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The floristics and conservation status of sand-dune communities in Wales

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Abstract. An inventory of the vascular plants, bryophytes, fungi and terricolous lichens recorded within the different sand-dune communities in Wales has been compiled and a summary of the importance of these different taxonomic groups to the ecology and conservation of sand dunes is provided. The total floristic assemblage amounted to 945 species, with vascular plants representing 439 of these. Fungi unexpectedly formed the next most important group with ca. 289 species, followed by bryophytes (171 species) and terricolous lichens (66 species). However, very few of these species are confined to sand dunes. Of the vascular plants only ca. 7 % (32 species) could be classed as either wholly dependent or strongly associated with sand dunes, whereas up to 13% (22 species) of the bryophytes fell within this category. Of the fungi only 4% (10 species) appear to be restricted to sand dunes, but none of the lichen species could be classed as being either limited to, or strongly associated with, this habitat.

Over 9% (91 species) of the total flora are considered to be rare, scarce or endangered within the UK or Europe, and ca. 8% of the vascular plant species are considered to be endemic or near-endemic to Europe. The inventory therefore not only provides an insight in the overall plant diversity of dune systems in Wales, it also gives an indication of the proportion of species that are under threat, and the numbers of species that are more-or-less totally dependent on sand dunes. In the discussion various relevant sand-dune management issues are addressed.

Keywords: Bryophyte; Dune slack; Ecology; Fungus; Lichen; Management; Plant community; Vascular plant; Vegetation.

Nomenclature: Stace (1997) for vascular plants, Hill et al. (1991, 1992, 1994) for bryophytes, Purvis et al. (1992) for lichens, and Dennis et al. (1960) for fungi (the latter outdated).

Abbreviations: NVC = National Vegetation Classification; SSSI =Site of Special Scientific Interest.

Introduction

Sand dunes represent one of WalesÕ most natural and species-rich habitats. However, much has been lost to industrial and urban development especially in south Wales, and a large area of the Welsh dune resource has been planted with commercial forests (Fig. 1). Altogether, there are only ca. 6500 ha of undisturbed dune habitat remaining and this equates to ca. 0.3 % of the land area of Wales. There is, for example, over four and half times (ca. 30 000 ha) as much ancient, semi-natural broadleaved woodland (Humphrey 1994). Nevertheless, within this comparatively small area, dune systems in Wales support 67 species that are either restricted to, or strongly associated with, the dune habitat, 51 Red Data Book species, 9 species protected under Schedule 8 of the UK Wildlife and Countryside Act, and 6 species protected under either Annex II or Annex V of EC Council Directive 92/43/EEC on the conservation of natural and wild fauna and flora (the EC Habitat and Species Directive). It is not surprising therefore that much of the remaining resource has been given some form of legal protection. Altogether 22 of the 52 sand-dune systems in Wales, comprising ca. 85% of the total area, have been notified as Sites of Special Scientific Interest (SSSI). Nine of these have also been declared National Nature Reserves, and several sites have been identified as important within a European context and have now been put forward for designation as Special Areas of Conservation (SAC) under EC Habitat and Species Directive (Table 1; see also Fig. 14.10 in Boorman 1993).

Sand-dune vegetation

Although sand dunes in Wales support a large variety of plant communities, only a few of these are confined to sand dunes. These represent the dune communities classified as SD4-SD18 and H11 (Table 2) under the National Vegetation Classification (NVC) (Rodwell in prep.; Malloch 1989; Boorman 1993). In addition, a further 70 major plant communities have been recorded on sand dunes or in sand dune transition zones in Wales (Table 2) and by far the most extensive of these is conifer plantation which occupies ca. 23% (177 3 ha) of all Welsh dune habitat (Fig. 1). Much of the remaining, ca. 37%, is dominated by *Ammophila arenaria-Festuca rubra* semi-fixed dune grassland (SD7) and *Festuca rubra-Galium verum* fixed

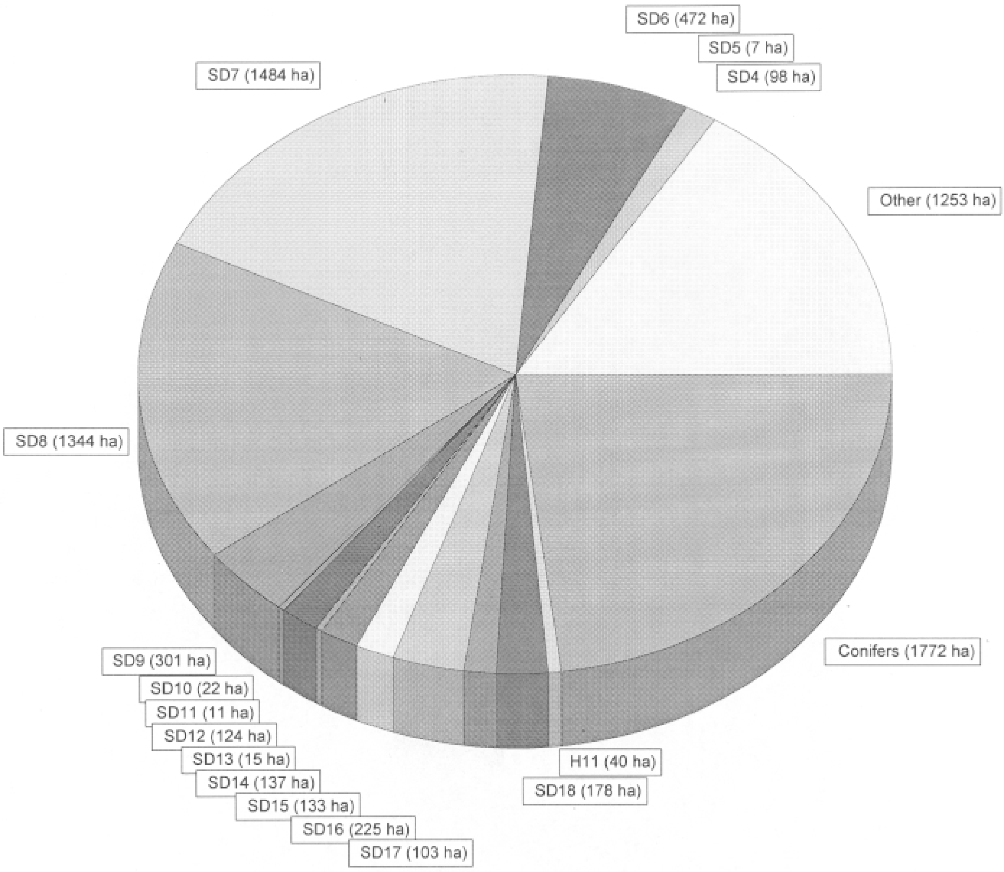

Fig. 1. Pie-chart showing the entire sand dune resource of Wales split into its component vegetation types. Some of the NVC-community types (see Table 2) include small elements of transitional vegetation.

dune grassland (SD8). Two other dune communities, *Ammophila arenaria* mobile dune grassland (SD6) and *Ammophila arenaria - Arrhenatherum elatius* (SD9) dune grassland, are also relatively abundant, but many of the other obligate dune communities such as *Carex arenaria* dune (SD10) and *Calluna vulgaris - Carex arenaria* dune heath (H11) are far less abundant than some of the communities that are not restricted to sand dunes, such as *Lolium perenne* mesotrophic grassland (MG7). However, the following account will be restricted to the communities confined to sand dunes (SD4-18, H11). In order to provide a more comprehensive evaluation of the floristic importance of the various NVC dune communities in Wales, floristic data collected during the Sand dune survey of Great Britain (summarized in Dargie 1995) and from various other sources have been collated for the whole of Wales - all of the notable species are listed in App. 1. Altogether the flora amounts to 946 species, 440 of which are vascular plants. Surprisingly, fungi form the next most important group with ca. 280 species, followed by bryophytes (171 species) and lichens (66 species).

Vascular plants

Despite the large number of vascular plants recorded on Welsh dune systems, only a tiny proportion can be described as either restricted to, or strongly associated with, sand dunes (App. 1). In total, only ca. 8% (34 taxa) of the vascular plant dune flora in Wales fall within this category, and many of these are considered to be rare or scarce. In addition, populations of several rare dune species, especially dune slack species such as *Gentianella uliginosa* and *Liparis loeselii* have undergone a steep decline in recent years (Lousley 1950; Vaughan et al. 1972; Kay 1972, 1996; Davis 1997). Stabilization and the resulting rarity of early successional phases of dune slack development appear to be partly responsible (Vaughan et al. 1972; Jones & Etherington 1992; Jones et al. 1995). Other factors include loss of habitat due to various forms of development including afforestation, industrial development and the construction of golf courses.

Tables 3 and 4 show that most of the vascular plants that are either confined to or strongly associated with

Table 1. Conservation status of protected sand-dune systems in Wales.

Site	Area (ha)	Region	SSSI	NNR	pSAC	LNR	AONB	HER	NP
Merthyr Mawr	342	Bridgend	x	proposed	x			x	
Kenfig Dunes	602		x	x	x				
Crymlyn Burrows	118	Swansea	x						
Pennard Burrows	87		x				x	x	
Oxwich Burrows	93		x	x			x	x	
Whiteford Burrows	142		x	x	x		x	x	
Pembrey Coast	591	Carmarthenshire	x						
Laugharne / Pendine	603		x						
Tenby Burrows	92	Pembrokeshire	x					x	x
Stackpole/Linney/Brownslade	432		x	part				x	x
Broomhill Burrows	183		x					x	x
Towyn Warren	30	Ceredigion	x						x
Ynylas	68		x	x					
Tywyn	111	Gwynedd	x						x
Morfa Dyffryn	313		x	x	x				x
Morfa Harlech	341		x	x	x				x
Morfa Bychan	169		x			x			
Morfa Dinlle	67		x						
Newborough Warren	529		x	x	x		x		
Penhrhnoedd	25		x						
Aberffraw	248		x		x		x		
Gronant/Talacre	190	Flintshire	x						

Abbreviations: SSSI = Site of Special Scientific Interest; NNR = National Nature Reserve; LNR = Local Nature Reserve; pSAC = proposed Special Area of Conservation; AONB; = Area of Outstanding Natural Beauty; HER = Heritage Coast; NP = National Park.

dune systems in Wales tend to be associated with mobile and semi-fixed dunes (SD4, 5, 6 & 7) and it is these particular communities, especially at the more mobile end of the spectrum, that are now considered to be under threat in Wales. This is mainly attributable to the fact that most dunes are becoming overly stable, and erosion along the seaward edge is preventing the creation of new foredunes. Finally, ca. 22% (ca. 98 taxa) of the vascular plant taxa recorded for sand-dune communities in Wales are considered to be endemic or near endemic to Europe (Davies 1994; cf. van der Maarel & van der Maarel-Versluys 1996). 23 of these are regarded as globally restricted, and three, *Dactylorhiza majalis* ssp. *cambrensis*, *Dactylorhiza incarnata* ssp. *coccinea* and *Epipactis leptochila* var. *dunense* and considered to be endemic to Britain.

Fungi

Rotheroe (1993a, 1995) compiled a list of ca. 289 species of macrofungi associated with sand-dune communities in Wales. Semi-fixed dunes (SD7) and dune slacks, particularly SD14 and SD15, appear to support the richest mycofloras. Ten species (ca. 4%) appear to be confined to dune systems (Rotheroe 1993b), and most of these, such as *Coprinus ammophilae*, are specially adapted to colonizing mobile dune vegetation (SD6). Sand dunes are also known to support a rich microfungus flora. Brown (1958) recorded 95 species on various calcareous dunes systems including Newborough Warren. A succession of species, described as comparable with that of higher plants, was found to occur across the dune systems with different assemblages occurring within the foredunes, semi-fixed dunes, fixed dunes and fixed dune pastures.

Many species of sand-dune macrofungi in Britain are considered to be rare (Ing 1992), and altogether ca. 10% (29 taxa) of the Welsh dune macromycetes are Red List species (App. 1). Coastal dunes are described as one of the most important habitats for fungi in Britain (Ing in prep.). Recent studies (Watling & Rotheroe 1989; Read 1989; Rotheroe 1993b; Rotheroe 1994) have shown that fungi are very important to the ecology of sand-dune ecosystems, both with regard to their role in decomposition and to the mycorrhizal associations they form with higher plants. In fact, with the exception of drift-line plants, it is now known that virtually all dune vascular plants rely on having a symbiotic relationship with fungi which helps them promote the uptake of phosphorus and nitrogen. Fungi are therefore thought to play a major role in facilitating colonization of dunes by higher plants. Problems such as the sporadic and irregular nature of the surface manifestations of fungi and difficulties with their identification have in the past made it difficult to cater for their conservation.

Table 2. Major plant communities recorded on Welsh sand-dune systems mostly based on the National Vegetation Classification (NVC) (taken from Dargie 1995).

NVC Code	NVC Name
Strandline and shingle communities	
SD1	*Rumex crispus - Glaucium flavum* shingle comm.
SD2	*Honkenya peploides - Cakile maritima* strandline comm.
SD3	*Tripleurospermum maritimum - Galium aparine* strandline comm.
Sand-dune communities	
SD4	*Elytrigia juncea* foredune comm.
SD5	*Leymus arenaria* mobile dune comm.
SD6	*Ammophila arenaria* mobile dune comm.
SD7	*Ammophila arenaria - Festuca rubra* semi-fixed dune comm.
SD8	*Festuca rubra - Galium verum* fixed dune comm.
SD9	*Ammophila arenaria - Arrhenatherum elatius* dune grassland
SD10	*Carex arenaria* comm.
SD11	*Carex arenaria - Coelocaulum aculeatum* dune comm.
SD12	*Carex arenaria - Festuca ovina - Agrostis capillaris* grassland
SD13	*Salix repens - Bryum pseudotriquetrum* dune-slack comm.
SD14	*Salix repens - Campylium stellatum* dune-slack comm.
SD15	*Salix repens - Calliergon cuspidatum* dune-slack comm.
SD16	*Salix repens - Holcus lanatus* dune-slack comm.
SD17	*Potentilla anserina - Carex nigra* dune-slack comm.
SD18	*Hippophae rhamnoides* dune scrub comm.
Dune heath communities	
H11	*Calluna vulgaris - Carex arenaria* dune heath comm.
Additional heathland communities	
H1	*Calluna vulgaris - Festuca ovina* heathland comm.
H7	*Calluna vulgaris - Scillla verna* maritime heathland comm.
H8	*Calluna vulgaris - Ulex gallii* heathland comm.
H10	*Calluna vulgaris - Erica cinerea* heathland comm.
Woodland communities	
W8	*Fraxinus excelsior-Acer campestre-Mercurialis perennis* woodland comm.
W10	*Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland comm.
	Acer pseudoplatanus woodland
	Conifer plantations
Scrub communities	
W21	*Crataegus monogyna - Hedera helix* scrub comm.
W22	*Prunus spinosa - Rubus fruticosus* scrub comm.
W23	*Ulex europaeus - Rubus fruticosus* scrub comm.
W24	*Rubus fruticosus - Holcus lanatus* scrub comm.
W25	*Pteridium aquilinum - Rubus fruticosus* scrub comm.
	Coastal privet
Wet woodland communities	
W1	*Salix cinerea - Galium palustre* woodland comm.
W2	*Salix cinerea - Betula pubesens - Phragmites australis* woodland
W4	*Betula pubescens - Molinia caerulea* woodland comm.
W6	*Alnus glutinosa - Urtica dioica* woodland comm.
Swamp communities	
S4	*Phragmites australis* swamp comm.
S5	*Glyceria maxima* swamp comm.
S6	*Carex riparia* swamp comm.
S7	*Carex acutiformis* swamp comm.
S8	*Schoenoplectus lacustris* swamp comm.
S10	*Equisetum fluviatile* swamp comm.
S12	*Typha latifolia* swamp comm.
S14	*Sparganium erectum* swamp comm.
S18	*Carex otrubae* swamp comm.
S19	*Eleocharis palustris* swamp comm.
S20	*Schoenoplectus tabernaemontani* swamp comm.
S21	*Bolboschoenus maritimus* swamp comm.
S25	*Phragmites australis - Eupatorium cannabinum* swamp comm.
S26	*Phragmites australis - Urtica dioica* swamp comm.
S28	*Carex rostrata - Potentilla palustris* swamp comm.
Mire communities	
M5	*Carex rostrata - Sphagnum squarrosum* mire comm.
M10	*Carex dioica - Pinguicula vulgaris* mire comm.
M23	*Juncus effusus / acutiflorus - Galium palustre* rush pasture
M25	*Molinia caerulea - Potentilla erecta* mire comunity
M27	*Filipendula ulmaria - Angelica sylvestris* mire comm.
M28	*Iris pseudacorus - Filipendula ulmaria* mire comm.
Mesotrophic grasslands	
MG1	*Arrhenatherum elatius* grassland comm.
MG5	*Cynosurus cristatus - Centaurea nigra* grassland comm.
MG6	*Lolium perenne - Cynosurus cristatus* grassland comm.
MG7	*Lolium perenne* grassland comm.
MG9	*Holcus lanatus - Deschampsia cespitosa* grassland comm.
MG10	*Holcus lanatus - Juncus effusus* grassland comm.
MG11	*Festuca rubra - Agrostis stolonifera - Potentilla anserina* grassland comm.
MG12	*Festuca arundinacea* grassland comm.
Calcicolous grasslands	
CG6	*Avenula pubescens* grassland comm.
CG7	*Festuca ovina - Hieracium pilosella - Thymus praecox* grassland comm.
Calcifugous grasslands	
U1	*Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland comm.
U4	*Festuca ovina - Agrostis capillaris - Galium saxatile* grassland comm.
U5	*Nardus stricta - Galium saxatile* grassland comm.
U6	*Juncus squarrosus - Festuca ovina* grassland comm.
Maritime cliff communities	
MC5	*Armeria maritima - Cerastium diffusum* maritime cliff comm.
MC8	*Festuca rubra - Armeria maritima* maritime grassland comm.
MC9	*Festuca rubra - Holcus lanatus* maritime grassland comm.
MC10	*Festuca rubra - Plantago* spp. maritime grassland comm.
MC12	*Festuca rubra - Hyacinthoides non-scripta* maritime grassland comm.
Salt marsh communities (SM)	
SM6	*Spartina anglica* saltmarsh comm.
SM8	Annual *Salicornia* saltmarsh comm.
SM9	*Suaeda maritima* saltmarsh comm.
SM10	Transitional low-marsh vegetation saltmarsh comm.
SM12	*Aster tripolium* saltmarsh comm.
SM13	*Puccinellia maritima* saltmarsh comm.
SM14	*Atriplex portulacoides* saltmarsh comm.
SM15	*Juncus maritimus - Triglochin maritima* saltmarsh comm.
SM16	*Festuca rubra* saltmarsh comm.
SM18	*Juncus maritimus* saltmarsh comm.
SM20	*Eleocharis uniglumis* saltmarsh comm.
SM24	*Elytrigia atherica* saltmarsh comm.
SM28	*Elytrigia repens* saltmarsh comm.

Added to this is the fact that up until quite recently sand dunes have tended to be neglected by mycologists, and it is only through the work of Maurice Rotheroe (e.g. Rotheroe 1985, 1986, 1987, 1992; Rotheroe et al. 1987) that the conservation importance of sand dunes for macrofungi in Wales has come to light. These new findings should go some way towards helping establish dune management regimes which are sympathetic to the requirements of their indigenous mycoflora.

Bryophytes

In addition to bryophyte data from the Welsh sand dune survey (summarized in Dargie 1995) information on dune bryophytes was compiled from Wade (1948, 1949), Smith (1964), Hill (1979, 1988) and Newton (1994). Altogether ca. 170 bryophyte species have been recorded on sand-dune systems in Wales, but most tend to be restricted to either fixed dune grasslands (SD8) or dune slacks (SD13-17). When compared with vascular plants, a higher proportion, ca. 13% (22 species), can be classed as either restricted to or strongly associated with sand dunes (App. 1). Most of the obligate dune species and all of the rare and protected species tend to be confined to dune slacks. Most of the Red Data Book *Bryum* species listed in App. 1 also have a requirement for early successional stages of dune slack development (M. Newton pers. comm.). Altogether, a total of 16 (or 9%) of the species listed in App. 1 are considered to be rare or endangered, and 10 of these are deemed to be important within a European context (Stewart et al. 1995).

Terricolous lichens

Information on terricolous, sand-dune lichens in Wales was gathered from various sources including Dargie (1995), Fletcher (1972), Fletcher et al. (1984) and Pentecost (1987). In total, ca. 66 species have been recorded on Welsh sand-dune systems. The most important NVC- communities for this group of lichens are the calcareous semi-fixed and fixed dune grasslands (SD7 & SD8) and the acidophilous communities (SD11, SD12 & H11). *Cladonia* is by far the most abundant genus in all of the above-mentioned communities, and *Cladonia*, together with *Peltigera*, are the only genera found to occur in the foredune community (SD4).

Welsh sand dunes do not support a particularly rich lichen flora, and there appears to be no obligate dune species (James et al. 1977). Furthermore, only one of the 16 dune community types (the *Carex arenaria* - *Coelocaulon aculeatum* community, SD11), described under the NVC is dominated by lichens. However, despite a general paucity of lichen species, several sand dunes in Wales support a number of rare and uncommon species. Stackpole Warren, for example, was declared a Grade 1 (internationally important) site for lichens of calcareous shell-sand, including *Fulgensia fulgens* by the British Lichen Society (BLS) (Fletcher et al. 1984), whereas Newborough Warren and Aberffraw were deemed to be of Grade 3 (nationally important) quality for their calcareous dune lichens, including species such as *Diploschistes muscorum*, *Ramalina farinacea* and *Toninia caeruleonigricans*. Dunes with acidic lichen communities in Wales are very rare, but Morfa Dinlle in North Wales has been designated a Grade 4 (regionally important) site by the BLS for its *Cladonia* heath.

Discussion and implications for conservation

The NVC has provided one way of classifying some of the numerous elements which make up the complex Ôpatchworks quiltsÕ characteristic of many sand-dune systems in the UK. The floristic tables in the NVC manual give an indication of some of the vascular plants, bryophytes and lichens likely to occur within each of these patches, although species occurring at frequencies of less than 5% are not normally included.

During the present exercise all species encountered during survey work have been included and it therefore gives a more comprehensive indication as to the potential each of these patches has for supporting species in Wales, especially some of the less common species. It also takes into account knowledge relating to the distribution of fungus species within the various dune communities in Wales - a group which is not normally considered during vegetation surveys. However, as previously explained, the data is based on the total number of species recorded for the entire resource of each dune community in Wales. The well known principle that species number tends to increase with area (e.g. MacArthur & Wilson 1967) means that it is highly unlikely that all of these species would occur within a given community at any particular site. Nevertheless, within the comparatively small area (ca. 6500 ha) of dune habitat in Wales, 64 of the species considered here (or 7% of the total number), are either wholly or highly dependent on certain dune communities, and 91 species (or 9% of the total number) are considered to be rare or endangered. Many more species could be added to these categories if other groups such as the invertebrates were considered. Table 3 shows that obligate dune species or species highly dependent on dune habitat tend to be concentrated in the *Ammophila*-dominated communities of SD6 and SD7.

Table 3. The numbers of uncommon species, obligate dune species (or species heavily dependent on dunes) and European endemic vascular plants recorded within each dune community in Wales.

NVC communities	Rare/scarce species	Obligate dune species	European endemic vascular plants
SD4	0	9	8
SD5	0	4	2
SD6	11	35	30
SD7	23	31	47
SD8	21	26	60
SD9	1	13	20
SD10	2	11	12
SD11	1	2	12
SD12	2	6	20
SD13	12	14	10
SD14	18	15	14
SD15	23	13	23
SD16	13	15	28
SD17	12	6	19
SD18	2	3	8
H11	5	3	25

The above figures are likely to be under-estimates since a number of relevant species have not been assigned to particular NVC- communities (see Table 3).

To a certain extent, this is not surprising since species capable of existing in the unstable conditions of mobile and semi-fixed dunes are likely to have undergone the greatest adaptation and therefore represent some of the most highly specialized of dune species.

Table 3 also shows that a comparatively large number of rare and scarce species are dependent on these unstable dunes, although the coincidence is partly due to the fact that many of these are also obligate dune species. Uncommon species also tend to be concentrated in the fixed dune grasslands (SD8) and the dune slack communities (SD13-17), although the large number of rare and scarce species recorded in the latter communities belie their size, since the combined area of dune slack communities in Wales adds up to less than the area of the fixed dune grassland community (Fig. 1).

Since species endemic to relatively small areas or a single country are likely to be more prone to extinction than other more widespread species, it is important that the levels of endemism amongst dune species are taken into account when considering sand-dune conservation. Provisional studies show that up to 8% of the vascular plants recorded in various sand-dune communities in Wales appear to be endemic or near endemic to Europe (Davies 1994). Some of these species are classed as globally restricted (App. 1), and yet several of these, such as *Anagallis tenella* and *Centaurea nigra*, are relatively common in Wales. This opens up the possibility that in global terms some of these species may be far less common than some of the species that are given special protection in the UK. Bryophytes tend to have wider world distributions than flowering plants, probably because of their greater antiquity (Stewart 1995), and although some species have limited distributions, especially some of the western oceanic species, this does not apply to any of the species listed here. At present there is insufficient information on the distribution of lichens and fungi to assess the levels of endemism amongst these groups.

In order to fully conserve the remaining sand-dune habitat resource in Wales, efforts are now being made to develop an all-Wales sand-dune, site management framework aimed at maximizing the conservation value of the resource as a whole. The framework is still being developed, but it seems likely that it will represent a strategic tier of guidance aimed at influencing the site management plans of various sand-dune reserves, and where possible, the future management of various unprotected sites. However, it will only be concerned with what are deemed to be the more strategic or important elements of management, rather than the more routine everyday aspects. The idea will be to identify the best sites for certain types of management, which in some cases may be highly disruptive, such as recommendations for artificial de-stabilization or dune slack creation. At other sites, the possibility of re-introducing rabbits is being considered, and in contrast, it has been suggested that a *laissez-faire* approach should be adopted at some ungrazed sites, so as to encourage the development of dune woodland.

The principal concerns over sand-dune conservation in Wales at present are mainly linked to the fact that there has been a general trend towards stabilization at most sites, which is resulting in a loss of early successional stages, such as mobile dunes and embryonic dune slacks. Related to this are problems associated with scrub encroachment and there has been a general decline in the species richness of dune grasslands due to a lack of appropriate grazing.

Many of the uncommon dune slack species tend to prosper during the early successional stages of dune slack development, and since these are no longer being generated through natural processes there is now an urgent requirement to either create new dune slacks or to rejuvenate some of the existing older dune slacks. This was seen as a particularly urgent requirement at Kenfig, due to it being one of the few sites to support the rare dune slack orchid *Liparis loeselii*. Therefore in 1994 a programme of close-mowing in a selection of older dune slacks was initiated (Jones 1998). This created a mosaic of bare soil and close-cut stem bases and has proved to be beneficial to *L. loeselii*. In addition to this, entire dune slacks have been created at three sites, Newborough Warren, Brownslade Burrows and Ynyslas, using mechanical excavators. Work at the latter site has proved to be particularly effective in producing an early dune slack community, and it was rapidly colonized by the dune slack liverwort, *Riccia cavernosa*.

As expected, studies in Wales have shown that plant species diversity in dune grasslands is closely correlated with levels of grazing (Boorman 1989a, b). At sites such as Oxwich Burrows where there had been virtually no grazing, species diversity was relatively poor, with no more than 13 species per quadrat (2 m × 2 m), whereas at Aberffraw, which has been heavily grazed by a combination of cattle, sheep, rabbits and hares, up to 33 species per quadrat have been recorded. Setting optimal grazing levels on traditionally grazed sites in Wales is therefore also seen as a high priority. This is particularly crucial at sites where the rabbit population has never recovered from myxomatosis and the dune grasslands are becoming very rank. At Newborough Warren this has been offset to a certain extent by introducing a variety of domestic stock including ponies. On the other hand, it will not be possible to use domestic stock at all sites, especially some of the unenclosed sites such as Kenfig. It is because of this that we are debating the possibility of re-introducing rabbits to certain key sites (see Whatmough 1995).

Scrub encroachment on sand dunes in Wales is a general problem involving various shrub and tree species. For example, Hodgkin (1984) regarded *Crataegus monogyna* as a problem at Newborough Warren, but also identified a further 18 species of trees and shrubs that had entered the dune system. The oldest birch (*Betula* spec.) on the site, for example, dated back to the year after most of the rabbits had been wiped out due to myxomatosis, and dendrochronological analysis indicated that there had been a more or less even rate of spread ever since. In the case of *C. monogyna*, it was found to decline with distance from the northern landward edge, suggesting that hedgerows bordering the northern side of the Warren had provided the initial seed source. Nevertheless, the tree had spread to within 330m of the sea, and it had colonized yellow dune, grey dune, dry slack, fixed dune grassland, and one individual was recorded in a wet slack, but it was unable to germinate on foredunes. However, there has never been any attempt to control this species at Newborough.

Of more pressing concern has been the spread of *Hippophae rhamnoides* (see for example Ranwell 1972). This species is not indigenous to Wales, and has proved to be invasive at some sites, especially in south Wales. At one of the worst affected sites, Merthyr Mawr, this has prompted a major *Hippophae* clearance programme.

There is still no general consensus on how to deal with the increasing maturation of sand-dune vegetation in Wales. Over the last three to four decades many sites have changed almost beyond recognition. For example, in the 1950s, nearly 75% of Newborough Warren consisted of mobile dunes and embryonic dune slacks with open vegetation (Ranwell 1958) whereas today, the site is dominated by fixed and semi-fixed dune grasslands and mature dune slacks. The loss of rabbits is often quoted to be one of the main causative factors for this, although throughout its history Newborough Warren, like many other European sand-dune systems Ð see for example, van der Maarel et al. (1985); Boot & van Dorp (1986) and De Raeve (1989) Ð appears to have undergone cycles of instability followed by intervening periods of relative stasis. There is some evidence at Newborough to suggest that these episodes of rapid change may be linked to periods of increased storminess and tidal maxima (Ranwell 1955, 1972). During the present period, there also appears to have been a continuous reduction in the quantity of offshore sand in the area adjacent to the Warren. Whether the present stabilization event could have been offset by a flourishing rabbit population is open to debate, although the site appears to have undergone previous stabilization events even in the presence of a large rabbit population. However, to call these changes cyclic may be inappropriate. De Raeve (1989), for example, described changes towards stabilization on sand dunes as being unidirectional and that their condition was only returned to some earlier successional stage by some form of catastrophic event such as a major climatic or coastal geomorphological change. Given the dynamic history of dune systems like Newborough Warren are we ever justified in attempting to either retard or reverse the process of change? Such action has certainly been a general characteristic of past conservation management. When dunes were more mobile we attempted to stabilise them; now the emphasis is often more on de-stabilization. Furthermore, when dealing with a naturally changing system should any given point on the spectrum of change be regarded as optimal in terms of conservation value? It is our view that sand-dune conservation has to embrace the fact that flux is an integral component of the habitat, and that more emphasis should be devoted towards assessing the direction of the current trends, and on extending the time scales over which future management is considered. We fully sympathize with the growing belief that the emphasis should be on process management with the aim of enabling or promoting the natural dynamic evolution of sand dunes wherever possible, rather than attempting to manage the individual patches or sub-habitats within the system (See for example Grootjans et al. 1997). Unfortunately, many sites are now probably too small to maintain their own natural disturbance regimes, and may actually represent completely closed systems with regard to their geomorphological processes. It is therefore likely that some form of patch management will be necessary for the foreseeable future, especially where this is essential for the long term survival of certain dune species. It may also be necessary to cause a degree of internal destabilization with these systems by creating artificial blowouts or reactivating some of the now stabilized blowouts (van Boxel et al. 1997).

Fortunately, sand-dune conservation in the United Kingdom is now being further promoted by the British Government, as part of its commitment to the Convention on Biological Diversity endorsed at the Earth Summit in Rio de Janeiro 1992. Since the Summit, a Biodiversity Action Plan has been drawn up aimed at enhancing conservation and maintaining biodiversity in the UK (Anon. 1994), and this has spawned the production of a series habitat and species action plans (Biodiversity: Anon. 1995a, b). These mainly comprise rare and endangered habitats and species (referred to as key habitats and species) for which the UK has an international responsibility. This will eventually result in the production of a sand dune Habitat Action Plan tailored to the habitats current conservation requirements. Action plans are also being developed for various sand-dune key species (see App. 1) including *Liparis loeselii*, *Rumex rupestris* and *Petalophyllum ralfsii* (Anon. 1997).

According to the habitat statement for sand dunes (see Anon. 1995a,b) there will be a commitment to maintain the extent and enhance the habitat quality of sand dunes, and to ensure the continuation of the natural processes that give rise to new dune habitat.

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For App. 1, see pp. 40-42.

App. 1. Species records for sand dune communities in Wales which are considered to be rare, scarce or strongly associated with dune systems in Wales or species considered to be endemic to Britain or Europe. Full descriptions of the community codes SD4, SD5 etc. are given in Table 2.

OS = Obligate dune species or species strongly associated with sand dunes in Wales; NR = Nationally rare species; NS = Nationally scarce species; S8 = species protected under Schedule 8 of the Wildlife and Countryside Act; KS = species designated Key Species for biodiversity in the UK; RDB /E/B = Red Data Book species (E = European Red List, B = British Red List); BC = Species listed under Appendix I of the Bern Convention; EC (II) & EC(V) = species listed under Annex II or Annex V of the EC Habitat & Species Directive; BE = British Endemics; EE = European Endemics or near endemics; ER = European Endemics with restricted distribution; ¥= present in community.

Vascular plants	Status	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14	SD 15	SD 16	SD 17	SD 18	H 11
Ammophila arenaria	OS, EE	¥	¥	¥	¥	¥	¥	¥		¥			¥	¥		¥	¥
Anagallis tenella	ER					¥			¥		¥	¥	¥	¥	¥		
Anthriscus caucalis	EE				¥												
Anthyllis vulneraria	ER			¥	¥	¥	¥				¥		¥	¥			
Arum italicum	NS					¥											
Asperula cynanchica	EE			¥	¥	¥											
Atriplex laciniata	EE	¥		¥													
Cakile maritima	OS		¥	¥	¥												
Calluna vulgaris	EE					¥			¥	¥				¥			¥
Calystegia soldanella	OS, EE			¥	¥	¥	¥										
Carex arenaria	OS, ER		¥	¥	¥	¥	¥	¥	¥	¥	¥	¥	¥	¥	¥		¥
Carex pulicaris	EE													¥	¥		
Centaurea nigra	ER				¥	¥	¥			¥		¥	¥	¥	¥		
Centaurium erythraea	EE			¥	¥	¥	¥	¥	¥	¥	¥		¥	¥	¥		
Centaurium littorale	OS, NS					¥						¥	¥	¥	¥		
Cerastium diffusum	OS			¥	¥	¥		¥		¥			¥	¥			
Cerastium semidecandrum	OS			¥	¥	¥											
Cirsium dissectum	ER					¥											
Cochlearia danica	ER				¥												
Crithmum maritimum	EE			¥	¥	¥											
Daucus carota	ER			¥	¥	¥	¥								¥	¥	
Digitalis purpurea	ER				¥					¥							
Eleocharis multicaulis	EE														¥		
Elytrigia atherica	OS, EE	¥		¥	¥	¥	¥										
Elytrigia juncea	OS	¥	¥	¥	¥	¥		¥									
Epipactis leptochila var. *dunensis*	OS, RDB/B, BE				¥									¥			
Equisetum variegatum	OS, NS, EE				¥	¥		¥		¥	¥	¥	¥	¥	¥		
Erica cinerea	ER									¥							¥
Erica tetralix	ER									¥							¥
Eryngium maritimum	OS, EE	¥		¥	¥	¥											
Euphorbia paralias	OS, EE	¥		¥	¥		¥	¥									
Euphorbia portlandica	NS, EE			¥	¥	¥	¥	¥	¥								
Filago vulgaris	EE					¥											
Galium saxatile	EE					¥				¥							¥
Gentianella anglica	S8, NS, EC(II), KS					¥											
Gentianella uliginosa	OS, S8, RDB/B, ER											¥	¥				
Hedera helix	EE				¥	¥	¥									¥	¥
Hippophae rhamnoides	OS, NS, EE			¥												¥	
Honkenya peploides	OS	¥		¥	¥			¥									
Hornungia petraea	OS, NS, EE			¥	¥												
Hyacinthoides nonscripta	S8, ER				¥	¥								¥			¥
Hydrocotyle vulgaris	EE					¥					¥	¥	¥	¥	¥		¥
Hypericum pulchrum	EE					¥											
Hypericum tetrapterum	EE												¥	¥			
Hypericum undulatum	NS														¥		
Inula conyza	EE				¥	¥											
Iris foetidissima	EE				¥												
Juncus acutus	NS				¥	¥							¥	¥	¥		
Juncus capitatus	RDB										¥						¥
Leymus arenaria	OS		¥	¥	¥	¥	¥										
Limonium binervosum	ER				¥												
Liparis loeselii	OS, S8, EC (II), BC, EE, KS											¥					
Lotus uliginosus	EE					¥	¥					¥	¥	¥	¥		¥
Matthiola sinuata	OS, RDB/B, EE			¥	¥												
Mibora minima	OS, RDB/B, EE			¥	¥	¥											
Moenchia erecta	EE				¥												
Myosotis discolor	EE					¥											
Myosotis ramosissima	EE				¥	¥									¥		
Odontites verna	EE				¥	¥											
Oenanthe lachenalii	EE						¥					¥	¥	¥	¥		
Oenanthe pimpinelloides	EE				¥		¥										
Oenothera biennis	OS			¥	¥	¥	¥										
Oenothera cambrica	OS			¥	¥												
Oenothera erythrosepala	OS			¥	¥	¥	¥	¥			¥						
Oenothera fallax	OS			¥	¥												
Oenothera stricta	OS			¥													

App. 1, *cont.*

Vascular plants (*cont.*)	Status	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14	SD 15	SD 16	SD 17	SD 18	H 11
Ononis repens	EE			¥	¥	¥	¥	¥	¥	¥	¥		¥	¥			¥
Ononis spinosa	EE			¥	¥												
Ornithopus perpusillus	EE				¥	¥											¥
Pedicularis sylvatica	EE														¥		¥
Phleum arenarium	OS, EE			¥	¥	¥		¥									
Polygala vulgaris	EE				¥	¥	¥		¥	¥	¥	¥	¥	¥	¥		¥
Potentilla sterilis	EE					¥			¥								
Primula veris	EE					¥	¥										
Primula vulgaris	EE					¥											
Pyrola rotundifolia	OS, NS, EE				¥	¥					¥	¥	¥	¥			
Radiola linoides	EE									¥		¥	¥	¥			
Raphanus raphanistrum maritimum	EE			¥	¥	¥											
Rosa pimpinellifolia	EE			¥	¥	¥	¥	¥		¥						¥	¥
Rosa rubiginosa	EE				¥	¥											
Rubia peregrina	EE				¥	¥											
Rumex rupestris	S8, RDB/B, EC (II), BC, ER, KS										¥						
Sagina maritima	EE				¥												
Sagina nodosa	OS	¥			¥	¥					¥	¥	¥	¥	¥		
Samolus valerandi	EE											¥	¥	¥	¥		
Salsola kali	OS	¥		¥													
Scabiosa columbaria	EE				¥	¥				¥							
Scutellaria minor	ER												¥		¥		
Scilla verna	ER					¥											¥
Sedum anglicum	ER				¥	¥											¥
Selaginella selaginoides	EE											¥		¥			
Sherardia arvensis	EE				¥												
Silene conica	OS, RDB/B, EE					¥											
Spergularia marina	EE			¥													
Teesdalia nudicaulis	OS, EE					¥											
Teucrium scorodonia	EE				¥	¥	¥		¥	¥				¥		¥	¥
Thymus praecox ssp. *arcticus*	ER			¥	¥	¥	¥	¥	¥	¥			¥	¥	¥		¥
Trifolium micranthum	EE					¥											
Ulex europaeus	EE				¥	¥	¥			¥			¥	¥			¥
Ulex gallii	KS, EE																¥
Valerianella locusta	EE				¥	¥			¥								
Veronica polita	EE				¥												
Vicia lathyroides	EE			¥	¥	¥											
Viola tricolor ssp. *curtissii*	OS, EE			¥	¥	¥	¥	¥	¥	¥				¥		¥	
Vulpia fasciculata	OS, EE			¥	¥	¥		¥						¥			

Bryophytes	Status	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14	SD 15	SD 16	SD 17	SD 18	H 11
Amblyodon dealbatus	OS											¥	¥				
Barbula reflexa	OS											¥	¥	¥			
Bryum calophyllum	OS, RDB/E/B, KS										¥				¥		
Bryum knowltonii	OS, RDB/E/B										¥						
Bryum marrattii	OS, RDB/E/B										¥						
Bryum neodamense	OS, S8, RDB/E/B, KS										¥			¥			
Bryum uliginosum	OS, RDB/E/B, KS										¥						
Bryum warneum	OS, RDB/E/B, KS										¥	¥	¥				
Campylium polygamum	OS, NS							¥					¥				
Catoscopium nigritum	OS											¥					
Drepanocladus lycopodioides	OS, RDB/E											¥				¥	
Drepanocladus sendtneri	OS, RDB/E											¥	¥	¥			
Meesia uliginosa	OS											¥					
Petalophyllum ralfsii	OS, S8, RDB/E/B, EC (II), BC, KS										¥	¥		¥			
Pleurochaete squarrosa	OS										¥			¥			
Racomitrium canscens s.s	OS					¥	¥			¥							
Rhynchostegium megapolitanum	OS														¥		
Riccia cavernosa	OS										¥						
Southbya tophacea	RDB/B ?							¥					¥				
Thuidium abietinum	OS					¥						¥	¥				
Tortella inclinata	OS											¥	¥				
Tortula ruralis ssp. *ruraliformis*	OS			¥	¥	¥	¥							¥			¥

Fungi	Status	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14	SD 15	SD 16	SD 17	SD 18	H 11
Agaricus devoniensis	OS			¥	¥												
Agaricus xanthodermus var. *lepiotoides*	RDB/B												¥	¥			
Agrocybe arenaria	RDB/B												¥	¥			
Agrocybe subpediades	OS				¥												
Bovista limosa	RDB/E/B				¥												
Conocybe dunensis	OS			¥	¥	¥							¥		¥		
Coprinus ammophilae	OS, RDB/B			¥													
Cyathus stercoreus	RDB/E/B			¥													

App. 1, *cont*.

Vascular plants (*cont.*)	Status	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14	SD 15	SD 16	SD 17	SD 18	H 11
Galerina paludinella	RDB/B												¥		¥		
Geastrum elegans	RDB/E/B				¥												
Geastrum nanum	RDB/E/B				¥												
Geoglossum umbratila	RDB/E											¥	¥				
Hebeloma vaccinum	RDB/B														¥		
Hohenbuehelia culmicola	OS, RDB/B			¥	¥												
Hygrocybe conicoides	OS			¥								¥	¥				
Hygrocybe insipida	RDB/E														¥		
Hygrocybe nitrata	RDB/E										¥						
Hygrocybe ovina	RDB/E				¥												
Hygrocybe pumicea	RDB/E											¥					
Inocybe arenicola	RDB/B				¥								¥				
Inocybe vulpinella	RDB/B											¥	¥				
Leucoagaricus pilatianus	RDB/B				¥							¥					
Melanoleuca albifolia	RDB/B				¥												
Melanoleuca cinereifolia var. *maritima*	OS, RDB/B			¥													
Melanoleuca leucophylla	RDB/B				¥												
Melanoleuca schumacheri	RDB/B										¥	¥	¥	¥	¥		
Melanoleuca subpulverulenta	RDB/B												¥				
Omphalina mutila	RDB/E				¥							¥					
Peziza ammophila	OS			¥													
Phallus hadriani	OS			¥													
Psathyrella ammophila	OS			¥													
Russula persicina	RDB/B												¥		¥		
Trichoglossum hirsutum	RDB/E				¥								¥				
Trichoglossum rasum	RDB/B											¥	¥				
Tulostoma brumale	RDB/E				¥												
Verpa conica	RDB/E											¥	¥				

Lichens	Status	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14	SD 15	SD 16	SD 17	SD 18	H 11
Cladonia ciliata	EC (V)					¥											¥
Cladonia portentosa	EC (V)				¥	¥				¥							¥
Fulgensia fulgens	KS					¥											
Teloschistes flavicans	S8, RDB/E/B, KS																¥

Other notable species recorded on sand dunes in Wales but which cannot be assigned at this stage to particular NVC-communities include:

Vascular plants		
Aconitum napellus	NS	Dune grasslands
Asparagus officinalis ssp. *prostratus*	RDB/B	Dune grasslands
Asperula cynanchica ssp. *oxidentalis*	OS, EE	Dune grasslands
Carex punctata	NS	Dune slacks
Coincya monensis ssp. *monensis*	RDB/B	Sandy ground
Cynodon dactylon	RDB/B, EE	Dune grasslands
Dactylorhiza incarnata ssp. *coccinea*	BE	Dune slacks
Dactylorhiza majalis ssp. *cambrensis*	BE	Dune slacks
Dianthus armeria	S8	Dune grassland
Dianthus deltoides	NS	Dune grassland
Epipactis phyllanthes	NS, ER	Dune grassland
Erodium moschatum	NS	Bare areas in dune grassland
Euphorbia peplis	Extinct	Sandy areas
Euphrasia ostenfeldii	NS	Sandy areas
Festuca arenaria	NS, EE	Mobile dunes
Mentha pulegium	S8, EE	Dune slacks
Monotropa hypopitys	EE	Dune slacks
Ophioglossum azoricum	ER	Dune slacks
Orobanche hederae	NS	Dunes with *Hedera helix*
Orobanche purpurea	RDB/B	Dunes with *Achillea millefolium*
Orobanche rapum-genistae	NS	Dunes with legumes
Otanthus maritimus	Extinct in Britain, EE	Dune grasslands
Parapholis incurva	NS, EE	Dune grasslands
Ranunculus tripartitus	NS, EE, KS	Dune slacks

Bryophytes		
Barbula acuta	NS	Dune slacks
Brachythecium salebrosum	NS	Dune grasslands
Bryum canariense	NS	Dune grasslands
Campylium elodes	OS, RDB/E	Dune slacks
Distichium inclinatum	NS	Dune slacks
Racomitrium elongatum	NS	Dune slacks
Riccia crystallina	NR	Dune slacks