64	2.14
Lancashire		
Cumbria	12.77	
Northumberland	1.05	0.62
Cleveland & Durham		
Humberside	2.36	
Lincolnshire	2.17	
Norfolk	10.53	
Totals	**42.57**	**2.76**

flourish whilst the humus also helps to retain moisture. Comparatively high rainfall and a degree of shelter also means that plants which are not particularly salt-tolerant can grow during the summer months.

3.5.3.2 Mobile dunes

The distributions and areas of the various communities and sub-communities of mobile dune vegetation are summarised in Table 9.

SD4 *Elymus farctus* foredune community

This type of pioneer dune vegetation occurs on, and binds together, wind-blown sand on foreshores in the zone that is still vulnerable to saltwater inundation. The community is particularly associated with the advancing fronts of accreting dune systems but also occurs in areas subject to cyclical erosion and accretion. It is normally a very open type of vegetation and quite species-poor. Sand couch *Elymus farctus*, a sand-binding grass that is relatively salt-tolerant, is often the only species that is abundant. The community will also normally contain some strandline species, and may include small quantities of other dune-building grasses, perhaps marking areas that are transitional between this community and the other foredune types. SD4 was generally distributed in suitable areas around England. The largest areas occur on the east coast in areas where comparatively sheltered conditions and very flat beach profiles favour the formation of this community.

SD5 *Leymus arenarius* mobile dune community

Lyme-grass *Leymus arenarius*, a tall and tussocky perennial grass, dominates this type of dune vegetation, forming either open or closed stands. It can colonise and fix mobile sand and can keep pace with substantial sand accumulation. The plant has a northerly distribution and the community in which it is dominant is found mainly on the north-east coast of England as far south as The Wash

Table 9 Mobile dune vegetation types (SD4–SD6) in surveyed English dune systems. Areas in hectares.

County	SD4	SD5a	SD5b	SD5c	SD5	SD6a	SD6b	SD6c	SD6d	SD6e	SD6f	SD6g	SD6
Kent	3.97					0.25				8.52			0.21
East Sussex	1.11				0.45	2.30	0.12			1.97			
West Sussex	3.12					7.74			1.07	4.68			0.95
Isle of Wight	0.15												
Hampshire							0.16	0.55		0.31			
Dorset	0.99	0.13	0.28			0.09	1.37			7.69	0.20		0.48
Devon	0.55				0.13	11.11	0.83	4.88	11.90	63.42	0.01	3.55	3.06
Cornwall	2.08					11.94			14.20	39.67		0.07	5.96
Isles of Scilly	2.18								2.18	7.29			
Somerset	2.91	1.29		0.41	0.09	0.08	7.23	1.26		0.46		0.10	
Avon	0.46									1.14			
Merseyside	6.45	1.34	2.60	2.33	15.58	14.62	6.92	6.79	57.08	34.84	4.14	1.41	10.06
Lancashire	0.94		3.01	0.01		0.59	0.97	1.40	1.82	3.91		0.02	0.22
Cumbria	4.20	0.03	0.34			10.27	4.52	0.87	20.05	51.60	15.34	0.25	1.94
Northumberland	6.07	3.15	8.55	2.94	0.29	11.00	16.73	8.86	2.45	24.51	40.42	3.13	0.68
Cleveland & Durham	26.84	0.55	18.40	0.30	0.32	4.96	6.13	0.26		6.38	8.76		0.13
Humberside	2.48		9.59	0.05	0.01	0.58	4.46			1.99	0.06		0.05
Lincolnshire	15.84	6.87	2.10	4.30		3.03	2.15	8.13	0.75	19.39			0.57
Norfolk	24.88			0.02	1.75	26.71	7.68	1.40	1.75	68.47	18.84	3.33	0.04
Totals	**104.72**	**13.36**	**44.83**	**10.36**	**18.62**	**105.22**	**59.27**	**34.40**	**113.25**	**346.24**	**87.77**	**11.89**	**24.35**

(Figure 40). In these areas lyme-grass-dominated vegetation is often prominent on the strandline and in the young dunes. Elsewhere this community tends to occupy smaller areas, particularly where there has been some disturbance or nutrient enrichment.

There are three sub-communities: SD5a, the species-poor type; SD5b, the *Elymus farctus* sub-community; and SD5c, the *Festuca rubra* sub-community. All the sub-communities appear to have similar geographical ranges within England. In the species-poor type lyme-grass can be the only species present and no other species are consistently associated with it. Lyme-grass remains the dominant species in SD5b but sand couch *Elymus farctus* is also found consistently, along with occasional marram and some plants of the strandline. SD5c is marked by the consistent presence of red fescue *Festuca rubra* and by a range of dicotyledonous species. These include strandline species such as sea rocket *Cakile maritima* and weedy species such as creeping thistle *Cirsium arvense*. This sub-community is especially associated with sites where the sand is rich in organic material, normally the result of the deposition of seaweed or other debris.

SD6 *Ammophila arenaria* mobile dune community

Marram *Ammophila arenaria* dominates most mobile dunes in England that are high enough to be removed from the risk of saltwater flooding. This very widespread community includes a range of distinctive sub-communities characteristic of different degrees of mobility with some well defined geographical variation. Because the sub-communities are so distinct they are described separately.

SD6a *Ammophila arenaria* mobile dune community, *Elymus farctus* sub-community

This is normally a very open type of foredune community in which small amounts of sand

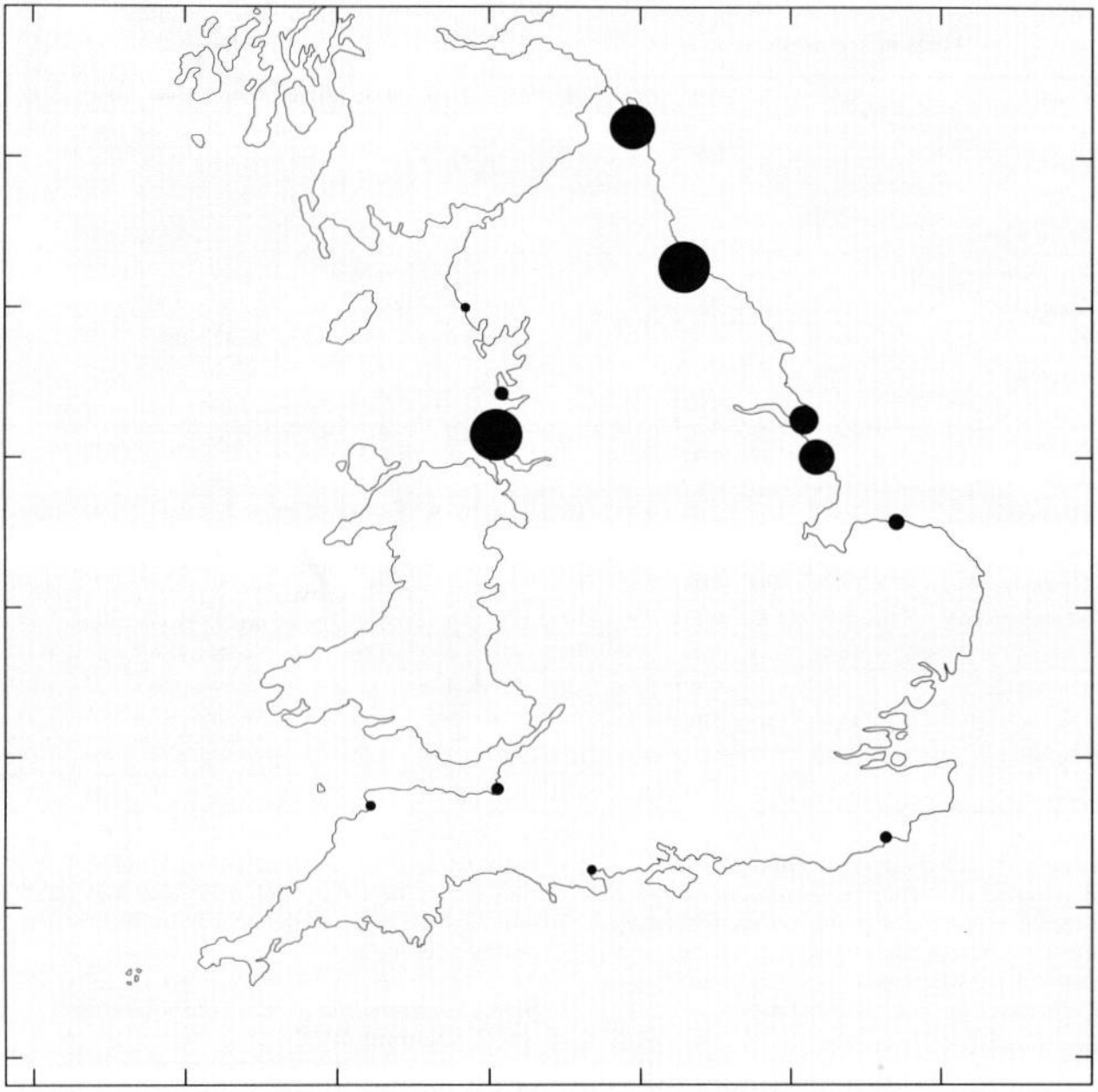

Figure 40 Distribution by county of SD5 *Leymus arenarius* mobile dune community. Symbol size is proportional to area occupied by the community.

couch *Elymus farctus* are a constant feature. Other salt-tolerant plants of the strandline and pioneer dune zone such as sea sandwort *Honkenya peploides* also occur in this sub-community alongside species typical of the community as a whole. This type of vegetation often occurs at the seaward edge of the marram-dominated dunes and immediately behind dunes dominated by sand couch (SD4). It is associated with considerable sand mobility and is found on dune systems in almost every part of the country, the only major concentration of dunes on which it was not found being the Isles of Scilly.

SD6b *Ammophila arenaria* mobile dune community, *Elymus farctus-Leymus arenarius* sub-community

Both sand couch *Elymus farctus* and lyme-grass *Leymus arenarius* grow with marram *Ammophila arenaria* in this sub-community. The relative quantities of the two subsidiary species are very variable and either or both may be subdominant. The other species associated with this sub-community are mainly salt-tolerant plants of the strandline and pioneer zone. This type of vegetation is found mainly along the seaward margins of the marram-dominated foredunes. The largest areas occur in north-east England, where lyme-grass itself is most abundant, but the community is widely distributed. There is a substantial area of this community on Berrow Dunes in Somerset. In areas where lyme-grass is not a major component of the dune vegetation this sub-community can generally be found in small patches in disturbed and possibly enriched areas such as the edges of major footpaths through the foredunes. It is associated with considerable sand mobility.

SD6c *Ammophila arenaria* mobile dune community, *Leymus arenarius* sub-community

Lyme-grass *Leymus arenarius* is constant in this normally very species-poor type. Other plants are normally few in number and largely confined to 'weedy' species. Like the last sub-community this type is found mainly along the seaward margin of the marram-dominated foredunes. The largest areas are again in the north of England but it is also widely distributed.

SD6d *Ammophila arenaria* mobile dune community,Typical sub-community

This sub-community, though described as typical, is far from being the most extensive type of marram *Ammophila arenaria* foredune. It occurs in areas where the rate of sand deposition is so rapid that few plants other than marram can survive. Such extreme conditions may occur on very actively accreting foredunes or at the downwind end of large blowouts. These situations are far more common on exposed western coasts and the distribution of the sub-community reflects this.

SD6e *Ammophila arenaria* mobile dune community, *Festuca rubra* sub-community

This type of vegetation is found where there is still considerable movement and deposition of sand but where the rates are slow enough to permit a wider range of plants to survive. It is still a very open community but red fescue *Festuca rubra* is consistently present beneath the marram. There are very few strandline species in this sub-community but the number of associated species is greater than in the more mobile areas of dune. They include some highly distinctive species such sea holly *Eryngium maritimum* and sea spurge *Euphorbia paralias*, especially in the southern part of England. A few bryophytes may occur in this type of vegetation. Substantial areas of SD6e are found on dunes throughout England.

SD6f *Ammophila arenaria* mobile dune community, *Poa pratensis* sub-community

In this sub-community red fescue *Festuca rubra* and smooth meadow-grass *Poa pratensis*, occasionally with some other grasses, form an open understorey beneath the marram. There is a wide range of associated species including several large 'weedy' dicotyledons such as hogweed *Heracleum sphondylium*. Very few strandline plants are found but bryophytes can be locally abundant. This is one of the major foredune communities in areas of moderate sand movement. It is widely distributed on dunes in northern and eastern England but is very scarce in the south and west (Figure 41). Where it occurs together with the red fescue *Festuca*

rubra sub-community it is normally found to landward of that type in areas which appear slightly less mobile.

SD6g *Ammophila arenaria* mobile dune community, *Carex arenaria* sub-community

Sand sedge *Carex arenaria* and marram *Ammophila arenaria* are often the only species to occur in any quantity in this sub-community. It is particularly associated with areas of secondary instability such as blowouts, especially near the margins of slacks and pools where the ground is a little moister. It is a scarce community with a widely scattered distribution.

3.5.3.3 Semi-fixed dunes

The distributions and areas of the semi-fixed dune vegetation types are summarised in Table 10.

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

This community is the major vegetation type of less mobile coastal sands where accretion has slowed but where there has been little modification of the soil. Marram *Ammophila arenaria* is normally still prominent in the vegetation but is less vigorous than in the more mobile foredunes. The smaller grasses, especially red fescue *Festuca rubra,* are more abundant; there is a characteristic assemblage of dicotyledonous plants; and bryophytes are a consistent feature. There are four sub-communities: SD7a, the Typical or species-poor type: SD7b, the *Hypnum cupressiforme* sub-community; SD7c, the *Ononis repens* sub-community; SD7d, the *Tortula ruralis* ssp. *ruraliformis* sub-community; and SD7e, the *Elymus pycnanthus* type.

The Typical sub-community (SD7a) is less species-rich than the others, but is not necessarily the commonest. It is found where the succession from mobile foredune to stable dune grassland is still at an early stage. The type lacks species such as restharrow *Ononis repens* which have a southern distribution. The largest areas in England were found on the east coast from Northumberland to Norfolk but smaller stands were also encountered in the south and west (Figure 42).

The *Hypnum cupressiforme* sub-community (SD7b) is marked by the abundance of this moss which, together with other bryophytes, forms an extensive carpet over the sand. Winter annuals are another feature of this type, which is found mainly on rather more stable areas than the typical sub-community. The largest concentrations are again on the east coast; the community is also found in the west and south-west but was not recorded from the south coast.

In the SD7c sub-community restharrow *Ononis repens* is abundant and several other plants with a southerly distribution, such as sea bindweed *Calystegia soldanella*, occur. Neither annuals nor bryophytes are particularly abundant in this type, which is found mainly on relatively unstable sands. Although fairly generally distributed within England this sub-community is most abundant on the west coasts (Figure 43), in contrast to SD7a.

The *Tortula ruralis* ssp. *ruraliformis* sub-community (SD7d) is found all round the coasts of England on areas more stable than those occupied by the *Ononis repens* type. Unlike SD7b, the largest areas are in the west and it does occur along the south coast. It is frequently found within areas of stable dune grassland on the steeper south-facing slopes. Here a combination of a harsh microclimate, rabbit scuffing and instability due to soil creep suppresses the vigour of perennial plants and maintains relatively open conditions. This type is characterised by the occurrence of a group of drought-avoiding winter annuals and by extensive carpets of bryophytes.

The SD7e sub-community is marked by the occurrence within semi-stable dune vegetation of sea couch *Elymus pycnanthus*. This grass is associated with upper saltmarshes and with sea walls but also occurs in dunes. Apart from the sea couch itself, there is little to distinguish this sub-community, which is often rather species-poor. Small stands of this type were quite widely scattered, but by far the largest areas were on the east coast in Humberside, Lincolnshire and Norfolk (Figure 44).

Table 10 Semi-fixed dune vegetation types (SD7) in surveyed English dune systems. Areas in hectares.

County	SD7a	SD7b	SD7c	SD7d	SD7e	SD7
Kent	0.04			3.82		12.02
East Sussex	3.06				4.06	1.06
West Sussex	0.28			0.34	1.16	1.68
Isle of Wight						
Hampshire			3.61		4.73	1.71
Dorset						4.71
Devon	6.46	6.72	82.20	214.75	17.34	5.07
Cornwall	5.95	6.21	18.58	6.63		3.64
Isles of Scilly						
Somerset						2.10
Avon						
Merseyside	0.84	10.06	276.80	150.29		83.05
Lancashire			12.57	5.20		
Cumbria		0.02	7.13	146.62	1.45	55.94
Northumberland	68.31	31.64	8.00	34.84		41.68
Cleveland & Durham	4.53		1.38	3.97		4.07
Humberside	2.55		0.67	0.40	9.90	
Lincolnshire	12.65	4.35	0.04	0.21	19.66	0.73
Norfolk	51.13	63.60	6.19	10.27	63.38	2.21
Totals	**155.83**	**122.60**	**417.17**	**577.34**	**121.68**	**219.67**

In the provisional version of the NVC, SD7a and SD7b are supposed to represent the range of variation in stability within semi-fixed dunes in northern Britain, whilst SD7c and SD7d do the same in southern Britain. The results of this survey show this to be something of an over-simplification. There is a different geographical bias in the distribution of these two sets of sub-communities, but it is more of an east/west divide than north/south. There is also a very great degree of overlap between them.

3.5.3.4 Dune grasslands

The distributions and areas of the communities and sub-communities of dune grassland vegetation are summarised in Table 11.

SD8 *Festuca rubra-Galium verum* fixed dune grassland

Red fescue *Festuca rubra* and a variety of other grasses, dicotyledons and mosses form the closed turf of this community. It occupies areas of stable, calcareous dune where sand accretion is no longer significant and where there has usually been some soil development. Marram may be present but is rarely a major component of the vegetation. There are five sub-communities of this type of dune grassland; the first three are variants found on free-draining soils, the last two are characteristic of somewhat damper conditions.

The Typical sub-community (SD8a) is the most widespread around the coasts of England. It is usually rather less species-rich than the other sub-communities. Mosses tend not to be very prominent and coarse grasses may occur. It is often found on sites which are rather undergrazed.

The SD8b *Luzula campestris* sub-community can often be rather species-rich. Both marram and field wood-rush *Luzula campestris* are frequent and common bent *Agrostis capillaris*,

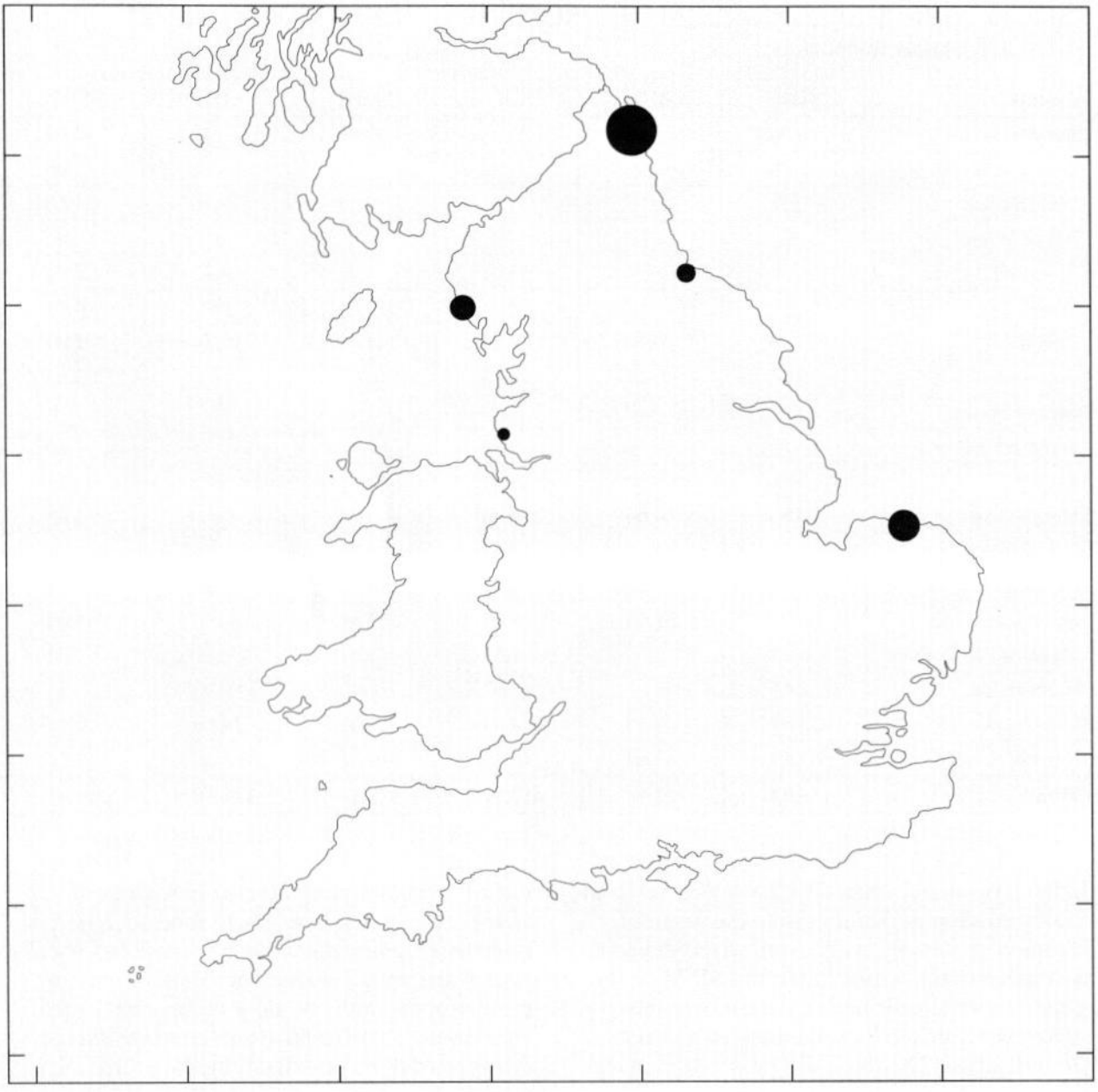

Figure 41 Distribution by county of SD6f *Ammophila arenaria* mobile dune, *Poa pratensis* sub-community. Symbol size is proportional to area occupied by the sub-community.

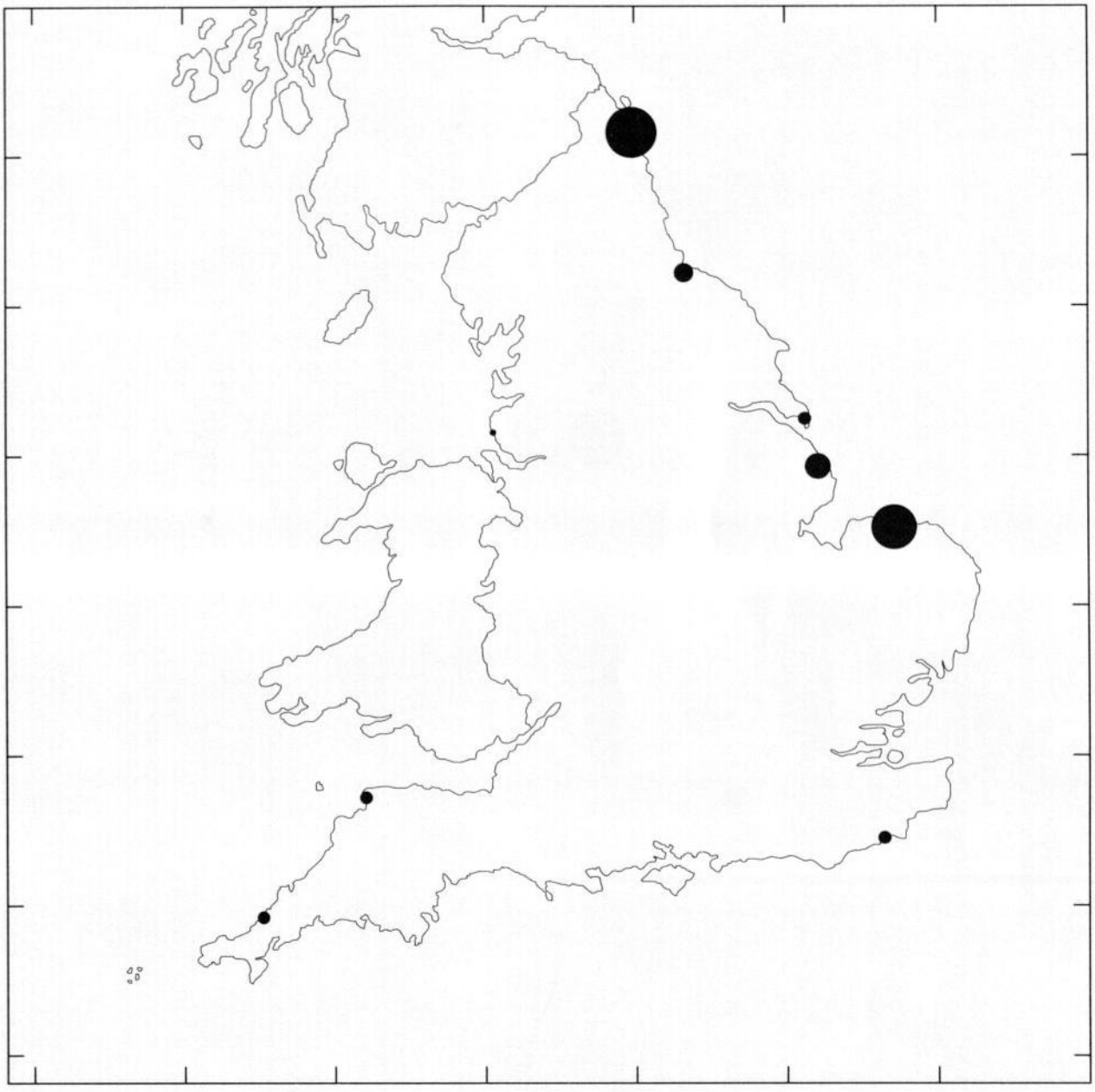

Figure 42 Distribution by county of SD7a *Ammophila arenaria-Festuca rubra* semi-fixed dune, typical sub-community. Symbol size is proportional to area occupied by the sub-community.

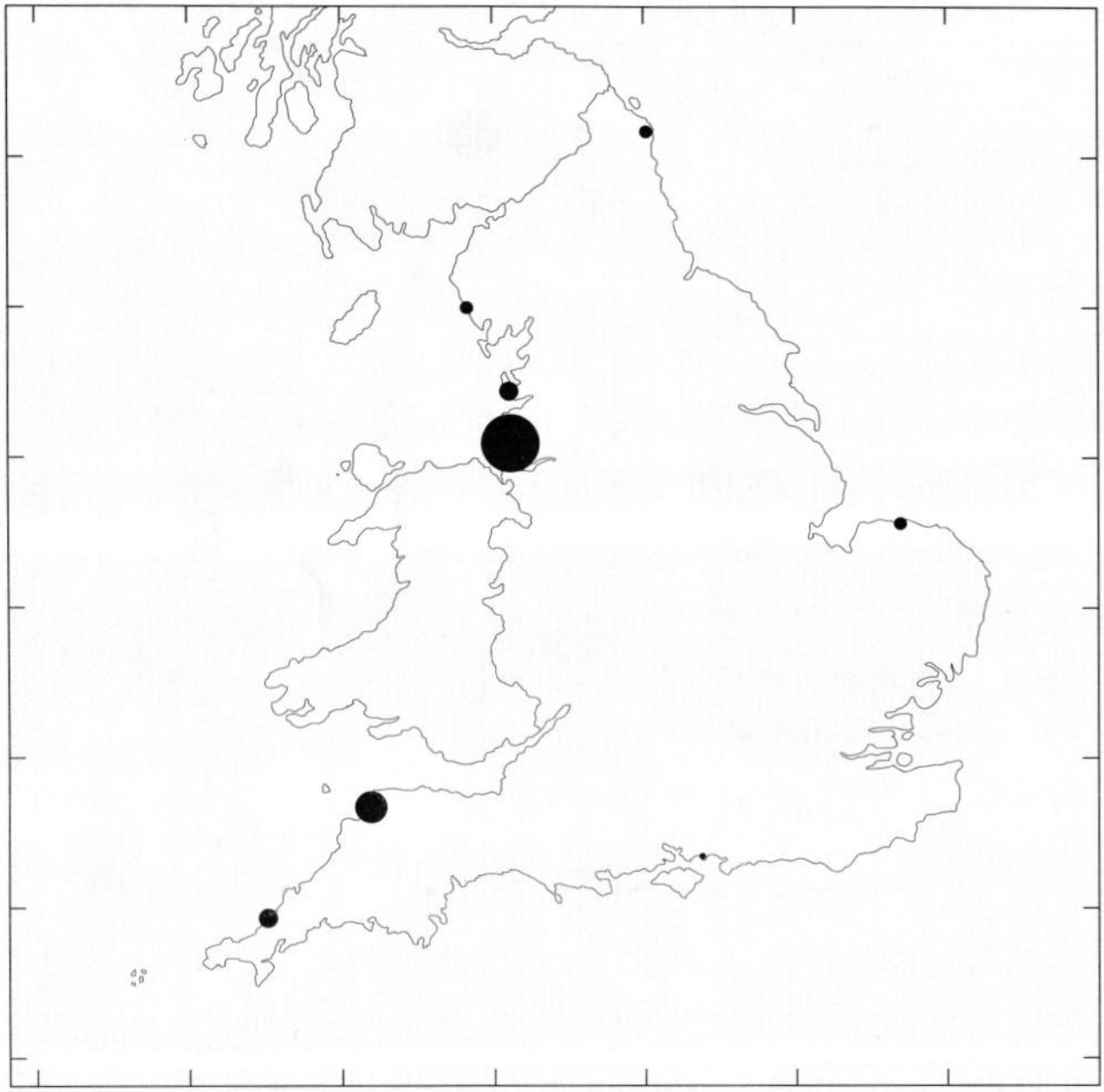

Figure 43 Distribution by county of SD7c *Ammophila arenaria-Festuca rubra* semi-fixed dune, *Ononis repens* sub-community. Symbol size is proportional to area occupied by the sub-community.

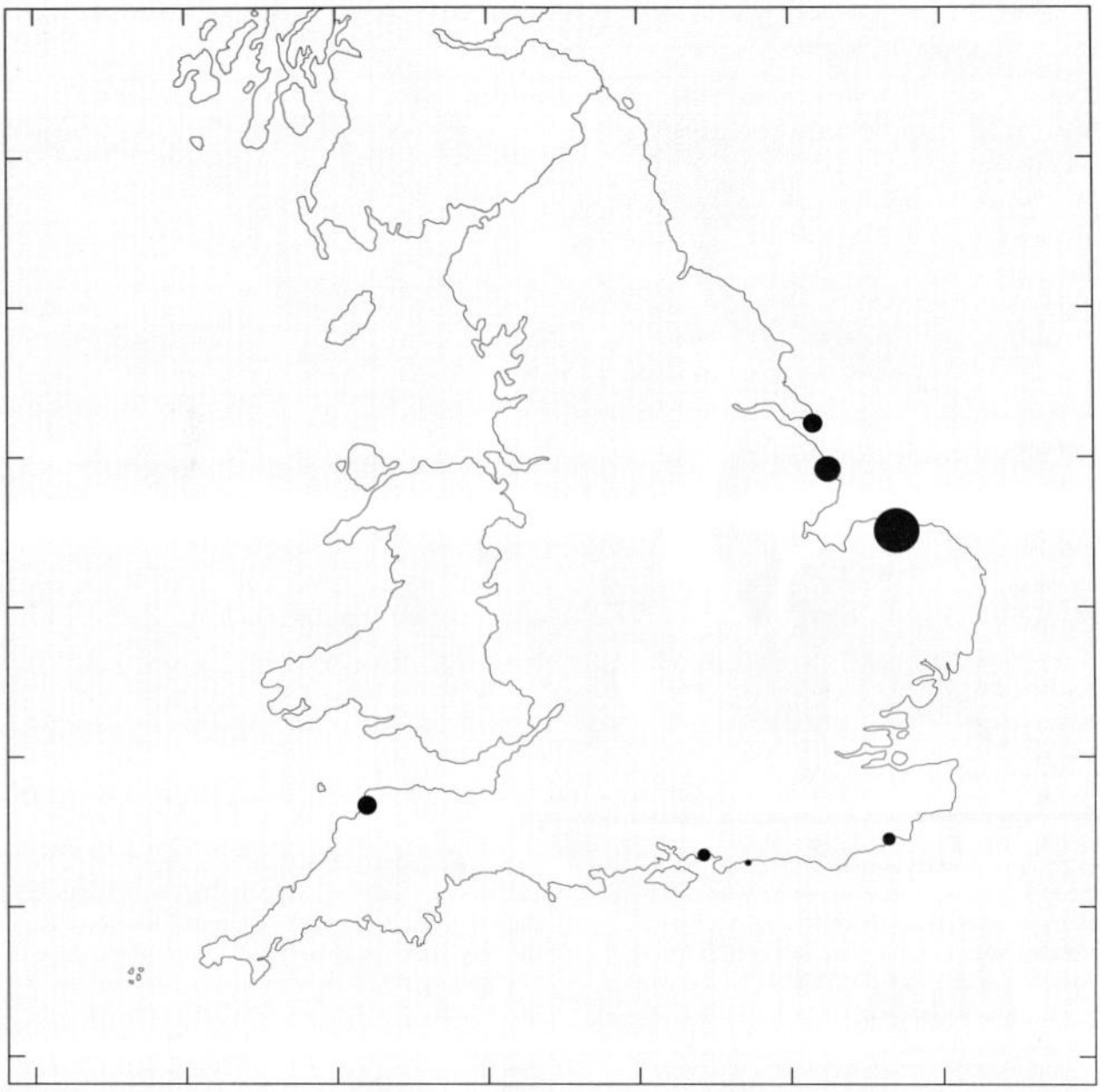

Figure 44 Distribution by county of SD7e *Ammophila arenaria-Festuca rubra* semi-fixed dune, *Elymus pycnanthus* sub-community. Symbol size is proportional to area occupied by the sub-community.

Table 11 Dune grassland vegetation types (SD8, SD9, SD12) in surveyed English dune systems. Areas in hectares.

County	SD8a	SD8b	SD8c	SD8d	SD8e	SD8	SD9a	SD9b	SD9	SD12a	SD12b	SD12
Kent	194.93	14.99				1.11	4.87			32.51		
East Sussex	6.87						6.20			2.74		
West Sussex						2.20						
Isle of Wight										2.02		
Hampshire										1.23		0.04
Dorset												0.17
Devon	50.86	0.10	39.97		1.40							0.19
Cornwall	56.97	72.46	331.12	28.57	8.39	216.91			2.71			
Isles of Scilly										0.94		
Somerset	3.25	12.69	12.59		0.06	5.16						
Avon												
Merseyside	58.54	29.53				40.64	53.38	1.95	2.61	15.57	6.60	44.95
Lancashire			1.05			0.43						
Cumbria	105.19	160.97	11.52	0.13		36.99	2.11	2.58	8.89	33.65		49.69
Northumberland	48.79	69.86			0.94	63.37	109.52	126.24	15.64	25.02	0.20	4.12
Cleveland & Durham	19.77	24.68	0.72		3.50	26.75	2.83	10.18	0.61			
Humberside	0.16		0.08			2.73	4.52					
Lincolnshire	6.71	9.22	1.42				82.81					0.19
Norfolk	20.71	2.56			0.33	1.24	8.32			30.72	2.65	10.77
Totals	**572.75**	**397.06**	**398.47**	**28.70**	**14.62**	**397.53**	**274.56**	**140.95**	**30.46**	**144.58**	**9.45**	**110.12**

sweet vernal-grass *Anthoxanthum odoratum* and sheep's fescue *Festuca ovina* may be common. Many of the typical dicotyledons are low-growing species, and there is a well marked variant in south-west England in which wild thyme *Thymus polytrichus* was constant and abundant in the samples taken. Moss cover can be quite high. *Rhytidiadelphus squarrosus* is common and other species occurring occasionally include *Rhytidiadelphus triquetrus*, *Brachythecium albicans* and *Pseudoscleropodium purum*. This sub-community shares some species with the stable grasslands of acidic dunes. The sub-community has a strongly northern and western distribution within England (Figure 45).

Marram is relatively frequent in the *Tortula ruralis* ssp. *ruraliformis* sub-community (SD8c) and annual plants can be fairly abundant. The most characteristic feature is, however, the cover of mosses such as *Homalothecium lutescens*, *Tortula ruralis* ssp. *ruraliformis* and *Rhytidiadelphus squarrosus*. This sub-community is found on some very calcareous sands and has affinities with some of the calcicolous grassland communities. It is also the type which is closest to the semi-fixed dune community (SD7). It is relatively abundant on the western coasts of England, but only a few small stands of this sub-community were recorded on the east coast. It was not found at all from The Wash to Land's End.

The *Bellis perennis-Ranunculus acris* sub-community (SD8d) is one of two that are especially characteristic of northern and western Britain, where cool, oceanic conditions reduce the incidence of severe droughts. In England it is a scarce type, and was only recorded from Cornwall and Cumbria.

The *Prunella vulgaris* sub-community (SD8e) usually forms a closed turf, which is kept short by grazing and/or trampling. Red fescue *Festuca rubra* is strongly dominant whilst marram is no more than occasional. Amongst the wide range of dicotyledonous species, self-heal *Prunella*

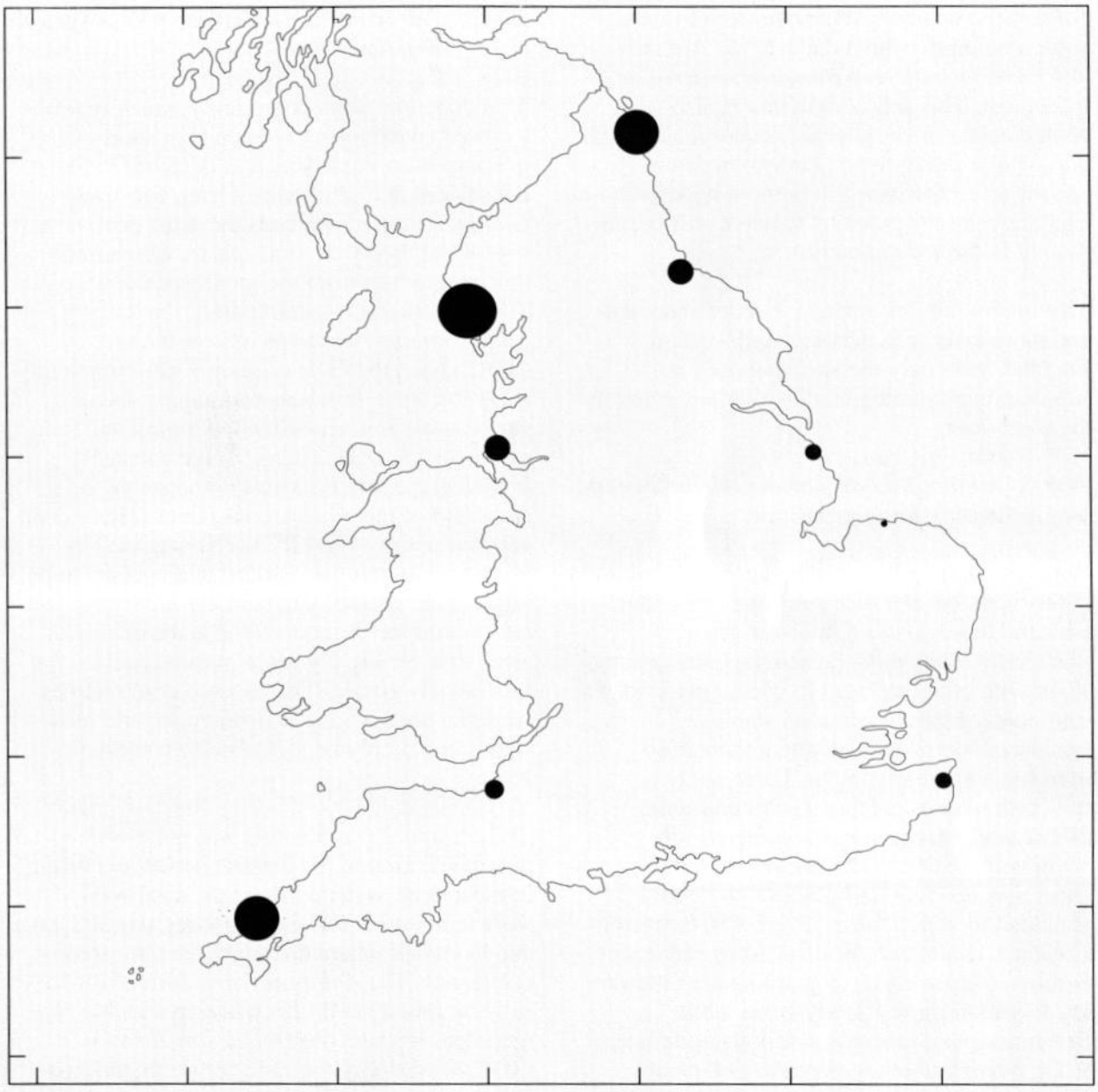

Figure 45 Distribution by county of SD8b *Festuca rubra-Galium verum* fixed dune grassland, *Luzula campestris* sub-community. Symbol size is proportional to area occupied by the sub-community.

vulgaris is especially characteristic of this sub-community, whilst daisy *Bellis perennis* and meadow buttercup *Ranunculus acris* are infrequent. This sub-community is also characteristic of cool oceanic conditions, which allow more mesophytic plants to become prominent in the sward. It is more widespread in England than the previous type but still occurs mainly in the west and north.

This community as a whole is more abundant and more diverse in northern and western England, with only the species-poor sub-community being at all well represented in the south-east.

SD9 *Ammophila arenaria-Arrhenatherum elatius* dune grassland

Dune grassland plants make a major contribution to this type, but the sward is generally rather rank and tussocky with false oat-grass *Arrhenatherum elatius* present in some quantity, along with other species of coarse grassland. The community tends to occur on stabilised dunes that are undergrazed and where there has been some soil enrichment. There are two sub-communities, a typical sub-community (SD9a) and a *Geranium sanguineum* sub-community (SD9b). The former is typically rather species-poor and grades into neutral grassland in which false oat-grass is dominant. The latter is normally dominated by red fescue *Festuca rubra* with varying amounts of marram and false oat-grass. Bloody crane's-bill *Geranium sanguineum* is a striking component of the sward and other characteristic plants include lesser meadow-rue *Thalictrum minus* and burnet rose *Rosa pimpinellifolia*.

The Typical sub-community (SD9a) has quite a wide distribution, though it was not recorded from the south and west between East Sussex and the Welsh border. By contrast, in England the *Geranium sanguineum* sub-community (SD9b) is found almost exclusively in the north-east (Figure 46). It is a major component of the dune vegetation of Northumberland and extends as far south as Cleveland. Here it stops abruptly. It is well represented at a site known as Hart Warren but it is entirely absent from the Tees Bay dunes, which are only a few kilometres along the coast.

SD12 *Carex arenaria-Festuca ovina-Agrostis capillaris* grassland

This dune grassland community typically forms a closed sward which is often kept short by grazing. Marram *Ammophila arenaria* is found, but seldom at high density. Heath bedstraw *Galium saxatile* is perhaps the most distinctive of a group of dicotyledonous plants which mark this community from the more calcicolous types. There are two sub-communities, the *Anthoxanthum odoratum* sub-community (SD12a) and the *Holcus lanatus* sub-community (SD12b). In the first sub-community sweet vernal-grass *Anthoxanthum odoratum* and field wood-rush *Luzula campestris* are constants. It is this type that is closest to the stable grassland of more calcareous dunes. The second sub-community (SD12b) is characterised by Yorkshire fog *Holcus lanatus* and appears to be rather more mesophytic than the *Anthoxanthum odoratum* type. It seems to be associated with areas that are slightly more nutrient rich and/or less heavily grazed. The two sub-communities were not always easy to distinguish, and many stands could only be identified to community level.

The community as a whole was quite widely distributed around the English coasts, occurring in most dune systems where the sand was sufficiently acidic. The biggest gap was in Devon and Cornwall where the dunes are almost all calcareous. The *Anthoxanthum odoratum* sub-community (SD12a) was also widely recorded, whereas the *Holcus lanatus* type (SD12b) was only found in the north and east.

3.5.3.5 Dune vegetation in which sand sedge Carex arenaria *is prominent*

The areas and distributions of the various classes of this type of vegetation are summarised in Table 12.

SD10 *Carex arenaria* dune community

Sand sedge *Carex arenaria* is normally the most abundant species in this type of vegetation, forming either open or closed stands, usually in blowouts or in areas that are revegetating after secondary disturbance. Although this community is associated with areas of open sand, it can

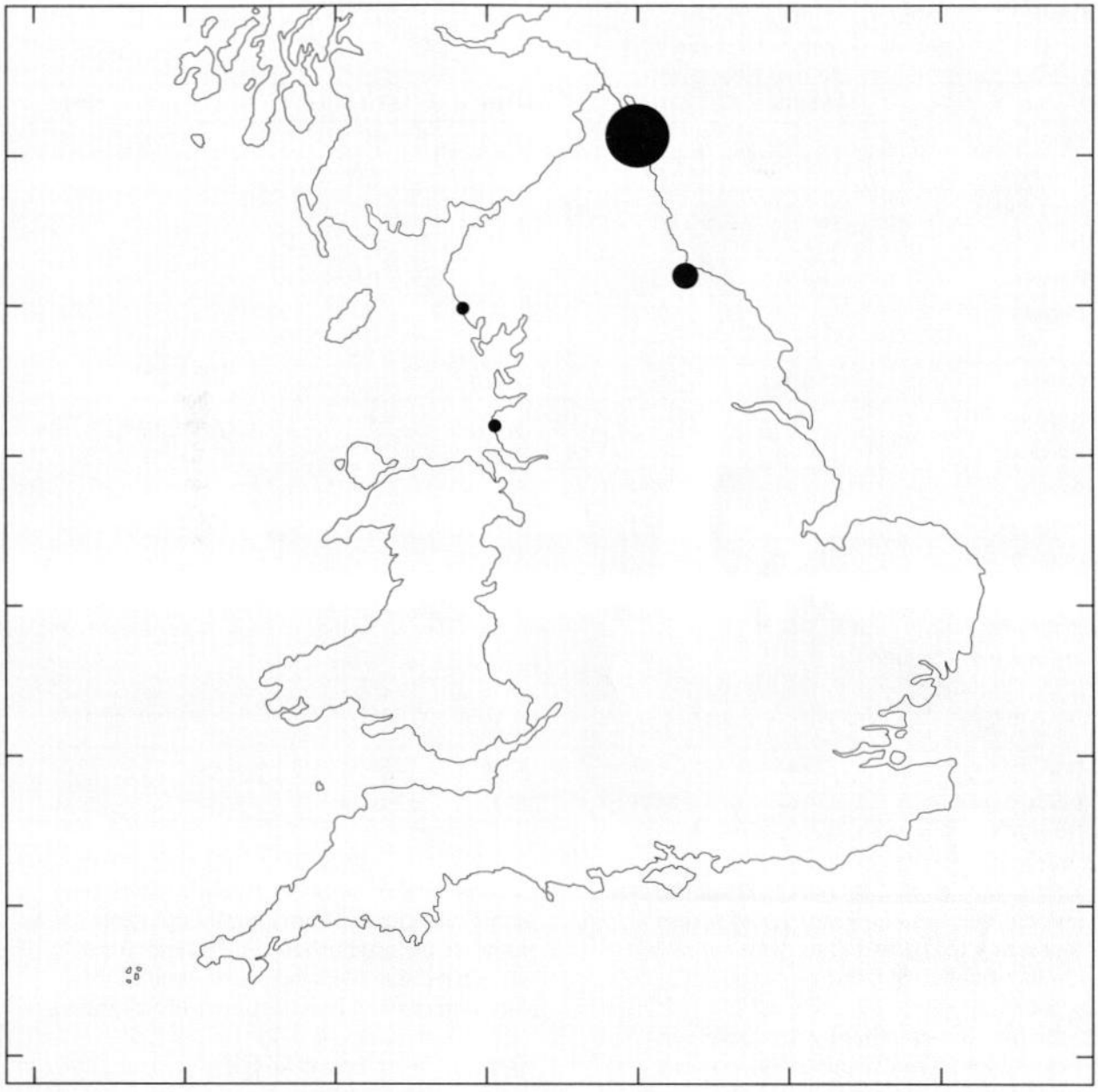

Figure 46 Distribution by county of SD9b *Ammophila arenaria-Arrhenatherum elatius* dune grassland, *Geranium sanguineum* sub-community. Symbol size is proportional to area occupied by the sub-community.

Table 12 Vegetation with prominent *Carex arenaria* (SD10, SD11) in surveyed English dune systems. Areas in hectares.

County	SD10a	SD10b	SD10	SD11a	SD11b	SD11
Kent		8.51	0.06	0.19		
East Sussex				4.08		
West Sussex				0.01		
Isle of Wight						
Hampshire	0.25		0.65	0.86		
Dorset		0.13				
Devon				1.29		
Cornwall	0.21		0.86			
Isles of Scilly						
Somerset	0.52		0.33			
Avon		0.14				
Merseyside	2.28	0.22	10.62	7.58	0.58	1.26
Lancashire						
Cumbria	0.55			62.22		
Northumberland	0.22		0.04	9.91		1.36
Cleveland & Durham						
Humberside						
Lincolnshire		0.80	0.21			
Norfolk	5.58	14.33	32.55	103.35	31.52	25.64
Totals	**9.61**	**24.13**	**45.32**	**189.49**	**32.10**	**28.26**

tolerate only limited accretion. There are two sub-communities, the *Festuca rubra* sub-community (SD10a) and the *Festuca ovina* sub-community (SD10b).

In the first sub-community sand sedge is associated with red fescue *Festuca rubra*, and some foredune species may also be present. These may include marram and sand couch *Elymus farctus* but only at low cover. In the second sub-community sand sedge is associated with sheep's fescue *Festuca ovina*, and foredune species are absent.

The first sub-community is widely distributed in coastal sand dunes around England as the characteristic vegetation of stabilising blowouts. The second sub-community is especially associated with inland sand dunes in the Breckland and Coversand areas of eastern England. It does, however, also occur on coastal dunes, with the largest areas being also in the east, in Norfolk and Kent.

A considerable number of stands where sand sedge was clearly dominant did not appear to fit either of the established sub-communities, suggesting that the subdivisions within this community would merit further investigation.

SD11 *Carex arenaria-Cornicularia aculeata* community

Sand sedge *Carex arenaria is* the only constant vascular plant in this community and even this is never a vigorous dominant. The most notable feature is the abundance of lichens. These often form a continuous grey carpet over the ground. There may also be substantial amounts of mosses present, though they are seldom as abundant as the lichens. The community is characteristic of very nutrient-poor sands and areas that are subject to severe drought. The distribution of this community on English coastal dunes is shown in Figure 47.

There are two sub-communities, the *Ammophila*

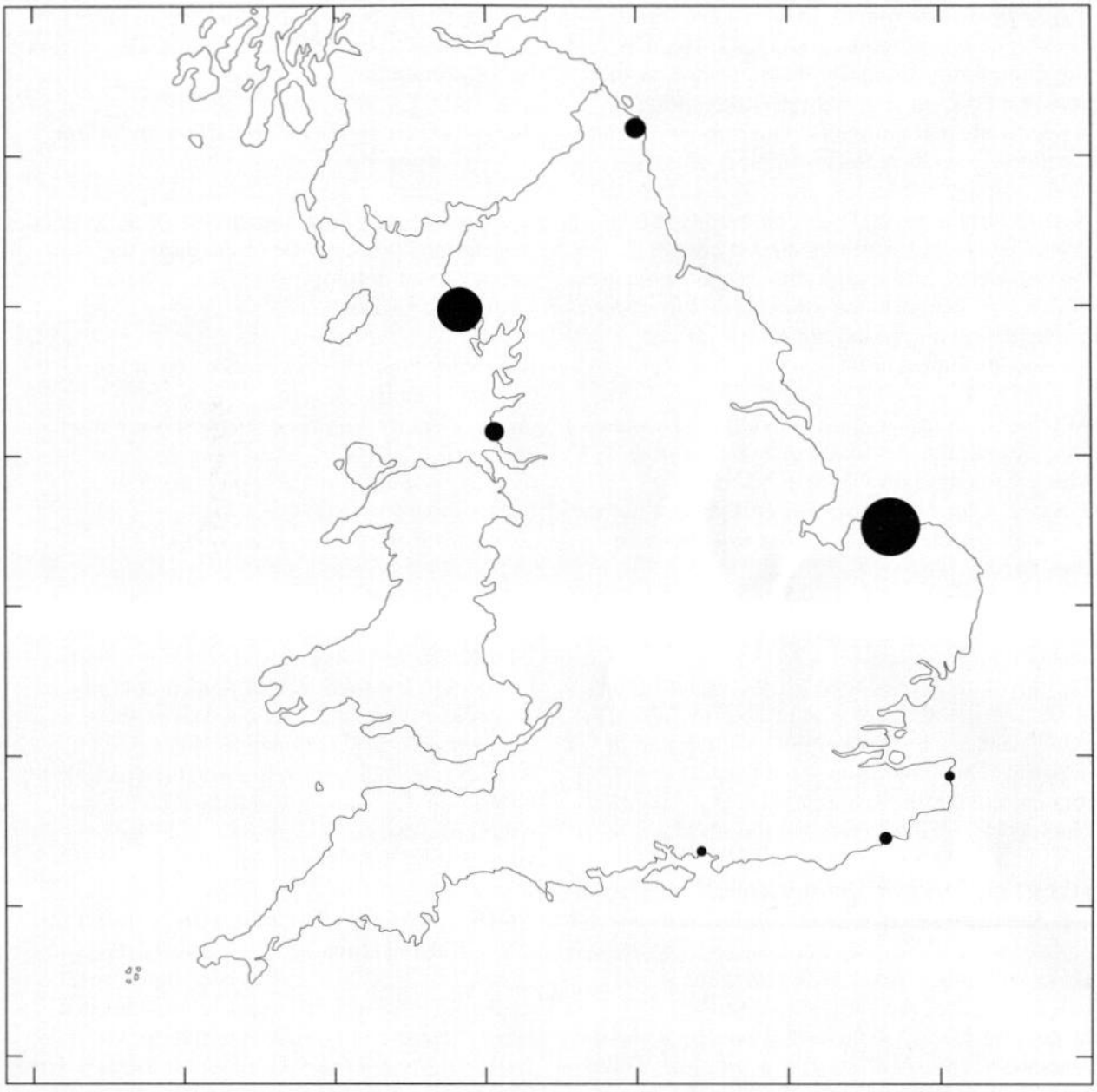

Figure 47 Distribution by county of SD11 *Carex arenaria-Cornicularia aculeata* dune community. Symbol size is proportional to area occupied by the community.

arenaria sub-community (SD11a) and the *Festuca ovina* sub-community (SD11b). The first sub-community is chiefly distinguished by the consistent presence of marram *Ammophila arenaria* in small amounts. This sub-community is relatively widespread on English coastal dunes, though the largest areas by far occur in Norfolk. In the second sub-community the fescue associated with it is almost always *Festuca ovina*, and marram is absent. Large areas of this type occur on the inland dunes in eastern England, and on coastal dunes it is almost confined to East Anglia.

At a few sites in Cumbria an additional variant of this community was found growing in areas where the underlying shingle had become exposed. *Carex arenaria* was still present but the dominant species was the moss *Racomitrium canescens.*

3.5.3.6 Slacks

The distributions and areas of the various types of slack vegetation are summarised in Table 13. Dune slacks as a whole are not widespread in England. This table shows that they are concentrated in four counties: Devon, Merseyside, Cumbria and Northumberland.

SD13 *Salix repens-Bryum pseudotriquetrum* dune slack

This community is one of two that are characteristic of the early stages of the successional development of dune slacks and the vegetation cover is often still incomplete. There are two distinctive variants, the *Poa annua-Hydrocotyle vulgaris* sub-community (SD13a) and the *Holcus lanatus-Festuca rubra* sub-community (SD13b). SD13 is a very rare community in England, and less than 12 ha was recorded throughout the whole country.

Only one small stand of SD13a was recorded during the survey, whilst SD13b was recorded in Northumberland and Merseyside. In Northumberland this type of vegetation was found in some of the younger slacks at the eastern end of The Snook, Lindisfarne, though the very youngest slacks were occupied by even sparser vegetation from which bryophytes were largely absent. On Merseyside some stands which clearly belonged to this community were found to be difficult to assign to sub-communities.

SD14 *Salix repens-Campylium stellatum* dune slack

This community is the other type of dune slack vegetation characteristic of the early stages of successional development. There are four distinctive variants:

Carex serotina-Drepanocladus sendtneri sub-community (SD14a),
Rubus caesius-Galium palustre sub-community (SD14b),
Bryum pseudotriquetrum-Aneura pinguis sub-community (SD14c),
Festuca rubra sub-community (SD14d).

Almost the full range of sub-communities was found on Braunton Burrows in Devon, with only SD14c absent. This one site contained three-quarters of the total area of this community recorded in England. Outside Devon there were small stands of SD14b and SD14c on Merseyside and there was a notable example of SD14a on The Snook, Lindisfarne. This was found in close association with the slacks occupied by the last community.

SD15 *Salix repens-Calliergon cuspidatum* dune slack

Creeping willow *Salix repens* dominates this type of mature dune slack vegetation whilst the moss *Calliergon cuspidatum* often forms a dense understorey. The vegetation is typically much more closed than that of the preceding communities. It tends to occupy the wetter areas of slacks. Four sub-communities are recognised:

Carex nigra sub-community (SD15a),
Equisetum variegatum sub-community (SD15b),
Carex flacca-Pulicaria dysenterica sub-community (SD15c),
Holcus lanatus-Angelica sylvestris sub-community (SD15d).

This community is more abundant and widespread than the types which are characteristic of the early stages of dune succession (Figure 48). A good range of

Table 13 Dune slack vegetation (SD13–SD17) in surveyed English dune systems. Areas in hectares.

County	SD13a	SD13b	SD13	SD14a	SD14b	SD14c	SD14d	SD14	SD15a	SD15b	SD15c	SD15d	SD15	SD16a	SD16b	SD16c	SD16d	SD16	SD17a	SD17b	SD17c	SD17d
Kent					0.04																	
East Sussex																						
West Sussex																						
Isle of Wight																						
Hampshire																						
Dorset																						
Devon				2.98	4.92		8.59	9.55	0.50	19.75	4.66	2.42	10.37	0.31	9.20		13.31	42.67				
Cornwall								0.03				1.73	1.16	0.82			0.09					5.44
Isles of Scilly																						
Somerset											0.18											
Avon																						
Merseyside	0.04	4.69	4.00		0.31	0.41		0.87	5.62	6.04	3.15	48.56	4.39	4.14	33.99	3.96	4.61	51.88				3.95
Lancashire																	3.73	0.92				1.46
Cumbria								0.33		10.64		10.64	0.98	1.66		4.84	2.38	10.04				18.28
Northumberland		2.63		6.21				0.04	0.13	0.22		2.50	1.49	4.92		0.02	7.65	16.81	5.43	15.29	0.04	7.79
Cleveland & Durham																0.03						
Humberside																						
Lincolnshire																						
Norfolk								0.22						3.38	0.26	4.50	0.56	0.91				
Totals	**0.04**	**7.32**	**4.00**	**9.19**	**5.27**	**0.41**	**8.59**	**11.04**	**6.25**	**36.65**	**7.99**	**65.85**	**18.39**	**15.23**	**43.45**	**13.33**	**32.32**	**123.23**	**5.43**	**15.29**	**0.04**	**36.92**

sub-communities were recorded in each of the four major dune slack counties. The largest areas were all found on the west coast, the small stands on Lindisfarne and Ross Links in Northumberland being the only ones encountered between the Tweed and Land's End.

SD16 *Salix repens-Holcus lanatus* dune slack

Creeping willow also dominates this type of mature dune slack vegetation, but the dense carpets of *Calliergon cuspidatum* are absent. The grass Yorkshire fog *Holcus lanatus* is constant and often abundant in this community, along with glaucous sedge *Carex flacca*. The community as a whole tends to occupy drier slacks than the preceding type, though the four sub-communities appear to span a considerable range of conditions. The *Ononis repens* sub-community (SD16a) contains a number of dry dune grassland species. A few of these persist through into the *Rubus caesius* and the *Prunella vulgaris-Equisetum variegatum* sub-communities (SD16b and SD16c respectively). They are, however, largely absent from the *Agrostis stolonifera* sub-community (SD16d), which instead contains species of wetter conditions such as marsh pennywort *Hydrocotyle vulgaris* and lesser spearwort *Ranunculus flammula*.

This was the most abundant and widely recorded dune slack vegetation community in England (Figure 49). A good range of sub-communities were found in all the four major dune slack counties. All four sub-communities were also present in Norfolk, where there was almost no other true dune slack vegetation.

SD17 *Potentilla anserina-Carex nigra* dune slack

In this mature dune slack community creeping willow *Salix repens* is often absent and glaucous sedge *Carex flacca* is largely replaced by common sedge *Carex nigra*. Some forms of this community are not dissimilar to *Carex nigra* base-poor fen. There are four sub-communities:

Festuca rubra-Ranunculus repens sub-community (SD17a),
Carex flacca sub-community (SD17b),
Caltha palustris sub-community (SD17c),
Hydrocotyle vulgaris-Ranunculus flammula sub-community (SD17d).

These again appear to span a considerable range of conditions. The preliminary work for the sand dune chapter of the NVC (Malloch 1985) suggested that this community was especially characteristic of Scotland. The present survey certainly revealed a strong northern bias (Figure 50). Northumberland had more of this community than any other county and it was also only in Northumberland that the full range of sub-communities was found. However, SD17d appeared to be more widespread than the other sub-communities (Figure 51), with a significant outlier of this type in Cornwall.

3.5.3.7 Other grasslands

A wide range of grassland communities not confined to sand dunes were recorded during the course of the survey, especially on the more inland parts of the larger dune systems. There were examples from all three grassland chapters of the NVC: mesotrophic grasslands (MG), calcareous grasslands (CG) and acidic grasslands (U). The areas and distributions of these vegetation types are summarised in Table 14.

MG Mesotrophic grasslands

The most widespread mesotrophic, or more correctly neutral, grasslands encountered during the survey were the *Arrhenatherum elatius* coarse grasslands (MG1), the *Cynosurus cristatus-Centaurea nigra* pastures (MG5), the *Lolium perenne-Cynosurus cristatus* meadows (MG6), the *Lolium perenne* leys and related grasslands (MG7) and the *Festuca rubra-Agrostis stolonifera-Potentilla anserina* inundation grasslands (MG11).

All the sub-communities of coarse grasslands dominated by false oat-grass *Arrhenatherum elatius* were encountered during the survey. By far the most widespread were the *Festuca rubra* sub-community (MG1a) and the *Urtica dioica* sub-community (MG1b). The next most abundant type was MG1e, the *Centaurea nigra* sub-community. MG1b is characteristic of undergrazed and nutrient-enriched dune. MG1e is more species-rich than the other sub-communities and has a number of species in

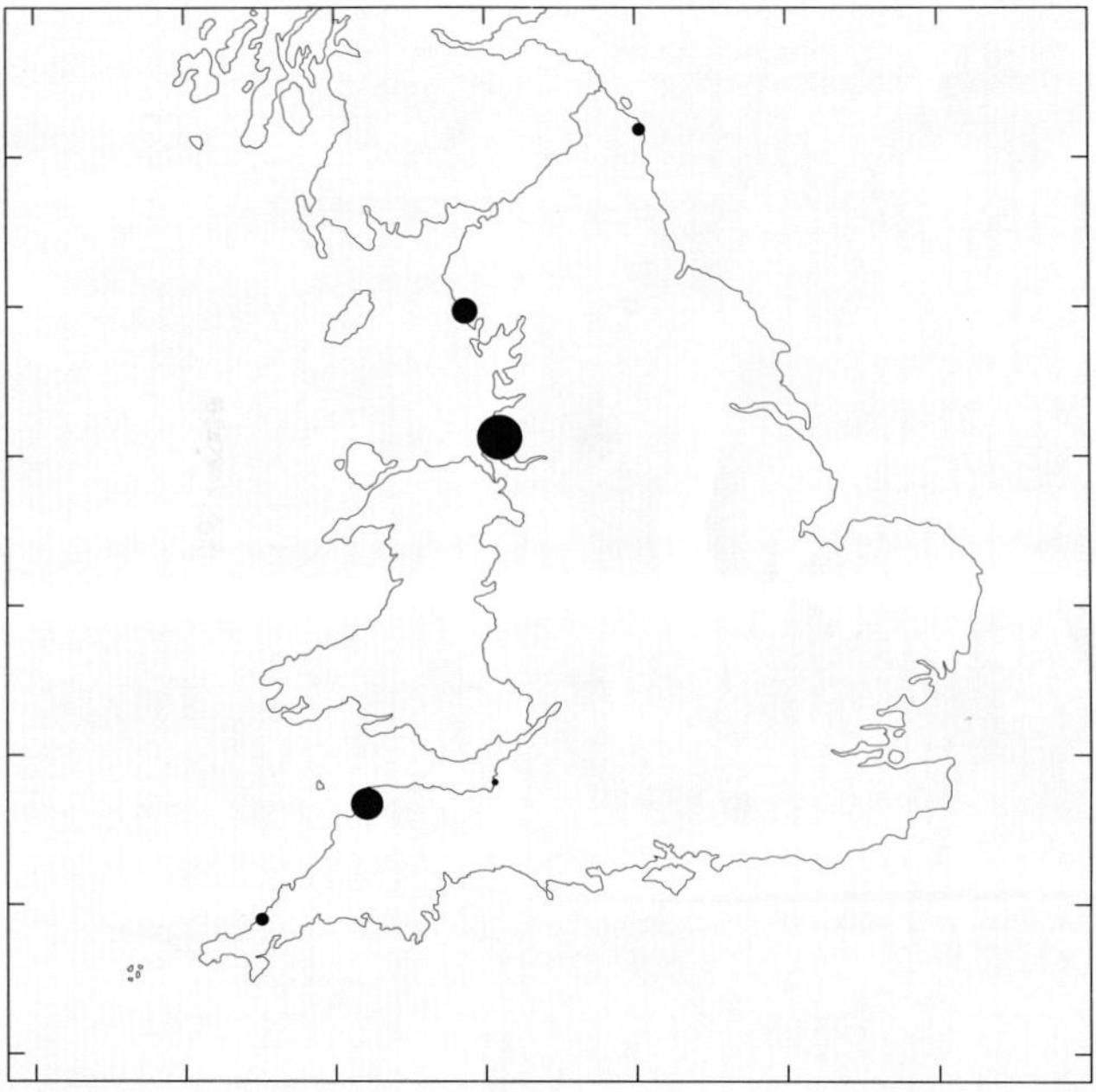

Figure 48 Distribution by county of SD15 *Salix repens-Calliergon cuspidatum* dune slack community. Symbol size is proportional to area occupied by the community.

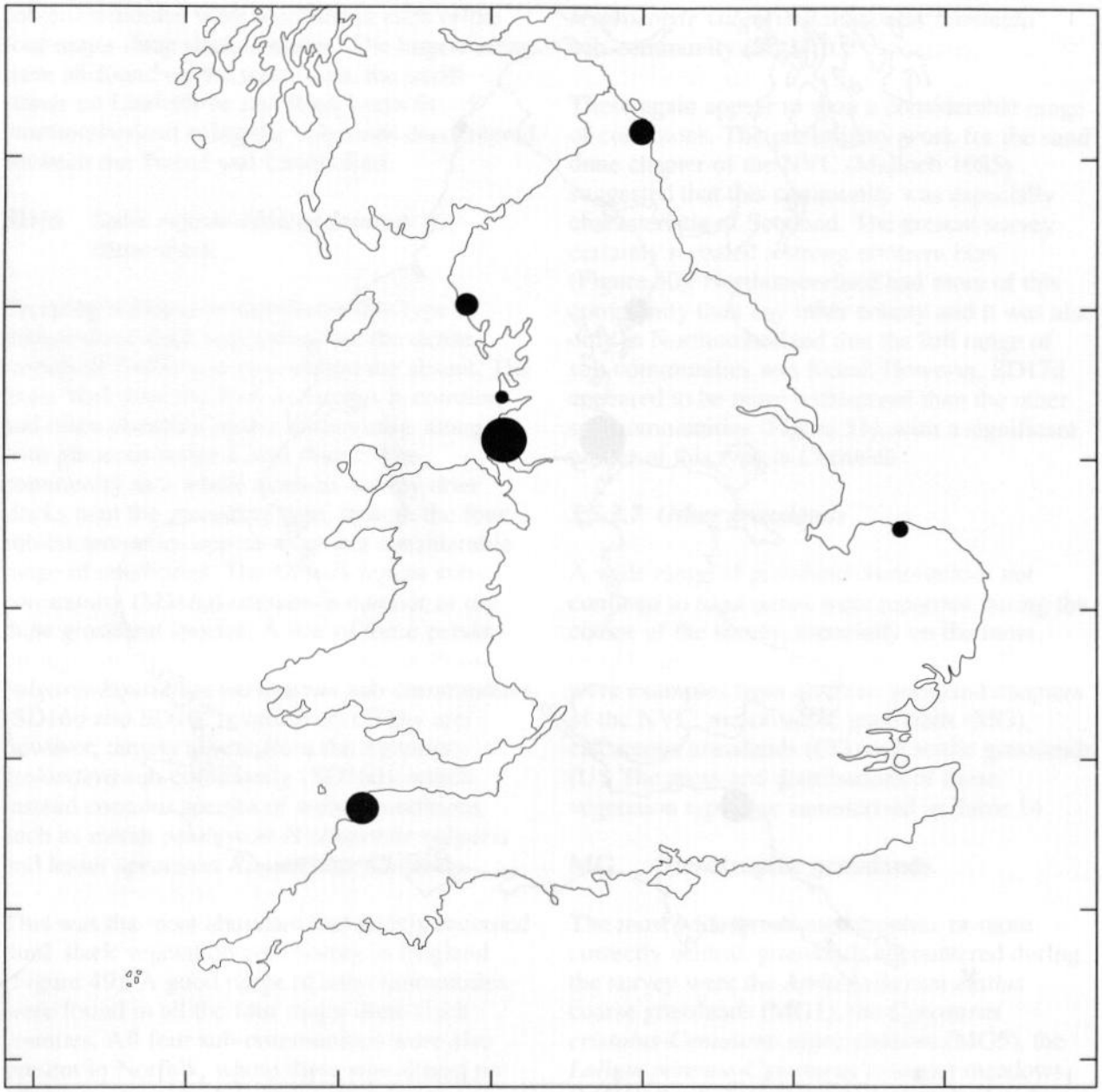

Figure 49 Distribution by county of SD16 *Salix repens-Holcus lanatus* dune slack community. Symbol size is proportional to area occupied by the community.

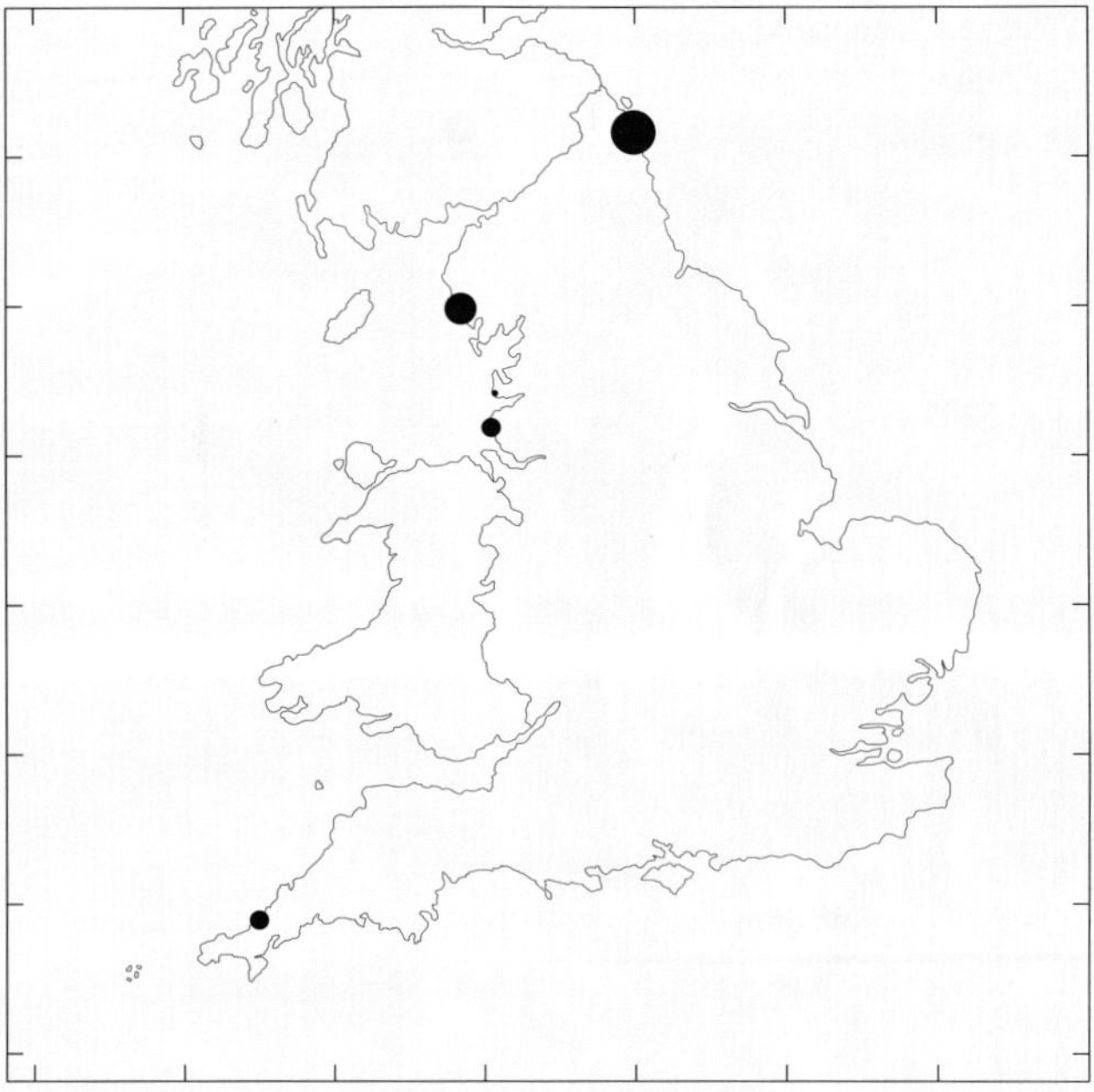

Figure 50 Distribution by county of SD17 *Potentilla anserina-Carex nigra* dune slack community. Symbol size is proportional to area occupied by the community.

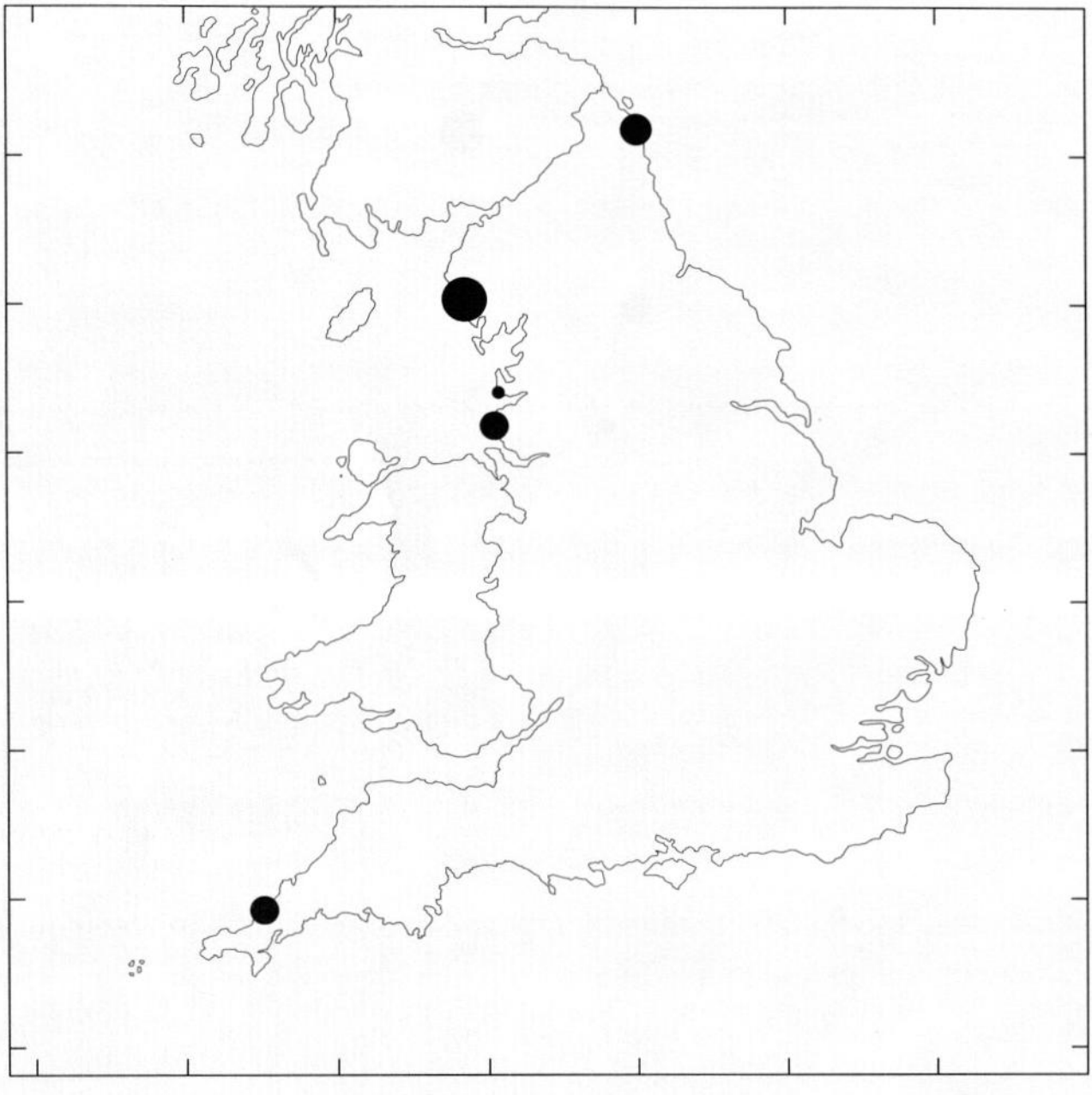

Figure 51 Distribution by county of SD17d *Potentilla anserina-Carex nigra* dune slack, *Hydrocotyle vulgaris-Ranunculus flammula* sub-community. Symbol size is proportional to area occupied by the sub-community.

common with both SD8 dune grassland and MG5 neutral grassland. The *Arrhenatherum elatius* coarse grassland community as a whole is closely related to SD9 *Arrhenatherum elatius* dune grassland. The two communities were often found together and, like the dune community, it was widely distributed. The largest areas were in Northumberland, which also had the largest areas of SD9.

The most abundant form of *Cynosurus cristatus-Centaurea nigra* pasture was the *Galium verum* sub-community MG5b. This sub-community shares many species with SD8 *Festuca rubra-Galium verum* dune grassland, especially the *Luzula campestris* sub-community (SD8b). MG5b was found in Cornwall, Cumbria and Northumberland, the three counties where the greatest areas of SD8b were recorded. Field observation showed that the two communities do indeed occur together and intergrade.

Lolium perenne-Cynosurus cristatus pasture (MG6) and *Lolium perenne* leys and related grasslands (MG7) occur on areas of stable dune that have been artificially modified. In these communities nutrient enrichment allows perennial rye-grass *Lolium perenne* to assume dominance. Some stands have developed as a result of agricultural modification, others on the managed fairways of golf courses or in levelled, reseeded and closely mown 'amenity' areas. The total areas of these communities on dunes has probably been considerably under-estimated, as they were only recorded if they occurred within areas that mainly supported less heavily modified vegetation.

Small areas of the *Lolium perenne* sub-community of *Festuca rubra-Agrostis stolonifera-Potentilla anserina* inundation grassland (MG11a) were found in seven widely scattered counties. This type of vegetation is adapted to periodic flooding, as is dune slack vegetation. It shares species such as silverweed *Potentilla anserina* and creeping bent *Agrostis stolonifera* with dune slack communities and most stands were found in slack-like hollows. At some sites this form of inundation grassland appeared to have displaced dune slack vegetation in areas that had been subject to nutrient enrichment. In other sites it appeared to occupy hollows where the physical conditions were naturally intermediate between those of dune slacks and those of periodically flooded areas inland.

CG Calcicolous grasslands

Calcicolous grasslands were very rarely found within dune sites in England. They were confined to high energy sites in Cornwall where lime-rich sand had been blown far inland to form a thin covering over free-draining slopes. In those places where the slopes were rocky with little soil, CG1e, the *Koeleria macrantha* sub-community of *Festuca ovina-Carlina vulgaris* grassland, was found. This typically formed a very short, open, species-rich sward which contained many interesting species including mountain everlasting *Antennaria dioica* and the yellow lichen *Fulgensia fulgens*.

Where the sand had blown over slightly deeper soils, CG6e, the *Dactylis glomerata-Briza media* sub-community of *Avenula pubescens* grassland was found. Both types of calcicolous grassland graded into SD8 dune grassland and there were substantial areas of intermediate vegetation.

Similar physical conditions occur more frequently on exposed west coast dunes in Wales and Scotland. It will be interesting to compare the calcicolous grassland communities found in these countries with those in the far south-west of England.

U Acidic grasslands

Acidic grasslands occupy areas of stabilised dune, well inland and composed of leached sand. Where such conditions occur, two acidic grassland communities were found. The first of these is *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland (U1). This community is floristically close to SD12 dune grassland, which sometimes grades into this type towards the inland margin of acidic dune systems. The stands recorded in the survey could not be slotted neatly into a sub-community, which suggests that they may still have some characteristics of the dune grassland community.

In similar situations a second, related, community was occasionally found. This is the *Festuca ovina-Agrostis capillaris*

Table 14 Mesotrophic (MG), calcicolous (CG) and acidic (U) grassland vegetation in surveyed English dune systems. Areas in hectares.

County	MG1a	MG1b	MG1c	MG1d	MG1e	MG5a	MG5b	MG6a	MG6b	MG7a	MG7e	MG10a	MG11a	CG1e	CG6a	U1	U2a	U6c	U6d	U20
Kent	26.81	7.99		9.49	0.13			8.36		3.14	41.85		1.48							0.04
East Sussex	1.04	0.02																		0.08
West Sussex				0.5	0.03															
Isle of Wight																5.54				
Hampshire																				
Dorset																				1.01
Devon																0.67				
Cornwall		5.49					25.56				0.20		4.92	33.67	43.90					
Isles of Scilly																				
Somerset		0.05																		
Avon										0.33										
Merseyside	3.75	4.77	0.01	2.20	0.49					8.49	10.85		0.11				10.02			
Lancashire																				
Cumbria	0.37	0.37					18.79	12.05		31.27		18.31	0.47			29.49		14.77	8.58	
Northumberland	32.20	24.18	0.46		7.99	0.16	0.92	7.34		6.51	2.73		0.60							
Cleveland & Durham	0.67	0.17																		
Humberside		0.31																		
Lincolnshire	5.54	11.90							0.91	0.07			2.01							
Norfolk	0.04	13.32			5.47			0.25	0.85		1.39	0.25	1.34				7.30			0.48
Totals	**70.42**	**68.66**	**0.47**	**11.74**	**14.11**	**0.16**	**45.27**	**28.00**	**1.76**	**49.81**	**57.02**	**18.56**	**10.93**	**33.67**	**43.90**	**35.70**	**17.32**	**14.77**	**8.58**	**1.61**

sub-community of *Deschampsia flexuosa* grassland (U2a). This community is not normally recorded in East Anglia, where the climate generally appears to be too dry. During this survey it was, however, found on dunes in Norfolk. It is possible that there is some climatic amelioration along the coastal fringe.

In Cumbria two sub-communities of *Juncus squarrosus-Festuca ovina* grassland (U6) were also found on dunes. This community is characteristic of base-poor, peaty, mineral soils and is found on acidic dunes in permanently damp hollows and at the inland margins. In these situations it grades into wet heath vegetation (M15 and M16) which also occurs in such conditions. The largest areas and the greatest diversity of acidic grassland types found on dunes in England were in Cumbria.

One other community needs to be briefly mentioned. This is the bracken-dominated *Pteridium aquilinum-Galium saxatile* community (U20) which is found mainly in Norfolk and Dorset.

3.5.3.8 Heaths and mires

This section includes dune-heath and other dry heathland communities described in the heathland chapter (H) of the NVC. It also includes wet heath and other communities covered in the mires chapter (M) of the NVC. The distributions and areas of these communities are summarised in Table 15.

H11 *Calluna vulgaris-Carex arenaria* dune heath

This type of heathland is exclusively associated with the dune environment. It is most clearly separated from more generally distributed heathland types by the presence of sand sedge *Carex arenaria*. Marram *Ammophila arenaria* is often found in the more mobile areas but often does not extend across the full width of dune heath vegetation. There are three variants:

H11a, the *Erica cinerea* sub-community,
H11b, the *Empetrum nigrum* sub-community,
H11c, the species-poor sub-community.

The *Empetrum nigrum* sub-community was not encountered in this survey. The most widespread type was that with bell heather *Erica cinerea*; it was encountered on suitable dune systems on the west and south coasts from the Scottish border to Hampshire. There was also a very small outlier on the east coast in Northumberland. The species-poor sub-community was recorded only on Merseyside.

Other dry-heath communities

Calluna vulgaris-Erica cinerea heath (H10) is very closely related to H11a and was encountered on the more inland parts of two dune systems on the south coast. *Calluna vulgaris-Festuca ovina* heath is the main dry heathland type in East Anglia and the *Carex arenaria* sub-community (H1d) was the only type of heath recorded from dunes in Norfolk. This sub-community is almost indistinguishable from H11c. It is probably fair to say that these stands could have been recorded under either vegetation type.

Wet heaths

Wet heaths on dunes, as elsewhere, are characterised by the occurrence of cross-leaved heath *Erica tetralix*. Both the main wet heath communities occur on dunes in England. M15 *Scirpus cespitosus-Erica tetralix* wet heath, the characteristic community of western and northern Britain, was recorded in Cumbria. The various forms of the southern and eastern wet heath community, *Erica tetralix-Sphagnum compactum* wet heath (M16), were more widespread. Distribution of the two communities overlapped, with M16 also being recorded in Cumbria.

In the south and east wet heath is tightly confined to slacks and slack-like depressions within acidic dune systems. On Drigg Dunes in Cumbria M15 wet heath also occurs more widely as a major component of the vegetation along the inland margin of the blown sand.

The stands of M16 found on sand dunes were classified into three different sub-communities. None of the samples fitted these sub-communities particularly well, the biggest differences being the species of *Sphagnum* moss that were present. There does appear to be at least one distinctively

Table 15 Heath (H) and mire (M) vegetation in surveyed English dune systems. Areas in hectares.

County	H1d	H6	H10	H11a	H11c	M15d	M16a	M16c	M16e	M23a	M23b
Kent											
East Sussex											
West Sussex											
Isle of Wight											
Hampshire				8.91							
Dorset			10.56	54.77			4.74				
Devon			0.22								1.08
Cornwall		0.57									
Isles of Scilly				25.16							
Somerset											
Avon											
Merseyside					14.21						
Lancashire											
Cumbria				52.63		14.90	0.26	1.73		19.42	3.24
Northumberland	1.70			0.06						2.85	1.67
Cleveland & Durham											
Humberside											
Lincolnshire											
Norfolk	28.26								5.45	21.70	4.26
Totals	**29.96**	**0.57**	**10.78**	**141.52**	**14.21**	**14.90**	**5.00**	**1.73**	**5.45**	**43.97**	**10.25**

coastal variant of this community that is not covered by the NVC at present.

At Studland Heath in Dorset M16 wet heath forms a distinctive band around the margins of the dry ridges. In the wetter parts of the hollows the vegetation grades into M25a, the *Erica tetralix* form of *Molinia caerulea-Potentilla erecta* mire. Bog-myrtle *Myrica gale* is a prominent feature of this type of vegetation.

Other mires

Both the *Juncus effusus* and *Juncus acutiflorus* sub-communities of *Juncus effusus-Galium palustre* rush pasture (M23a and M23b) were recorded from the more inland parts of some dune systems, where drainage was impeded. These types of vegetation were found in Cumbria and Northumberland but also in Norfolk, which is well outside the area normally associated with this community of "the cool and rainy lowlands of western Britain" (Rodwell 1991b).

3.5.3.9 Swamps and tall-herb fens

A wide range of swamp and tall-herb fen vegetation was found on dunes in England. They occupy the more permanently wet areas of those dune systems where conditions are not sufficiently acidic and nutrient-poor for mire vegetation to develop. The areas and distributions of these communities is summarised in Table 16.

The NVC divides swamp vegetation into communities on the basis of the dominant species. Dunes and their landward transitions support a wide range of stands dominated by single species. These include two communities dominated by brackish species: S21 *Scirpus maritimus* swamp and S20 *Scirpus lacustris* ssp. *tabernaemontani* swamp. They also include brackish variants of communities dominated by essentially freshwater species. In this class comes S4d, the *Atriplex hastata* sub-community of *Phragmites australis* reed-bed and S19c, the *Agrostis stolonifera* sub-community of *Eleocharis palustris* swamp.

Table 16 Swamp and tall-herb fen (S) vegetation in surveyed English dune systems. Areas in hectares.

County	S4a	S4d	S6	S8	S10a	S12a	S12b	S14	S19c	S20b	S21c	S25	S26b	S28b
Kent	2.53	1.92				0.43			0.11		0.04		2.37	
East Sussex														
West Sussex														
Isle of Wight														
Hampshire														
Dorset	5.34					1.01					1.01			
Devon		0.54												
Cornwall				0.04										
Isles of Scilly														
Somerset	13.71	0.77					0.08	0.12						
Avon														
Merseyside														
Lancashire														
Cumbria	0.32				3.42									
Northumberland	0.05		1.52						0.01		0.25		0.82	0.95
Cleveland & Durham						0.62			1.13	0.28	0.08			
Humberside	0.03	1.61									4.11			
Lincolnshire			7.35										3.03	
Norfolk	1.33		0.13	0.10						0.15		10.31	1.31	
Totals	**23.31**	**4.83**	**8.99**	**0.14**	**3.42**	**2.05**	**0.08**	**0.12**	**1.25**	**0.43**	**5.48**	**10.31**	**7.53**	**0.95**

All these brackish types occur as small stands in the outfalls of streams discharging onto the beach and in artificial ditches where the water is brackish. They may also occupy larger areas where sections of beach plain are partially isolated from the sea by the formation of dune ridges. A good example of this was the vegetation of the Cleethorpes to Humberstone dunes, Humberside. Here sizeable stands of sea club-rush *Scirpus maritimus* swamp (S21c) and brackish reed-bed (S4d) were found mixed with saltmarsh communities between the low dune ridges of this prograding site.

Swamp vegetation also occurs on dunes in a variety of freshwater situations. It is found fringing the larger bodies of permanent fresh water such as the 'Little Sea' on the Studland Dunes in Dorset, which is fringed by reed-swamp (S4a). A large stand of *Carex riparia* swamp (S6) occupies an isolated section of former beach-plain on the Saltfleetby-Theddlethorpe dunes in Lincolnshire and there are several examples of freshwater reed-swamp (S4a) in similar situations.

Eutrophic species such as bulrush *Typha latifolia* (S12) and branched bur-reed *Sparganium erectum* (S14) appear to be associated with localised areas of nutrient enrichment. One example was the stand of bulrush swamp (S12a) encountered near to the ferry terminal at the northern end of Studland Dunes. *Equisetum fluviatile* swamp (S10a), by contrast, occurs in more oligotrophic dune water bodies and during this survey was only found in Cumbria.

Tall-herb fen vegetation is often associated with the landward transitions of dune systems and with areas that have been subject to some drying-out. The three communities recorded during this survey were S25 *Phragmites australis-Eupatorium cannabinum* fen, S26 *Phragmites australis-Urtica dioica* fen and S28 *Phalaris arundinacea* tall-herb fen. The first two of these communities were both found on the inland margins of the Horsey to Winterton dunes in Norfolk in an area where the dunes grade back into a partially drained area of former grazing marsh.

3.5.3.10 Woodland and scrub

Two contrasting types of vegetation are contained within this category. The first is the scrub that invades freely-drained, stabilised dunes and the woodland into which it eventually develops. The second is the scrub and woodland that invades dune slacks and other dune wetlands. A third category, plantations and their self-sown derivatives, is not covered by the NVC but will be briefly covered later. The areas and distributions of NVC woodland and scrub types are summarised in Table 17.

SD18 *Hippophae rhamnoides* dune scrub

This is the only woody community that is confined mainly to dunes. Two successional stages are recognised in the NVC: an early stage in which dune grasses persist under the sea buckthorn *Hippophae rhamnoides* scrub (SD18a) and a mature phase where the dune vegetation is obliterated and replaced by a sparse population of nitrophilous species such as stinging nettle *Urtica dioica* and bittersweet *Solanum dulcamara* (SD18b). During the course of the survey it was also possible to distinguish variation within the mature stands. The older stands tended to contain a higher proportion of elder *Sambucus nigra* in the canopy, with this species occasionally replacing sea buckthorn altogether. In some cases there was evidence of succession to woodland dominated by sycamore *Acer pseudoplatanus*. This type of scrub is generally reckoned to be native in eastern England but to be an introduction elsewhere. The results of this survey partially support this view. At Eskmeals in Cumbria, for example, sea-buckthorn scrub was recorded as covering huge areas though the Ministry of Defence's records suggest that it was introduced only in 1942.

Although generally longer established, there is, however, no guarantee that the populations on east coast sites are wholly natural. In Lincolnshire and Humberside for example, sea

Table 17 Woodland and scrub (SD18,W) vegetation in surveyed English dune systems. Areas in hectares.

County	SD18a	SD18b	W1	W2	W4a	W4b	W4c	W16a	W21	W22	W23	W24	W24a	W25	W25a
Kent	0.05	0.78		0.01					0.22	0.02	0.80	0.19	0.08		
East Sussex	4.59	1.66	0.01						0.69	0.01	0.35				
West Sussex											0.66				
Isle of Wight		0.89							1.53		0.43				
Hampshire										0.92	12.29			0.04	
Dorset			0.04		0.10	21.66	8.02	3.90			2.44			1.39	
Devon			0.10	0.54					0.09		2.96	3.47	0.50	0.44	
Cornwall	0.21	2.22							1.48	5.99	11.12	27.81	1.84	0.53	1.29
Isles of Scilly											6.42			64.27	58.07
Somerset	8.04	48.27								0.22		1.64			
Avon		2.67													
Merseyside	0.94	18.40	33.84						0.38	0.27	7.82	0.87	0.09	0.01	
Lancashire		0.20													
Cumbria	1.80	41.43								0.25	10.69	0.38		1.51	
Northumberland	0.12								12.53	0.54	0.51	0.10		29.86	0.40
Cleveland & Durham	1.32	2.70							0.34		0.07	0.97			
Humberside	8.43	13.94							1.45	0.32		0.33			
Lincolnshire	33.79	169.70	0.88						6.81	1.28	0.02				
Norfolk	3.00	7.04	2.87	0.32					2.13	0.55	12.90	4.10	0.70	6.99	1.70
Totals	**62.29**	**309.90**	**37.74**	**0.87**	**0.10**	**21.66**	**8.02**	**3.90**	**27.65**	**10.37**	**69.48**	**39.86**	**3.21**	**105.04**	**61.46**

buckthorn planting has been, and in places still is, a standard technique used to maintain the integrity of dunes for flood defence purposes.

What is not in doubt is the invasive powers of this species. It appears to be able to invade all types of free-draining dune vegetation and was even recorded in embryo dunes. It is found on dunes in all parts of the English coastline.

Other scrub of free-draining dunes

Three NVC scrub communities and two underscrub communities were recorded during the survey. In most cases the stands encountered could be identified to the community without difficulty, but there were often problems in classifying to sub-community level. Many stands appeared to lie outside the range of variation specified by the NVC, suggesting that there may be distinctive coastal variants of these communities. Several fairly well defined scrub communities were also found that had no place in the NVC classification.

Hawthorn *Crataegus monogyna* scrub (W21) was widely distributed in the less exposed parts of dune systems. Few of the stands could be assigned to a sub-community and ivy *Hedera helix*, supposedly a constant in all sub-communities, was rarely found.

Blackthorn *Prunus spinosa* scrub (W22) was again widely distributed and was especially associated with some of the Cornish dunes. The variant found on dunes was close to that found on maritime cliffs and privet *Ligustrum vulgare* was frequently a major component. Indeed, in the most exposed stations, blackthorn was absent and privet was the dominant woody plant. The ground flora of these stands was generally very sparse.

Gorse *Ulex europaeus* scrub (W23) was, after sea buckthorn, the most abundant and widely recorded type, though again the stands often did not fit the published sub-communities. W24 *Rubus fruticosus* agg.-*Holcus lanatus* underscrub consists of a mixture of brambles, rank grasses and tall dicotyledons. Many of these stands could be assigned to a sub-community, W24a, the *Cirsium arvense-Cirsium vulgare* type.

When bracken *Pteridium aquilinum* invades the more base-rich dune soils, it forms the *Pteridium aquilinum-Rubus fruticosus* agg. underscrub community (W25). This bracken community is especially prevalent on the dunes of Northumberland and the Isles of Scilly. Many stands were allocated to the *Hyacinthoides non-scripta* sub-community (W25a).

Naturally occurring woodland on free-draining dunes is as yet rare on dunes in England. Apart from stands dominated by sycamore *Acer pseudoplatanus* or self-set plantation species, the only examples found were on Studland Dunes in Dorset, where stands of *Quercus* spp.-*Betula* spp.-*Deschampsia flexuosa* woodland (W16) were recorded.

Scrub and woodland of dune wetlands

Sallow *Salix cinerea* scrub sometimes colonises dune slacks and other dune wetlands. Two communities were recorded during the survey, W1 *Salix cinerea-Galium palustre* woodland, and W2 *Salix cinerea-Betula pubescens-Phragmites-australis* woodland. Most stands were very small but larger concentrations were recorded on the dunes of Merseyside and of Norfolk.

Downy birch *Betula pubescens* dominates the W4 *Betula pubescens-Molinia caerulea* woodland that has developed over much of the mire vegetation between the dune ridges of Studland Dunes in Dorset. Stands of all three sub-communities of this type were recorded. Royal fern *Osmunda regalis* is a prominent component of the understorey of some stands.

3.5.3.11 Transitions to other coastal habitats

Dune vegetation grades into three other types of terrestrial coastal vegetation: maritime cliff, saltmarsh and shingle. The areas and distributions of these transitional communities are summarised in Table 18.

Maritime cliff transitions are almost confined within England to Cornwall, though they are more common in Wales and Scotland. Two communities were recorded, MC5 *Armeria maritima-Cerastium diffusum* maritime grassland and MC8 *Festuca rubra-Armeria maritima* grassland. The latter community occurred as sizeable stands around the margins of the two big hindshore dune systems on the north Cornish

Table 18 Transitions to maritime cliff (MC), saltmarsh (SM) and shingle (SD1) habitats in surveyed English dune systems. Areas in hectares.

County	MC5	MC8	MC8d	SM16	SM21a	SM24	SM25a	SM25b	SD1a	SD1b
Kent						3.08			4.08	
East Sussex									0.18	1.55
West Sussex						0.01			2.00	
Isle of Wight						0.19			0.14	
Hampshire				0.76		1.84			1.97	
Dorset										
Devon						0.43				
Cornwall	12.08	4.22	12.07							
Isles of Scilly										
Somerset						0.46				
Avon						0.25				
Merseyside										
Lancashire										
Cumbria						8.07			2.06	
Northumberland		1.46		5.75		1.44				
Cleveland & Durham				11.34		0.28				
Humberside						7.89				
Lincolnshire						71.00				
Norfolk				4.81	0.37	14.14	8.29	0.49	17.38	
Totals	**12.08**	**5.68**	**12.07**	**22.66**	**0.37**	**109.08**	**8.29**	**0.49**	**27.80**	**1.55**

coast, Penhale Dunes and Gwithian to Mexico Towans. Many of these stands fitted the *Holcus lanatus* sub-community (MC8d). The presence of thrift *Armeria maritima* instantly marked out this type of vegetation from that of the adjacent dunes.

Saltmarshes occur not uncommonly in association with sand dunes and the transition zone between the two is often of great interest. By far the most widespread transition community is SM24 *Elymus pycnanthus* saltmarsh. Sea couch *Elymus pycnanthus* also occurs on dunes, especially in eastern England.

It is perhaps not surprising that the largest areas of this community are found on the extensive dune/saltmarsh interfaces of the Lincolnshire coast.

The other county with particularly extensive dune/saltmarsh transitions is Norfolk. Here saltmarshes have colonised the areas sheltered by the barrier islands and spits occupied by the dunes. The transition zone is marked by two geographically restricted vegetation communities which are both dominated by shrubby sea-blite *Suaeda vera*. The first of these is SM21 *Suaeda vera-Limonium binervosum* saltmarsh, characterised by the occurrence of rock sea lavender *Limonium binervosum* agg. This community is restricted to Norfolk and it was the typical sub-community (SM21a) that was recorded. The other community is the *Suaeda vera* drift line, of which both the *Elymus pycnanthus* sub-community (SM25a) and the *Halimione portulacoides* sub-communities were recorded. This community is restricted nationally to North Norfolk and Essex. Only in North Norfolk does it mark the transition from saltmarsh to dune vegetation.

Away from East Anglia, several other dunes have particularly diverse and well developed transitions to saltmarsh. Two of the best are to be found on Lindisfarne in Northumberland and the Drigg Coast in Cumbria.

Sand dunes often form over shingle spits, so it is

not surprising that there should be some overlap in the vegetation. SD1 *Rumex crispus-Glaucium flavum* shingle vegetation was recorded in seven counties, mostly in southern and eastern England though with a significant outlier in Cumbria. Of the counties surveyed, Norfolk had the greatest area of dune/shingle transition vegetation. It should, however, be noted that there are even more extensive stands along the Suffolk coast which were not covered by this survey because of problems of definition.

3.5.3.12 Non-NVC vegetation types

These fall into a number of broad categories, some of which have already been alluded to. These are:

1. Ruderal vegetation of dunes heavily fertilised by stock feeding.
2. Vegetation of golf-course fairways.
3. Plantations and other woodlands dominated by exotic species.
4. Scrub vegetation.
5. Bramble- and bracken-dominated vegetation of dunes on the Isles of Scilly.
6. Vegetation of waste ground on dunes.

There are, in addition, some non-NVC codes which were used where, because of either the limitations of the survey or the intrinsically low interest of the vegetation, detailed analysis of the vegetation was not carried out. The areas and distributions of non-NVC vegetation types are summarised in Table 19.

Vegetation of dunes heavily fertilised by stock feeding

This is mainly a feature of dunes in Northumberland, some of which are intensively stocked with cattle in the winter. These dunes suffer both massive disturbance from trampling and massive nutrient enrichment from the imported feed and the resultant manure. The vegetation in areas so affected is dominated by species that can colonise quickly and grow rapidly to survive intense competition for the abundant nutrients. Three distinctive assemblages were recognised:

PPWG *Poa pratensis* weedy grassland;
ERWG *Elymus repens* weedy grassland;
DEWG *Dactylis glomerata-Elymus repens* weedy grassland.

Floristic tables for these three types of vegetation are reproduced in Table 20. Two of these types appear to be very localised but the third, *Elymus repens* weedy grassland, was also recorded from dunes in two other counties and may be a nationally recognisable ruderal community.

Vegetation of golf course fairways

Where fairways are heavily fertilised and/or watered they often support rye-grass-dominated vegetation that can be referred to MG6 or MG7. There is, however, another characteristic assemblage in which annual meadow-grass *Poa annua* is prominent, with a mixture of other species including common couch *Elymus repens* and some other annuals such as common stork's-bill *Erodium cicutarium*. The vegetation of heavily modified fairways was not always classified in great detail, so that the figures in Table 19 for the area of 'F' are aggregates.

Plantations and other woodlands dominated by exotic species

The two species most frequently used for afforesting dunes in England are Scots pine *Pinus sylvestris* and Corsican pine *Pinus nigra* var. *maritima*. Both can spread by natural regeneration from the areas where they were planted. All stands dominated by these species were coded as PS and PN respectively. The largest areas by far are on Holkham Dunes in north Norfolk and on the Sefton Coast Dunes, Merseyside. There is considerable variation in the vegetation beneath the canopy. Young stands, whether self-set or planted, become very dense after canopy closure and the ground vegetation is often almost eliminated. In slightly older or slightly more open stands sand sedge *Carex arenaria* and the moss *Hypnum cupressiforme* are often the only prominent species. In still older stands brambles *Rubus fruticosus* agg. may form a sub-shrub layer and a variety of self-set tree and shrub species can start to diversify the structure of the stand. At Holkham Dunes evergreen oak *Quercus ilex* is now an established part of the canopy.

Although rarely planted, sycamore *Acer*

Table 19 Non-NVC types of vegetation in surveyed English dune systems. Areas in hectares.

County	BS	BG	OW	I	PPWG	DEWG	ERWG	F	EPG	CLS	PS	PN	AP	SN	A
Kent	1.71							83.90	6.08		0.84	2.74			
East Sussex	0.87		1.84					19.44						0.96	
West Sussex	3.08							0.13						0.01	
Isle of Wight									0.19						
Hampshire	1.16		6.14					3.19	1.73						
Dorset	3.28		33.67								1.15				
Devon	41.88	0.06	0.21	18.52				25.79		15.35		0.01	0.07		
Cornwall	58.37	0.23	0.97	26.35				19.09		10.25			0.63	0.49	
Isles of Scilly	3.22	0.57	8.69	10.90						1.24					13.30
Somerset	0.41							35.23							
Avon	0.29			0.12											
Merseyside	44.91	1.69	61.99	1.68			0.83	38.31		0.02	17.26	227.83	15.82	0.02	9.95
Lancashire	3.34														
Cumbria	26.12	1.98	6.58	29.86				20.49				10.50	0.03	0.15	
Northumberland	13.96	12.75	2.33	22.87	0.63	12.85	7.09	50.17	0.04		0.21	13.52	2.04	0.05	
Cleveland & Durham	4.86	0.17	10.23	10.01			0.97	24.73							
Humberside	2.13	0.04	8.66	3.93					8.13						
Lincolnshire	11.06		24.20	12.19					4.07				0.81		10.91
Norfolk	32.68		8.82	9.21				54.97	1.43	2.00		98.08	0.10	4.81	
Total	**253.32**	**17.49**	**174.33**	**145.64**	**0.63**	**12.85**	**8.89**	**375.44**	**21.67**	**28.86**	**19.46**	**352.68**	**19.50**	**6.49**	**34.16**

BS, bare sand: BG, bare ground; OW, open water; I, agriculturally improved grassland; PPWG, *Poa pratensis* weedy grassland; DEWG, *Dactylis glomerata-Elymus repens* weedy grassland; ERWG, *Elymus-repens* weedy grassland; F, golf course fairway; EPG, *Elymus pycnanthus* waste ground; CLS, *Ligustrum vulgare* scrub; PS, *Pinus sylvestris* woodland; PN, *Pinus nigra* var. *maritima* woodland; AP, *Acer pseudoplatanus* woodland; SN, *Sambucus nigra* scrub; A, arable.

Table 20 Weedy vegetation of winter stock-feeding areas, Druridge Bay, Northumberland

Community type		DEWG			ERWG		PPWG
Quadrat number		**21**	**29**	**31**	**20**	**33**	**30**
1	Grid reference 100 km square	NZ	NZ	NZ	NZ	NZ	NZ
2	Grid reference easting	275	278	281	274	284	279
3	Grid reference northing	971	958	950	975	945	956
5	Slope (degrees)	0	5	0	0	0	0
6	Aspect (degrees)		225				
11	Herb height (centimetres)	34	21	12	40	42	
22	Bare soil/litter (incl. sand)		0	0	0	0	10
	Dactylis glomerata	4	4	5			
	Achillea millefolium		3	4	1		
	Lolium perenne		4	7			
	Poa trivialis	5		3			
	Elymus repens	8	8	6	10	10	
	Stellaria media		3	4		2	
	Artemisia vulgaris	3	6		2		
	Urtica dioica				2		
	Atriplex patula					3	
	Poa pratensis	7		5			7
	Polygonum aviculare		3	3	3		5
	Chenopodium album						7
	Chenopodium murale						7
	Chamomilla suaveolens						3
	Matricaria maritima						1
	Silene alba		3		1		
	Capsella bursa-pastoris						2
	Galium verum		3				
	Geranium sanguineum				4		
	Heracleum sphondylium				1		
	Lotus corniculatus		2				
	Odontites verna		3				
	Potentilla reptans		2				
	Rosa pimpinellifolia				2		
	Rumex longifolius				1		
	Sonchus asper					1	
	Trifolium repens			5			

Note: Figures are Domin scores in 2 x 2 metre quadrats.

pseudoplatanus is one of the most widespread trees on English dunes. Stands in which it is dominant were coded as AP. As already mentioned, there sometimes appears to be a succession from sea buckthorn scrub (SD18) to sycamore woodland.

Scrub vegetation

Two nationally recognisable scrub communities appear to fall outside the NVC classification. The first of these is scrub dominated by elder *Sambucus nigra* (SN). As already mentioned, at least some of these stands appear to be associated with degenerate stands of sea buckthorn but stands also occur in other nutrient-rich situations. The second is scrub dominated by privet *Ligustrum vulgare* (CLS). This also appears to be related to coastal forms of W22 *Prunus spinosa* scrub but on many sites it forms a highly distinctive community. In north Cornwall the ground flora often includes the stinking iris *Iris foetidissima* (Table 21).

Bramble- and bracken-dominated vegetation of dunes on the Isles of Scilly

The vegetation of dunes on the Isles of Scilly differs from that on the mainland in many ways. Among the most striking are the dominance of bracken *Pteridium aquilinum* and bramble *Rubus fruticosus* agg. which here can invade all types of dune vegetation down to and including the earliest fore dunes. The NVC communities containing these species do occur but there are also other associations, especially with mobile

Table 21 *Ligustrum vulgare* scrub, Penhale Dunes, Cornwall

Community type	***Ligustrum vulgare* scrub**			
Sample number	**T4**	**Q10**	**T28**	**T26**
Grid reference 100 km square	10	10	10	10
Grid reference easting	767	763	771	771
Grid reference northing	573	573	577	575
Ligustrum vulgare	*	*	*	*
Iris foetidissima	*	*	*	*
Hedera helix	*	*	*	*
Rubus fruticosus agg.	*		*	*
Cirsium arvense	*			*
Eupatorium cannabinum				*
Galium aparine	*			
Geranium robertianum	*			
Glechoma hederacea	*			
Heracleum sphondylium			*	
Holcus lanatus	*			
Ranunculus repens				*
Rumex crispus	*			
Salix caprea			*	*
Sambucus nigra	*		*	
Senecio jacobaea	*			
Solanum dulcamara	*			
Urtica dioica			*	

* Presence in 2 x 2 metre quadrats.

dune species. Full details of these vegetation types and of the other Isles of Scilly specialities are given in the site report (Dargie 1990).

Vegetation of waste ground on dunes

A wide variety of ruderals occupy disturbed areas of dunes, though England has nothing to compare with the communities of cultivated machair found in the Western Isles. One widely recognisable community, coded EPG, is dominated by sea couch *Elymus pycnanthus* but without the semi-fixed dune or the saltmarsh species of the two NVC communities in which this grass is dominant. Instead, the associates are a mixture of plants from a wide range of habitats including tall grassland and waste ground. In Humberside and Lincolnshire common reed *Phragmites australis* also occurs in this community (Table 22).

3.6 Nationally rare and scarce plants

Nationally rare plants are defined as those occurring in 1–15 of the 10 x 10 km squares of the National Grid. Nationally scarce plants are those found in 16–100 of these 10 km squares (Nature Conservancy Council 1989). Throughout Great Britain, saltmarshes, shingle, maritime grasslands, cliffs, open areas, dunes and dune slacks taken together support 48 nationally rare and 65 nationally scarce species. These represent about 8% of the total British flora. Many of them have shown a marked decline since 1930 (Table 23).

Many of the nationally rare and scarce plants found on the coast are not confined to a single habitat. They are plants of unstable, ever-changing conditions and many require a strong maritime influence.

One species which provides a good example of this type of distribution and which illustrates the effects of widespread recreational pressure is the shore dock *Rumex rupestris*. This plant grows at the top of the beach, just above the strandline, in precisely the zone where holiday-makers like to sit. It has suffered accordingly and is now confined to relatively undisturbed parts of north-west Spain and France, the Channel Islands, Cornwall, Devon and Gwynedd. It is vulnerable

Table 22 *Elymus pycnanthus* grassland of north Humberside dunes

Community type	***Elymus pycnanthus* grassland**	
Quadrat number	**37**	**40**
Grid reference 100 km square	54	54
Grid reference easting	414	412
Grid reference northing	167	173
Slope (degrees)	0	0
Aspect (degrees)		
Herb height (centimetres)	85	55
Bare soil/litter (incl. sand)	30	0
Elymus pycnanthus	7	8
Phragmites australis	7	2
Leymus arenarius	1	1
Elymus farctus ssp. *boreali-atlanticus*	1	
Arrhenatherum elatius		6
Atriplex hastata	1	
Potentilla anserina	1	
Sonchus arvensis		3

Table 23 Nationally rare maritime species that have declined markedly since 1930 on dunes in England

Species name	No. of 10 km sq. pre 1930	No. of 10 km sq. post 1930
Allium ampeloprasum	9	2
Asparagus officinalis ssp. *prostratus*	10	5
Euphorbia peplis	22	1
Geranium purpureum ssp. *forsteri*	7	2
Geranium purpureum ssp. *purpureum*	22	1
Juncus capitatus	10	5
Lactuca saligna	32	4
Lavatera cretica	3	1
Limonium bellidifolium	10	5
Matthiola sinuata	15	2
Oenothera stricta	39	13
Orobanche maritima	36	9
Petrorhagia nanteuilii	4	1
Polygonum maritimum	11	2
Rumex rupestris	27	8
Scrophularia scorodonia	25	8
Spergularia bocconii	9	2

throughout Europe and has declined significantly in Britain. At present it is known from only twelve British sites, with an approximate total population of 300 plants. This is the largest remaining population in Europe and therefore in the world.

The shore dock does grow in association with dunes, though it is essentially a strandline plant. Many other nationally rare and nationally scarce species mainly associated with other habitats occur on dunes. In total 21 such nationally rare and 39 such nationally scarce species were either recorded during the sand dune survey or were mentioned for dune sites in reliable, recent records. These are listed in Table 24. For many of these species the dune populations often represent a sizeable proportion of the total.

Five nationally rare and eleven nationally scarce plants are wholly or mainly confined to dunes and dune slacks (Table 25). All but one of these (the dune gentian *Gentianella uliginosa*) occur in England. These species are described in more detail below.

3.6.1 Nationally rare dune plants

Dune helleborine *Epipactis leptochila* var. *dunensis* is an endemic species growing on stabilised sand dunes in Merseyside, Northumberland, Lincolnshire and in Wales on the Anglesey coast. All its sites have some degree of protection and there are populations of several thousand plants at Freshfield in Merseyside (part of the Sefton Coast system) and on Lindisfarne in Northumberland.

The Jersey cudweed *Gnaphalium luteoalbum* is confined to one site in Great Britain, at Burnham Overy in Norfolk. It has been recorded there since 1909. It is an annual, requiring open, sandy conditions for germination.

The bedstraw broomrape *Orobanche caryophyllacea* is confined in Britain to Kent, where it has one major population on Royal St George's Golf Course at Sandwich Bay. It is protected under the Wildlife & Countryside Act 1981 as a species listed in Schedule 8.

Table 24 Nationally rare and nationally scarce plants primarily associated with other habitats but which were recorded on dunes during the sand dune survey.

Nationally rare plants	Main habitat
Rumex rupestris shore dock	Beaches
Matthiola sinuata sea stock	Sea cliffs
Romulea columnae sand crocus	Coastal grassland
Viola kitaibeliana dwarf pansy	Coastal grassland
Himantoglossum hircinum lizard orchid	Inland
Allium ampeloprasum var. *ampeloprasum* wild leek	Rocks
Allium ampeloprasum var. *babingtonii* Babington's leek	Rocks
Valerianella eriocarpa hairy-fruited cornsalad	Banks & walls
Scrophularia scorodonia balm-leaved figwort	Hedgebanks
Liparis loeselii fen orchid	Fens
Mibora minima early sand-grass	Wet sandy places
Silene conica sand catchfly	Sandy pastures
Limonium bellidifolium matted sea-lavender	Upper saltmarsh
Dryopteris cristata crested buckler-fern	Wet heaths
Orobanche caryophyllacea clove-scented broomrape	Dry grassland
Petrorhagia nantueilii childing pink	Waste ground
Geranium purpureum ssp. *purpureum* little robin	Shingle
Geranium purpureum ssp. *forsteri* little robin	Shingle
Poa infirma early meadow-grass	Sandy places
Polycarpon tetraphyllum four-leaved allseed	Sandy places
Ornithopus pinnatus orange bird's-foot	Open, sandy soil
Nationally scarce plants	
Ranunculus baudotii brackish water crowfoot	Saltmarshes
Parapholis incurva curved hard-grass	Saltmarshes
Suaeda fruticosa shrubby sea-blite	Shingle
Juncus acutus sharp rush	Open areas, sandy
Polygonum raii Ray's knotgrass	shores & waste
Rhynchosinapis monensis Isle of Man cabbage	places
Primula scotica Scottish primrose	Coastal grassland
Dianthus deltoides maiden pink	Inland
Arum italicum large cuckoo pint	Stony ground
Eleocharis acicularis slender spike-rush	Lakes & pools
Verbascum virgatum twiggy mullein	Waste places
Parentucellia viscosa yellow bartsia	Coastal grassland
Orobanche hederae ivy broomrape	Coastal districts
Coralorhiza trifida coralroot orchid	Woods
Apera interrupta dense silky bent	Sandy fields
Poa bulbosa bulbous poa	Coastal limestone
Hordeum marinum sea barley	Coastal grassland
Orchis ustulata burnt orchid	Calcareous grassland
Pyrola rotundifolia larger wintergreen	Fens, woods etc.
Frankenia laevis sea-heath	Upper saltmarsh
Hornungia petraea rock hutchinsia	Limestone rock
Aceras anthropophorum man orchid	Chalk
Medicago minima small medick	Heaths

Table 24 *(cont.)*

Moenchia erecta upright chickweed	Gravelly pastures
Silene nutans Nottingham catchfly	Dry slopes
Oenanthe pimpinelloides corky-fruited water dropwort	Meadows
Scilla autumnalis autumn squill	Coastal grassland
Thesium humifusum bastard toadflax	Calcareous grassland
Vulpia ambigua bearded fescue	Waste places, sandy shores & open areas
Trifolium glomeratum clustered clover	Sandy grassland
Trifolium ornithopodioides bird's-foot clover	Waste places
Trifolium suffocatum suffocated clover	Rocks
Raphanus maritimus sea radish	Shallow water
Carex punctata dotted sedge	Rocks
Cicuta virosa cowbane	Pine woods
Asplenium trichomanes maidenhair spleenwort	Woods
Goodyera repens creeping lady's tresses	Coastal grassland
Epipactis phyllanthes helleborine	
Ophioglossum azoricum small adder's tongue	

Table 25 Nationally rare and nationally scarce plants found mainly or exclusively on dunes

Nationally rare species	No. of 10 km sq. in GB
Epipactis leptochila var. *dunensis* dune helleborine	9
Gentianella uliginosa dune gentian	5
Gnaphalium luteoalbum Jersey cudweed	1
Orobanche caryophyllacea bedstraw broomrape	2
Teucrium scordium water germander	3
Nationally scarce	
Centaurium littorale perennial centaury	42
Corynephorus canescens grey hair-grass	16
Equisetum variegatum variegated horsetail	89
Erodium maritimum sea stork's-bill	77
Euphorbia paralias sea spurge	92
Euphorbia portlandica Portland spurge	74
Festuca arenaria rush-leaved fescue	27
Hippophae rhamnoides sea buckthorn	36
Juncus balticus Baltic rush	47
Oenothera stricta fragrant evening primrose	32
Vulpia fasciculata dune fescue	44

Water germander *Teucrium scordium* is a plant of marginal habitats on calcareous substrates with a seasonal fluctuation in water levels. It is found in Britain in the extensive dune slacks of Braunton Burrows, Devon, and inland in Cambridgeshire. This species has been declining rapidly in many parts of Europe and is also listed in Schedule 8 of the Wildlife & Countryside Act 1981.

3.6.2 Nationally scarce species

Seaside centaury *Centaurium littorale* is a plant of open dunes found mainly in the north and west of the British Isles.

Grey hair-grass *Corynephorus canescens* is a fine-leaved grass that dominates the semi-stable dune vegetation of a few sites in East Anglia.

Table 26 Nationally rare and nationally scarce plants of dunes on the Isles of Scilly (compiled from Dargie 1990).

Nationally rare	Nationally scarce
Viola kitaibeliana	*Parentucellia viscosa*
Polycarpon tetraphyllum	*Crambe maritima*
Ornithopus pinnatus	*Raphanus maritimus*
Allium ampeloprasum var. *ampeloprasum*	*Euphorbia paralias*
Scrophularia scorodonia	*Euphorbia portlandica*
Poa infirma	*Trifolium suffocatum*
Spergularia bocconii	*Ophioglossum azoricum*
Rumex rupestris	

The plant has a very restricted distribution in Britain, though the individual populations are often large.

Variegated horsetail *Equisetum variegatum* is a component of certain types of dune slack vegetation. Within England and Wales, it is largely restricted to dune slacks, though it does occur inland in northern England and Scotland. Where suitable habitat exists, populations can be quite large.

Sea stork's-bill *Erodium maritimum* is a plant of short dune grassland. It is found mainly on the coasts of south-west England and Wales.

Sea spurge *Euphorbia paralias* is a distinctive component of foredune vegetation in southern Britain. On the east coast it extends as far as Norfolk, whilst on the west coast it reaches into southern Scotland. It is most abundant in the south-west, where there are healthy populations on most dune sites.

Portland spurge *Euphorbia portlandica* occurs in similar habitats to the previous species, though it tends to favour slightly more stable conditions. Its range is more restricted and it is not recorded east of Hampshire. The plant is again most abundant in the south-west.

Rush-leaved fescue *Festuca arenaria* is another foredune species and grows mixed with red fescue *Festuca rubra* in the slightly more stabilised foredunes. It has a scattered distribution on the south and east coasts of Britain and is particularly abundant in some of the Norfolk dunes.

Sea buckthorn *Hippophae rhamnoides* is probably native at some sites on the east coast of England but has been widely introduced and is spreading rapidly to form extensive stands of relatively species-poor scrub.

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. It also occurs on the Sefton Coast dunes in Merseyside.

Fragrant evening-primrose *Oenothera stricta* is an established introduction found mainly in south-west England. Although primarily a dune plant, it has also been recorded inland.

Dune fescue *Vulpia fasciculata* is a plant of open conditions within dunes and it has a scattered distribution within the southern half of Britain. It is more abundant on the southern and western coasts, from Kent to Cumbria.

3.6.3 Distribution of nationally rare and scarce plants

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 southern, south-eastern or scattered distribution. 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.

There is a particular concentration of rare and scarce plant species on dunes in the Isles of Scilly. This grouping of mostly small sites, lacking many of the habitats of larger mainland dunes, supports eight nationally rare and seven nationally scarce species (Table 26). These include two species, the dwarf pansy *Viola kitaibeliana* and the orange bird's foot *Ornithopus pinnatus* that are not found on mainland Britain.

4. Discussion

4.1 The nature conservation value of dunes

A survey of this type which is aimed at defining the national resource must address the question of the overall nature conservation value of the resource and the range of quality within it. Assessing nature conservation value is inevitably subjective but Ratcliffe (1977) proposed a series of criteria: naturalness, diversity, rarity, fragility etc. against which judgements could be made in a structured way. These criteria are widely accepted, underpin the selection of sites for statutory conservation protection and are used here, though in a slightly modified form.

4.1.1 Naturalness

There are no dunes in England that are wholly natural, but natural processes have played an obvious part in the formation of almost all dune systems. The geomorphological processes that have led to their formation can usually still be determined and in some cases are still operating in a largely unconstrained fashion. Dune plants interact with geomorphological processes to produce both the dune landscape and the vegetation. Prograding dunes can show very clearly the processes of dune building and their progressive stabilisation by vegetation as the supply of sand diminishes. Even retreating or static dunes can show complex patterns of secondary destabilisation and restabilisation.

The vegetation of most, if not all, English dunes has been influenced by a long history of pastoral management, in many cases stretching back to the very formation of the dunes. This form of human intervention has operated over a sufficient period of time to produce the consistent, complex and apparently sustainable plant communities of semi-fixed dunes, dune grasslands and heaths. In this respect dunes are similar to highly valued inland habitats such as calcareous grassland.

Many factors combine to reduce the naturalness of most English dune systems and some of these will be reviewed later, but the general level of naturalness is high by the standards of lowland England.

A few dune sites have managed to escape most of the more obvious human impacts. Perhaps the least modified of all is Scolt Head Island, north Norfolk. This barrier island system forms part of a functioning geomorphological unit largely unaffected by coast protection or flood defence works. The dunes themselves have no recent history of stock grazing and are entirely clothed by semi-natural vegetation. The island receives only comparatively small numbers of visitors and there is only one permanent building. This site, and a select group of other coastal systems containing dunes, represent some of the most natural areas remaining in lowland England.

4.1.2 Diversity

The most obvious and striking feature of dune vegetation is its diversity. The length of Section 3.5 bears witness to this fact. Dune vegetation exhibits four principal axes of variation. These are:

1. variation along successional gradients;
2. variation across transitions to other coastal habitats;
3. variation to inland vegetation;
4. variation along gradients of soil moisture.

The general level of habitat diversity within dune systems is high. The most diverse dune systems exhibit variation along all or most of these axes. For example, Drigg Dunes in Cumbria contain 31 types of vegetation, excluding transitions and mosaics, and these are plotted to form a vegetational 'spectrograph' in Figure 52. This figure shows that the site contains dune communities distributed along the stability gradient from strandline and mobile dunes to fixed, acidic dune grassland. It also shows that site includes a zone of transition to inland habitats including heath, mire and acidic grassland and to another coastal habitat, saltmarshes. The fourth axis of variation is also represented by a range of slack vegetation communities.

Figure 53 shows the same information for Lindisfarne in Northumberland, another diverse system with the same number of vegetation types. Here there is an even broader range of dune vegetation, well spread out along the stability gradient from strandline to calcareous

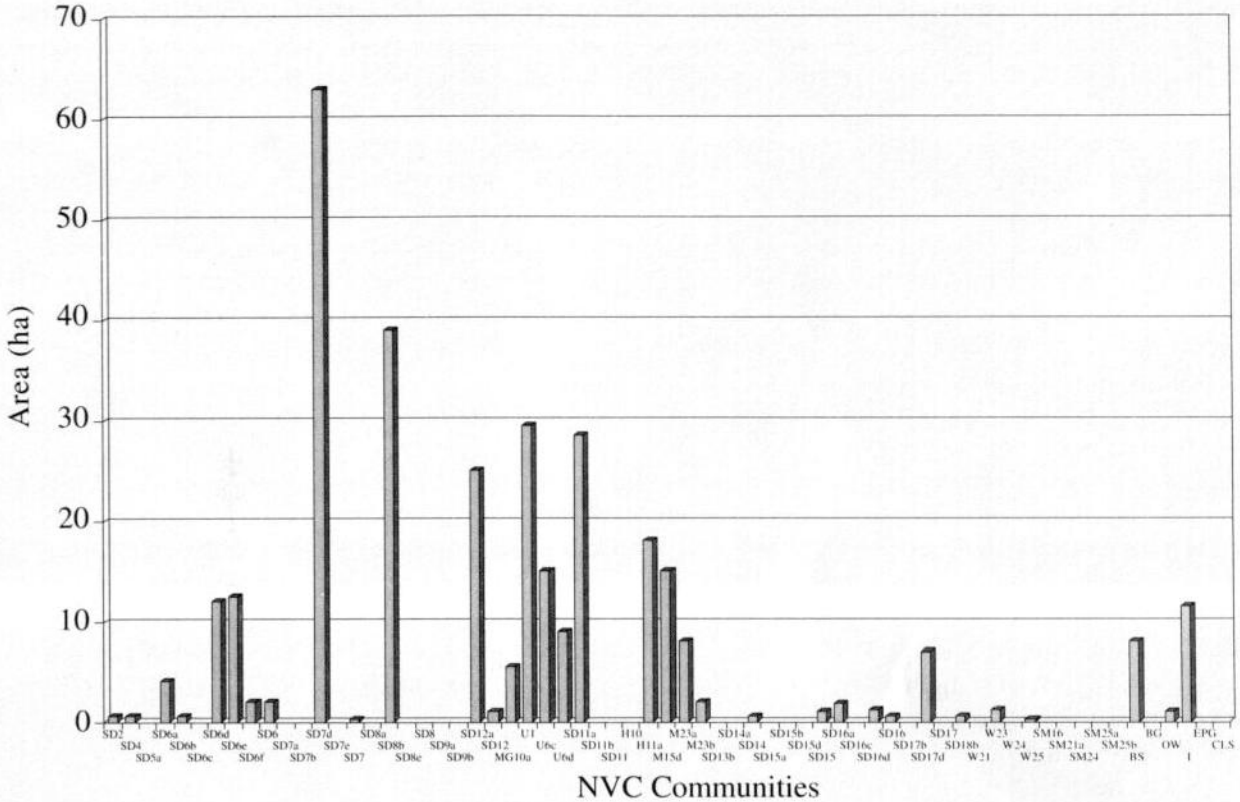

Figure 52 Vegetation communities of Drigg Dunes, Cumbria

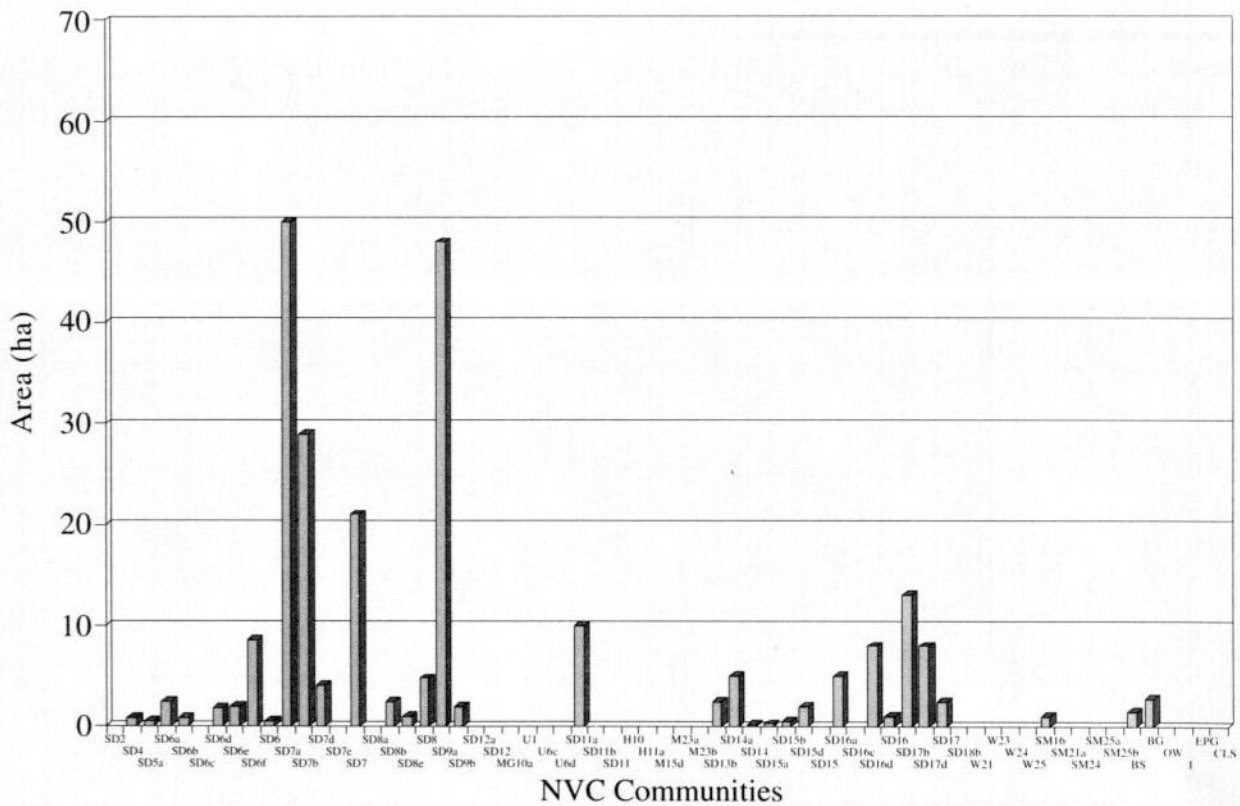

Figure 53 Vegetation communities of Lindisfarne Dunes, Northumberland

dune grassland. Transitions to inland types are less well represented, reflecting the island nature of the site, but the soil moisture gradient is well covered by a range of slack communities. There is also a series of communities representing the transition to saltmarsh.

Diversity is often directly related to naturalness; the more natural sites which have not been truncated by development or isolated from coastal processes tend to span a greater range of conditions and so support more types of vegetation. There are, however, sites which would score highly on naturalness but which are inherently low on diversity. Scolt Head Island is an example. Figure 54 illustrates this point. The site is a long, thin island largely devoid of freshwater wetlands or transitions to stable dune grasslands or inland vegetation. The scope for diversity is therefore restricted to the more mobile end of the stability spectrum and to the transitions to other coastal habitats, for which this site is highly regarded.

No attempt was made during this survey of dune vegetation to measure species diversity or to collect comprehensive species lists for individual sites. Nevertheless, it is obvious that many dunes do support a very large number of plant species. The highest species counts recorded in the course of the survey came from the larger sites in southern and eastern England. The biggest count of all came from Sandwich Bay, Kent, where 279 plant species were recorded in the course of a three-day visit in mid-September. This is obviously likely to be a gross underestimate of the total species complement.

4.1.3 Rarity

The criterion of rarity may be applied at three different levels: geomorphological type, vegetation community and species. The rarest geomorphological types in England are offshore island dunes and nesses/cuspate forelands (Figures 7 and 8) . The former are particularly worthy of note as they include some of the most widely recognised, classic examples of this type in Britain.

Dune vegetation *sensu stricto* is highly specialised and almost confined to areas of

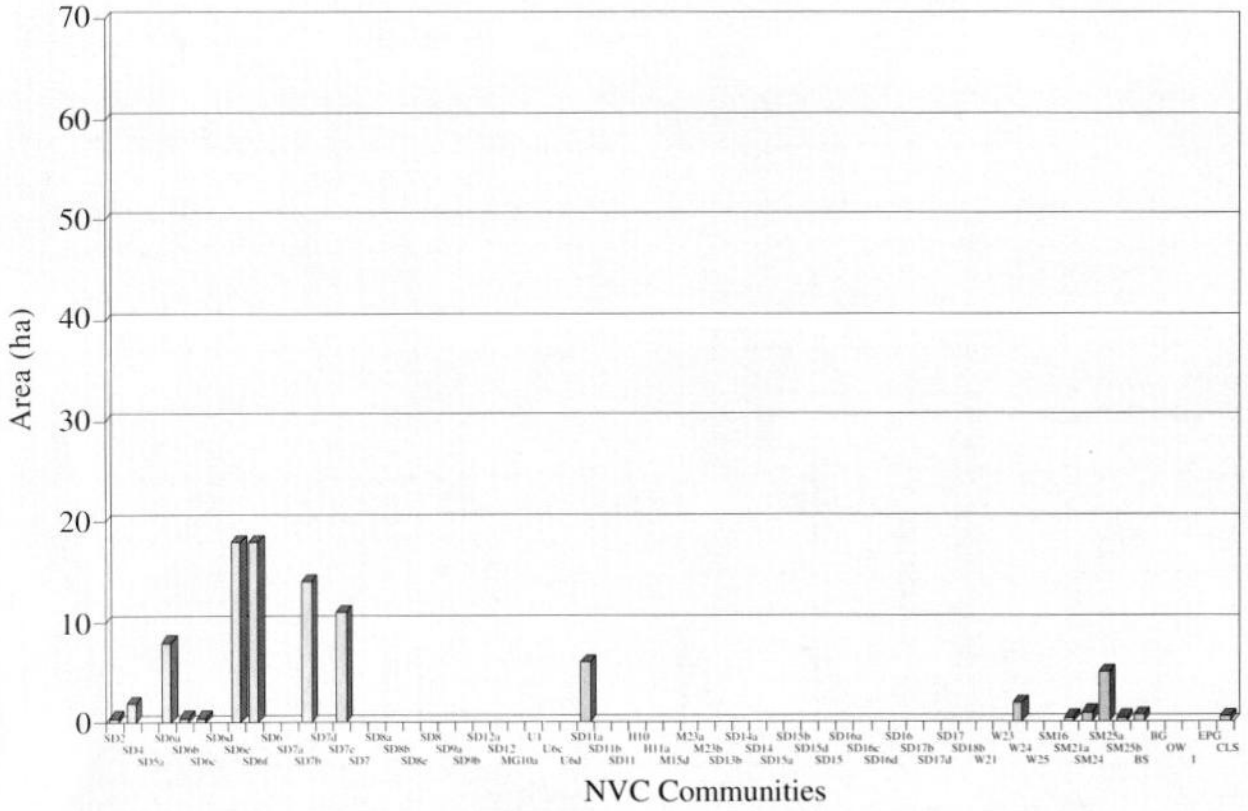

Figure 54 Vegetation communities of Scolt Head Island, Norfolk

wind-blown sand. Even as a whole it is a scarce resource in England. Taking the broadest possible definition, including all the transition zones and heavily modified areas, it covers no more than 12,000 ha and so has considerable rarity value. Tables 8 to 13 show that there are fourteen types of sand dune vegetation whose total area in England is less than 10 ha whilst 43 of the 61 types occupy less than 100 ha.

As a group, the vegetation communities of dune slacks are by far the rarest. None of the 22 types occupied more than 100 ha and eleven occupied less than 10 ha. Of the dune-slack types, the rarest of all are those of the early successional stages. Seven out of eight types occupied less than 10 ha and they were found on only a handful of dunes. Lindisfarne, Northumberland, the Sefton Coast in Merseyside, and Braunton Burrows in Devon are the three main strongholds for these types of vegetation.

Dune heathland is another very rare habitat. Where it is found it tends to occupy larger areas than the slack communities, but its distribution is very restricted. Studland, Dorset, contains by far the largest acreage of any one site (54 ha). Only five other sites, all in Merseyside or Cumbria, contain more than 10 ha.

As well as rare habitats, dunes also contain a range of rare plants. These are described in detail in Section 3.6. It is worth pointing out that dunes support both important populations of rare but wide-ranging species and some species which are wholly or largely confined to dunes. It is also important to mention that the greater preponderance of rare species in the south of England means that there are major concentrations of rare plants on some sites in this area, especially on the south coast and in the Isles of Scilly, that on habitat grounds alone would seem to be rather unexciting.

This survey does not cover the dune fauna but when discussing rare species, animals must be mentioned. For example, the scarab beetle *Aegialia rufa* is known in Britain only from the dunes of the Liverpool district and Barmouth (Wales); the spider wasp *Evagetes pectinipes* has been found only on the Deal-Sandwich dunes; and Braunton Burrows support the largest of the known British colonies of the sandbowl snail *Catinella arenaria*. In addition, important populations of smooth snake and sand lizard depend on dunes, and natterjack toads are now largely confined to this habitat.

4.1.4 Fragility

In some ways dunes are extremely robust. Most dune vegetation has a remarkable capacity to recover from disturbance. This was demonstrated when many English sites, including Braunton Burrows in Devon, were almost totally de-stabilised by a combination of rabbits and military activity in the Second World War and the years immediately afterwards. It is apparent from photographs and file notes in the possession of English Nature that these areas recovered fully within the space of little more than a decade. In other ways, however, the nature conservation interest of dunes can be very fragile. Dunes themselves are somewhat ephemeral structures and interference with coastal processes, sometimes at a considerable distance, can easily precipitate or accelerate erosion. Dune vegetation is vulnerable to nutrient enrichment; to the continued, concentrated wear characteristic of heavy visitor pressure; and to loss of diversity as a result of over-zealous protection. The more stable, landward areas of dunes are frequently developed.

Perhaps the most fragile aspect of all is the subjective and unquantifiable quality of wildness. This can be all too easily destroyed by developments whose direct ecological impact may be negligible. It can even be destroyed by some forms of conservation management, such as the digging of ponds for natterjack toads.

4.1.5 Typicalness and position in an ecological/geographical unit

These two characters are closely bound up with one another. The results of this survey, described in Section 3.5, show that even within the confines of England, dune vegetation is by no means uniform. Some classes of dune vegetation are very widespread and are more or less uniform across their range. Many more either exhibit regional variation, often expressed at the sub-community level of classification, or are restricted in their geographical range.

These vegetational differences are reinforced by the regional variations in the structure of dune systems discussed in Section 3.2. These include the restriction of hindshore dune systems to exposed west-facing coasts, the predominance of narrow bay dunes along the Northumberland coast and the concentration of spits and barrier islands with their associated saltmarshes on the coasts of Humberside, Lincolnshire and north Norfolk.

The geographical differences in dune vegetation are very complex and there are several axes of variation. There is, for example, at least as much variation east-west as north-south. An attempt is made to summarise this information in Table 27. From this confusing mass of overlapping distributions it is possible to draw out some general patterns:

1. a northern and eastern element in mobile dune vegetation consisting of those communities in which lyme-grass *Leymus arenarius* is abundant (Table 9, Figure 40);

2. the restriction of some semi-fixed dune communities to the east coasts (Table 10, Figure 44);

3. the strongly northern and western distribution of most forms of calcareous dune grassland (Table 11, Figure 45);

4. the eastern distribution, centred on Norfolk, of the more lichen- and bryophyte-rich forms of sand sedge *Carex arenaria* vegetation (Table 12, Figure 47);

5. the generally northern and western distribution of dune-slack vegetation; within this the northern distribution of slack vegetation dominated by common sedge *Carex nigra* (SD17), and the south-western distribution of SD14 *Salix repens-Campylium stellatum* dune slack (Table 13 Figures 48, 49, 50 and 51);

6. the restriction of transitions to calcicolous and maritime grasslands to the south-west (Table 14);

7. the southern and western distribution of dune heath (H11) and its replacement at suitable sites in the east by H1 *Calluna vulgaris-Festuca ovina* heath (Table 15);

8. the much greater areas and range of saltmarsh transition communities in the east (Table 18);

9. the concentration of dune/shingle transitions in the south and east (Table 18);

10. some examples of localised distributions such as that of SD9b, the bloody crane's-bill *Geranium sanguineum* sub-community of *Ammophila arenaria-Arrhenatherum elatius* tall dune grassland (Figure 46) and of the anomalous, non-NVC communities of the Isles of Scilly.

Put together with the regional variation in dune geomorphology and in other factors such as the distribution of rare species, it is possible to distinguish some broad biogeographical zonation amongst English dune systems. The following zones appear to have some substance and internal consistency.

1. North-eastern bay and spit dunes with *Leymus arenarius* in the foredunes and often with *Geranium sanguineum* a feature of the dune grassland.

2. Northern and north-western dunes with varying combinations of dune heath and, calcareous and acidic dune grassland and with a range of dune slacks, including some dominated by common sedge. These dunes often retain transitions to inland vegetation.

3. Dunes of the exposed north coast of the south-west peninsula with extensive areas of calcareous dune grasslands, dune slacks and transition zones to inland vegetation, including calcicolous grassland, and to maritime grassland.

4. Mainly narrow spit and island dunes of the east coast between north Humberside and north Norfolk, occurring in close association with saltmarshes, with diverse semi-fixed dune vegetation, and with areas of lichen/bryophyte-dominated vegetation.

5. Shingle-based, often species-rich, dunes and sandy shingle of the south and south-east coasts.

6. Species-rich, highly anomalous, bracken- and bramble-dominated dunes of the Isles of Scilly.

Table 27 Regional distribution patterns of vegetation communities

Vegetation group	Scattered/ widespread	Northern	North & east	North-east	Eastern	North & west	North-west	Western	South & west	South-west	Southern	South & east
Strandline	SD2	SD3										
Mobile dunes	SD4 SD6a SD6e SD6g		SD6f	SD5a SD5b SD5c SD6b SD6c				SD6d				
Semi-fixed dunes	SD7c				SD7a SD7b SD7e					SD7d		
Dune grasslands	SD8a SD9a SD12a		SD12b	SD9b		SD8b SD8e		SD8c SD8d				
Carex arenaria	SD10a SD11a				SD10b SD11b							
Slacks	SD13a SD16a SD16b SD16c SD16d SD14c	SD13b SD17a SD17b SD17c SD17d				SD15a SD15b SD15c SD15d				SD14a SD14b SD14d		
Meso-grasslands	MG1a MG1b MG1c MG1d MG1e MG6a MG7a MG7e MG10a MG11a U1 U2a U20			MG5a	MG6b	MG5b	U6c U6d			CG1e Cg6a		
Heath & mires	H11c M16c				H1d M16e				H11a M16a	H6 H10		
Swamps & fens	All types											
Woods & scrub	SD18a SD18b All others										W4a W4b W4c W16a	
Coastal transitions	SM24 SM16				SM25a SM25b SM21a					MC5 MC8 MC8d		SD1a SD1b
Non-NVC	All others	ERWG		PPWG DEWG						CLS Scilly types		EPG

It must be emphasised that these zones do not cover all the dunes of England. The widely scattered dunes of the western half of the south coast do not form a coherent group. It is also important to realise that within these broad zones there are a substantial number of sites that do not conform well to the general pattern. Nevertheless these zones may prove a useful framework against which to assess the typicalness of an individual site or to pick out the important geographical outlier.

4.1.6 Recorded history and educational value

The study of English dune systems has had an important impact on the development of scientific thinking. They have been used for classic studies of geomorphological processes (Diver 1933), succession (Ranwell 1960), the influence of physical factors (Willis 1963, 1965, 1985), soils (Salisbury 1922), autecology (Gemmell, Greig-Smith & Gimingham 1953; Willis 1964) and many other branches of ecology. There are also many classic descriptive papers, some of which are listed in the sand dune bibliography (Radley & Woolven 1990). At least some of this work has the potential to be repeated or re-examined in order to take advantage of the passage of time to provide fresh insight.

Dunes are also superb ecological classrooms. This has been effectively demonstrated in Wales by the intensive educational use made of Ynyslas and Oxwich dunes. A field studies officer is employed at Ynyslas and in 1992 taught 5,189 people. Ecological principles such as succession, competition, dispersal and survival strategies can be demonstrated with unusual clarity. Dunes also lend themselves to the teaching of geomorphology and geography and to interdisciplinary studies.

4.1.7 Intrinsic appeal

This survey did not include any quantitative measurement of the extent to which people appreciate dunes, but there can be little doubt that they do. The strongest indication of this is that recreation was the most widely recorded form of land use during the survey (Section 3.4.3). It is easy to see why dunes have appeal. They adjoin bathing beaches, they 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. It is also often possible to explore them dryshod and without hindrance.

4.2 Factors affecting the nature conservation value of dunes and their vegetation

4.2.1 Limitations of the data available from a one-off survey

This survey does not provide any direct information on the historical background to current patterns of land use or direct observations of their impact over time. What it does provide is a very broad view of what was happening on and to a large number of dunes when they were visited once during the years 1987 to 1990.

4.2.2 Erosion and sea defences

Erosion is frequently seen as a threat to dunes. Erosion is, however, also the necessary counterpart of accretion in the dynamic processes which shape and maintain coastal dunes.

The results given in Section 3.3 do suggest that there is a preponderance of dunes undergoing net erosion and that the dune resource of England is therefore a diminishing asset. The results from Section 3.4.5 suggest that a very widespread reaction to erosion has been to construct sea defences, most frequently of the traditional 'hard engineering' kind. From the conservation point of view, however, this is frequently a very imperfect answer and may even exacerbate the problem. This is because the sea defences themselves can adversely affect the nature conservation interest of dune systems. The effects are most obvious with traditional hard defences such as sea walls which place a physical barrier between the beach and dune. These have the local effect of inhibiting the remobilisation and redistribution of sand and lead to a loss of diversity as mobile and semi-fixed dunes are stabilised. That part of the dune system is then effectively 'fossilised' and loses the capacity to renew itself. There may also be more widespread consequences. On many

unconstrained dune sites there are areas of both erosion and accretion. On such a site cutting off the supply of sand to the beach by protecting the eroding sections is likely to lower beach levels and inhibit the transfer of sand that was building or sustaining other sections. Works of this type therefore tend to displace rather than cure erosion and they do so at the cost of a substantial reduction in habitat diversity and naturalness.

Other types of defences, such as groynes, which inhibit the natural movement of sand can also precipitate or accelerate the erosion of dune systems. Even works at some distance from a dune may have an effect by interrupting long-shore drift.

Relatively few examples of the newer 'soft engineering' type of defences, (i.e. beach feeds, offshore breakwaters), were encountered during this survey, and their effects on dunes and their nature conservation interest are in any case likely to be more subtle.

4.2.3 Influence of land usage

4.2.3.1 Agriculture and recreation

Traditional agriculture shaped much of the dune vegetation that we have inherited today, but the traditional low input, low intensity, pastoral systems within which dunes were often grazed have now largely disappeared. In common with other habitats of the traditional, pastoral landscape, many dunes have undergone one of two changes. In the south and east of England many have become 'peripheral' (Webster & Felton in press); they no longer fit within the farming system and so are neglected or converted to other uses. In the north and west, many dunes remain integrated with the farming system, but livestock husbandry has often moved towards more intensive methods, and practices such as re-seeding, use of herbicides and fertilisers and, particularly in Northumberland, the winter feeding of high densities of stock have adversely affected dune vegetation.

Some dunes have, with varying degrees of assistance from conservation bodies, retained a close approximation to traditional management and their integration with local farming systems. Perhaps the best example of this is Sandscale Haws in Cumbria, where the National Trust has largely retained the pre-existing pattern of grazing. This site is grazed all year round by cattle and by two separate sheep flocks. The sheep flock grazing during the winter are Herdwicks, which in summer graze the nearby fells.

The results of this survey (reported in Section 3.4) suggest that leisure and not agriculture is now the most widespread form of land use on English dunes. The ecological effects of this change are complex. Sometimes they can be dramatic. Dune systems close to large concentrations of holiday-makers or urban populations can suffer massive destabilisation as a result of heavy usage which, because of the continuous trampling, will not stabilise without large-scale intervention. The destabilisation and restoration of Camber Sands is a classic example (Pizzey 1975; Ranwell & Boar 1986). Continued instability on a large scale, unlike cyclical or occasional disturbance, does adversely affect diversity. It destroys the vegetation of the longer established and more stable dunes which is never able to recover. Restoration can reverse this damage, though at the cost of greatly increased artificiality. It can also cause additional damage if drastic measures such as the importation of topsoil are used.

Informal recreational usage has many other ecological impacts. The presence of visitors and particularly of dogs makes stock grazing difficult. The risk of fire is likely to increase and in some urban fringe sites personal observation suggests that there may be a significant input of nutrients from dog faeces.

Not all the effects of recreation are negative. Studies of the effects of trampling show that it can to some extent mimic and replace those of grazing (Liddle & Greig-Smith 1975a, 1975b). Localised destabilisation may also be of benefit. It is also likely that widespread public usage and enjoyment of dunes has helped to ensure their protection.

Of all the many forms of more formal recreational usage to which dunes have been put, golf is undoubtedly the one that is most widespread and that has had the biggest effect. On the positive side, golf courses often appear to

have protected sections of the landward margins of dunes that would otherwise have been lost to development. Golf course roughs do also preserve sections of the pre-existing dune vegetation. Against this, the requirement for a relatively even and durable playing surface means that the vegetation of at least a proportion of the dune has to be drastically modified. Fragmentation of the remaining areas of dune vegetation, combined with the absence of stock and tight control of rabbit populations, can result in accelerated successional change. The fact that golf courses represent major capital investments, and attract the loyalty of their members, also means that there is great pressure to resist erosion wherever this threatens to encroach on the course.

4.2.3.2 Development and industrial usage

This survey recorded widespread development on, and adjacent to, dunes in England (see Section 3.4.4). Both industrial and residential development were widely noted. The building of houses, factories or other fixed structures has primarily affected the more stable, inland areas of dunes. Holiday chalets, caravan parks and beach huts are more widely distributed and are even found right at the edge of the beach. All such developments cause a direct loss of habitat, but they also often have other effects. Residential and leisure-related developments are almost invariably associated with trampling and erosion, whilst the presence of buildings renders unacceptable the unconstrained natural movement of a dune system and leads to stabilisation and coast protection works.

The large-scale quarrying of sand or shingle from dunes and foreshore is a practice which, though not widespread, can have a major impact. Quarrying from within dunes has drastically modified large sections of some dunes. The dunes of St Ives Bay, Cornwall, have probably been amongst those most affected. Quarrying from the beach or the inshore zone has the obvious effect of lowering beach levels, intercepting longshore drift and either inhibiting accretion or facilitating erosion. The casual observations made during this survey were not capable of isolating the erosion due to quarrying from that due to other factors, but the active removal of sand from the foreshore was found in association with localised areas of erosion on three sites.

Quarrying within dune systems can create wetland habitats. Where the quarrying has been localised and irregular, as has happened on parts of North Walney in Cumbria, these habitats can have considerable value. It must, however, be remembered that their creation caused the destruction of other, more natural habitats.

4.2.3.3 Conservation management

The results reported in Section 3.4.9 suggest that nature conservation is now established as a major land use of dunes. What is not so easy to assess is the ecological impact of this usage. The protection of sites by statutory designation and by management as nature reserves has undoubtedly reduced the impact of some competing forms of land use, though quantifying this reduction is well outside the scope of the data collected here. What is of greater interest is the direct impact of conservation management.

Dune stabilisation has long been a priority of many dune managers and very large-scale programmes have been undertaken on sites such as the Sefton Coast and Braunton Burrows. Where systematically executed and maintained, such schemes have frequently been very successful in combating excessive instability. Occasionally, as at Braunton, they have been so successful that there is now concern about over-stabilisation.

Scrub clearance is another long established and widespread conservation practice and has been the subject of much debate (Ranwell 1972). The results of this one-off survey are of little use in assessing its extent and its success as a means of maintaining herbaceous dune vegetation. They may, however, provide a baseline against which to measure the impact of this and many other management practices in the years to come.

One impact that has already been mentioned is that of perpetuating, reinstating or mimicking traditional pastoral management. Well established, conservation-orientated grazing schemes were recorded on several dune systems and a number of trial schemes were also

encountered, supporting an impression that this form of management is increasing.

Habitat creation is another activity which appears to have been widespread. Much of the activity has centred around the creation of wetlands for the benefit of amphibians and birds. Most amphibian pools are small. Because of this and because they attempt to mimic natural dune slacks, their impact on vegetation and on physical features has generally been limited. Scrapes and pools designed for birds are often much bigger. Some examples appear to have been created at the expense of considerable tracts of semi-natural dune vegetation. Examples of large-scale habitat creation exercises of this nature were noted on two sites in Lincolnshire: Donna Nook and Gibraltar Point.

4.2.3.4 Forestry

There was comparatively little evidence of recent afforestation on dunes in England. The two sites with the most extensive plantations have both reached maturity and are both now outside the mainstream of commercial forestry. An interesting issue for conservation managers to consider is whether established plantations should be cleared or managed as woodlands. Observations from Whiteford Burrows in Wales and Tentsmuir in Scotland during the course of this survey suggest that young coniferous stands can revert rapidly to dune grassland. An experiment is currently under way on Ainsdale National Nature Reserve to see if this is true of older stands.

Some older stands have, however, developed interest in their own right, the passage of a century having allowed considerable structural, if not species, diversity to develop. There may be a case for retaining some of these stands and allowing them to develop into analogues of natural dune woodlands.

5. Summary of conclusions and recommendations

5.1 Statutory protection

Within England dunes are a scarce resource. They contain some exceptionally rare habitats and species, they show considerable geographical variation and they are amongst the least modified of lowland terrestrial habitats. They score highly on all the criteria traditionally used to evaluate nature conservation importance and appear to be appreciated by a substantial section of the public. For all these reasons the relatively high proportion of the resource afforded statutory protection would appear to be justified.

The National Nature Reserves are of uniformly high quality and have wide geographical distribution. The series contains a high proportion of the largest, most diverse, least modified and most geomorphologically dynamic sites.

There are several examples of dunes being successfully managed for nature conservation and public enjoyment under Local Nature Reserve agreements. Northam Burrows and Dawlish Warren in Devon are two examples. This is a mechanism which appears to be particularly well suited to the conservation of sand dunes and could be more widely used.

5.2 Dunes and coastal zone planning

This survey has shown that many dune systems, like other coastal habitats, are at risk from the process of "coastal squeeze" (Davidson *et al.* 1991). Their landward and often their lateral margins are constrained by development or agriculture and their seaward margins are being squeezed by erosion. If dunes are to escape from this squeeze, two major issues will have to be addressed: the way that coastal defence is planned and executed and the way in which coastal land around dunes is allowed to be used.

The first priority for coastal defence is to take a more strategic view, so as to identify areas of eroding coast that are vital sources of sediment, to plot the patterns of sediment movement that feed and sustain the beaches and to recognise and encourage accretion where this is likely. With this knowledge the wider consequences of any intervention may be assessed. This information must be used to decide whether the balance of advantage lies with defence or with non-intervention. Where intervention is necessary, softer engineering techniques, such as beach feeding, need to be more widely employed. These work with rather than against coastal processes.

If coastal defence is to be remodelled on these lines one consequence will be an acceptance of some coastal erosion as well as accretion. A decision to remodel coastal defence also implies the roll-back of coastal habitats such as dunes as they are remobilised by retreating shorelines. There are already long sections of coastline where the density and capital value of coastal development would make this unacceptable. On these sections the option of continued mobility is therefore closed. There is an urgent need to formulate and implement planning policies which protect from development sufficient land around those sections of the coast that are still geomorphologically dynamic, to ensure that they can remain active for the foreseeable future.

5.3 Some principles of dune conservation management

5.3.1 The management of instability

A recurring theme during this survey has been the management of instability. Instability is an essential creative force, renewing and diversifying dune vegetation. It can also be destructive, leading to the loss of complex, long-established vegetation communities. Conservation managers need to use instability as a tool but must be alert to its destructive potential. One general point that is worth making is that, away from the continuously mobile foredunes, most of the biological interest resulting from instability seems to come during the period of recolonisation, after the original cause of the instability has been removed. Instability that is cyclical and which allows for periods of recovery is therefore more likely to have desirable consequences than continuous instability of the sort that happens, for example, on unmanaged dunes situated between major leisure developments and popular beaches.

Conservation managers also need to think through carefully their reaction to the erosion of dunes by the sea. Erosion cannot be divorced from accretion. Both are manifestations of the same coastal processes that shape and sustain dune systems. There should therefore be a strong presumption against coast protection for conservation purposes. There may well be cases where the coastline as a whole is so constrained that the only alternative to protection is total loss, but protection should be a position of last resort.

5.3.2 The management of recreation

This issue is related to the last. The scale of recreational use and development on and around dunes means that it is vital to seek better ways of accommodating the recreational use of dunes and of limiting its adverse impact. The issue has to be addressed at several levels. At the planning level it is vital to consider both the direct and indirect impacts of leisure-related developments on dune systems. One simple example is the siting, size and design of car parks, which often have a crucial influence on the amount and distribution of public access. The carrying capacity of the car park should not exceed that of the dune system and should not channel visitors into particularly sensitive areas.

At the management level it is vital to seek ways of allowing visitors to enjoy and appreciate dunes without destroying what they have come to see. Much has already been achieved through techniques such as signposting, provision of through routes to beaches and environmental education. There may well be opportunities to make more use of visitor trampling as a management tool to achieve cyclical instability. It is also necessary to be aware of new forms of recreational activity, such as the recent rise in the use of off-road vehicles, and come up with ways of managing them or limiting their impact.

5.3.3 The management of succession

This survey has highlighted what appears to be a dramatic change in the land use of sand dunes: the decline of traditional low-intensity grazing. This raises the question of whether it is better for conservation to attempt to continue, re-establish or mimic this traditional form of land use or to welcome its disappearance as an opportunity, allowing dunes to develop a more natural climax vegetation.

The extent to which grazing has moulded dune vegetation and the diversity and complexity of the resultant dune grassland and other communities suggest that, for many sites, grazing is the best option. The best results seem to come from grazing regimes which most closely resemble traditional management and where the grazing is done in large enclosures. It is also vital severely to restrict, and wherever possible prohibit, the use of imported feed. It is also worth pointing out that the rabbit is in many ways an ideal grazing animal for sand dunes. It requires no husbandry, it creates a mosaic of grazed and ungrazed areas and, by scratching and burrowing, it creates numerous small patches of temporary instability.

There are, however, also sites and parts of sites where the re-introduction of grazing may not be the best course of action. This is particularly likely to be the case where the successional changes resulting from the cessation of grazing are already far advanced. In these cases attempting to wrest the site back to what it may have looked like in the past may produce less benefit than allowing it to continue developing and adapting to the new situation.

By adopting a combination of both approaches over a suite of sites it should be possible to enjoy the benefits of both. English Nature, which through the SSSI network is in a unique position to influence the management of dune sites as a series, is well placed to achieve this goal.

5.3.4 The importance of naturalness

The discussion section of this report highlighted the relative naturalness of many dune systems as a crucial asset. It is important to try to protect this elusive quality, both in regulating the use others make of dunes and in managing dunes for conservation. Obtrusive fence-lines outlining rectangular compartments, ill-judged habitat creation schemes and badly sited interpretative facilities can all help to destroy naturalness. The importance of maintaining naturalness as a management goal will vary from site to site, but for the least-modified sites, such as Scolt Head Island, it must be a central goal. Since many of

English Nature's National Nature Reserves fall into this category, naturalness is an aspect that English Nature needs to take very seriously.

5.4 Future uses of this survey

This survey was always intended to be more than a stock-taking exercise and it has become apparent that the information it has collected can contribute to a number of current conservation issues.

5.4.1 Implementation of the Habitats Directive

As we now have a fairly comprehensive inventory of English dune vegetation using the National Vegetation Classification, it should be a comparatively simple matter to select a series of dune sites to which the provisions of the European Community Habitats Directive should apply.

5.4.2 Monitoring of future change

The detailed and comparatively accurate vegetation maps of dune vegetation compiled for this survey provide an ideal baseline against which to measure ecological change over the longer term and at the larger scale. The potential of this technique has been illustrated by a pilot study of changes in the vegetation of Ross Links, Northumberland, by comparing vegetation maps compiled at different dates (Dargie 1992).

6. References

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7. List of sand dune sites surveyed in England, with publication details

Site name	Site report No.	Publication series and number
Haverigg Haws, Cumbria	1	CS10
Sandscale Haws, Cumbria	2	CS11
Silloth to Maryport Dunes, Cumbria	3	CS12
Penhale Dunes, Cornwall	4	CS13
Holywell Dunes, Cornwall	5	CS22
Fistral and Crantock Dunes, Cornwall	6	CS28
North Walney, Cumbria	7	CS24
Gwithian to Mexico Towans, Cornwall	8	CS25
Drigg Dunes, Cumbria	9	CS26
Constantine Bay, Cornwall	10	CS27
Godrevy Towans, Cornwall	11	CS29
Lelant Dunes, Cornwall	12	CS31
South Walney, Cumbria	17	CS49
Rock Dunes, Cornwall	18	CS50
Eskmeals Dunes, Cumbria	19	CS44
Lindisfarne, Northumberland	20	CS46
Ross Links, Northumberland	21	CS45
Bamburgh to Seahouses, Northumberland	22	CS51
Cleethorpes to Humberstone, Humberside	23	CS47
Embleton Bay, Northumberland	24	CS52
North Northumberland Coast	25	CS55
Alnmouth Town Dunes, Howdiemont and Sugar Sands, Northumberland	26	CS53
Seahouses to Beadnell Dunes, Northumberland	28	CS57
Alnmouth Dunes, Northumberland	29	CS56
Beadnell to Newton Dunes, Northumberland	30	CS54
Lynemouth, North Seaton and Cambois Dunes, Northumberland	31	CS59
Druridge Bay, Northumberland	32	CS58
Warkworth Dunes, Northumberland	33	CS65
Amble to Hauxley, Northumberland	34	CS63
Newbiggin, Northumberland	35	CS62
Blyth to Seaton Sluice, Tyne and Wear	36	CS67
Hart Warren and Crimdon Dene, Cleveland	37	CS66
Tees Bay Dunes, Cleveland	38	CS80
North Humberside Dunes	39	CS81
North Lincolnshire Coast Dunes	40	CS68

Site name	Site report No.	Publication series and number
Skegness to Sutton-on-Sea, Lincolnshire	41	CS82
Hunstanton and Holme Dunes, Norfolk	69	CS119
Thornham, Titchwell and Brancaster, Norfolk	70	CR1108
Scolt Head Island, Norfolk	71	CS121
Holkham Dunes, Norfolk	72	CR1109
Blakeney Point, Norfolk	73	CR1112
Winterton Dunes, Norfolk	74	CS124
Yarmouth North Denes, Norfolk	75	CR1091
Sandwich Bay, Kent	76	CR1126
Romney Warren, Kent	77	CR1117
Camber Sands, East Sussex	78	CR1107
Pagham Beach, West Sussex	79	CR1111
Climping Beach, West Sussex	80	CR1118
East Head, West Sussex	81	CR1122
Hayling Island Dunes, Hampshire	82	CR1114
St Helen's Duver, Isle of Wight	83	CR1124
Studland, Dorset	84	CR1131
Dawlish Warren, Devon	85	CR1120
South Cornwall Dunes	86	CR1129
Grune Point, Cumbria	87	CR1132
Wirral Dunes, Merseyside	88	CR1140
Weston Dunes and Sand Bay, Avon	89	CR1130
Berrow Dunes, Somerset	90	CR1133
Saltfleet Dunes, Lincolnshire	91	CR1135
Braunton Burrows, Devon	138	JN103
Northam Burrows, Devon Instow Sands, Devon Croyde Bay, Devon Woolacombe Warren, Devon	139	JN104
Isles of Scilly Dunes	-	CR1179
Saltfleetby–Theddlethorpe dunes, Lincolnshire	-	ES
Gibraltar Point, Lincolnshire	-	ES
Sefton Coast Dunes, Merseyside	-	CR917

Explanation of abbreviations

CS Nature Conservancy Council Contract Survey series (ISSN 0952-4355).

CR Nature Conservancy Council Chief Scientist Directorate Contract Report series (unpublished).

ES Unpublished report to the National Rivers Authority by Ecosurveys Ltd.

JN Joint Nature Conservation Committee Report series (ISSN 0963-8091)