

Coastal dunes of Wales; vulnerability and protection

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Abstract. The coastal dune systems of Wales fall under a range of conservation designations from Sites of Special Scientific Interest to National Parks. A checklist system has been applied to selected major systems (> 50 ha) to assess the vulnerability of individual sites and to measure of the level of protection introduced at these locations and to compare this with their conservation status. 26 systems were surveyed and analysis consisted of structured use of a rating scheme to assess the environmental condition and range of protection measures existing at each site. This included the following categories of information: Site and beach morphology, Beach condition, Surface character of the seaward 200 m of the dune system, Pressure of use and Recent protection measures. The percentage of the maximum possible rating for each category of information was calculated and summation of the above information gives a Vulnerability Index (VI) which ranged from 23.8% to 65.1%. A Protection Measure Index (PM) was also calculated and this ranged from 13.6% to 68.2%. It should be noted however, that low PM scores do not necessarily mean inappropriate management strategies. A VI/PM ratio was calculated and systems with a ratio in the range of 0.8 -1.3 are regarded as having an equilibrium relationship between vulnerability and protection; sites with values < 0.8 are out of equilibrium because they are highly protected and those with a ratio of > 1.3 are out of equilibrium because they are under protected. An alternative, descriptive categorization of the vulnerability relationship was also derived from the data and dune systems were categorised as 1. Low vulnerability - Low response, 2. High vulnerability - High response, 3. Low vulnerability - High response or 4. High vulnerability - Low response.

The structured checklist approach improves the levels of objectivity in dune vulnerability measurement and it can provide a useful basis for pro-active management of these coastal environments. Overall, Welsh sand dune systems seem to have achieved a level of protection which matches the level of vulnerability identified by the objective measures of the checklist survey. There appears to be little difference between the level of vulnerability/protection and the type, or number, of conservation designations at the dune site.

Keywords: Checklist; Conservation.

Abbreviations: PM = Protection Measure Index; VI = Vulnerability Index; see further Table 1.

Introduction

The Welsh coastline supports a wealth of habitats and only ca. 30% does not qualify for some form of protection or conservation designation (Smith et al. 1995). Excluding afforested areas, the surviving Welsh sand dunes represent some 12% of the total dune area to be found in Great Britain covering an area of some 6406 ha (Doody 1985). Ca. 83% of the UK dune area is protected under UK legislation because of biological interest. In the context of the European Union 3060 ha of the Welsh dunes qualify for Special Areas of Conservation (SAC) status and seven systems in Wales are proposed for this classification (Table 1). All the investigated dune systems are under some form of designated conservation and in most cases there is multiple classification for individual sites (Table 1), though this degree of designation can be excessive and unnecessary (Ritchie 2001).

In the past there has been a piecemeal and reactive approach to dune management and many have been destroyed or damaged through afforestation policies, intensive recreational usage or development (Houston 1992). In contrast, traditional grazing practices have helped create much of the existing diversity in British dune systems (Boorman 1989). Actions which ensure permanent stability, particularly through fixed vegetation, are counterproductive to the natural needs of dune systems which require a mobile, changing and responsive environment (Ritchie 2001). Unfortunately, in this context, most of the Welsh dune systems are fixed dunes with herbaceous vegetation.

Clearly, the potential for successful management will be limited by fragmentation of ownership and regulatory frameworks (Ritchie 2001). Welsh dunes have a range of management objectives applied to them and are under a variety of ownership and administrative structures. The Countryside Council for Wales, Local Authorities, National Trust, National Parks, Ministry of Defence and private owners all contribute to dune management (Davies 2001). Consequently, attainment of pro-active

Table 1. Conservation designations of selected major (> 50 ha) sand dune systems in Wales.

Site	Sand dune survey area*(ha)	Unitary authority	SSSI	NNR	pSAC	LNR	AONB	HER	NP
Methyr Mawr	342	Bridgend	x	proposed	x			x	
Kenfig Dunes	602	Bridgend	x	x	x				
Crymlin /Baglan	118	Swansea	x						
Pennard Burrows	87	Swansea	x				x	x	
Oxwich Burrows	93	Swansea	x	x			x	x	
Hillend/Broughton	225	Swansea	x				x	x	
Whiteford Burrows	142	Swansea	x	x	x		x	x	
Pembrey Coast	591	Carmarthenshire	x						
Laugharne / Pendine	603	Carmarthenshire	x						
Tenby Burrows	92	Pembrokeshire	x					x	x
Stackpole /Linney / Brownslade	432	Pembrokeshire	x	part				x	x
Broomhill Burrows	183	Pembrokeshire	x					x	x
Towyn Warren	30	Ceredigion	x						x
Ynyslas	68	Ceredigion	x	x					
Tywyn	111	Gwynedd	x						x
Morfa Dyffryn	313	Gwynedd	x	x	x				x
Morfa Harlech	341	Gwynedd	x	x	x				x
Morfa Bychan	169	Gwynedd	x			x			
Morfa Dinlle	66.6	Gwynedd	x						
Traeth Crugan	23	Gwynedd					x	x	
Newborough Warren	529	Ynys Mon	x	x	x		x		
Penrhynoedd	25	Ynys Mon	x						
Aberffraw	248	Ynys Mon	x		x		x		
Conway/Prestatyn	120	Flintshire	x						

* Based on Dargie (1995).

Abbreviations: AONB = Area of outstanding natural beauty; HER = Heritage coast; LNR = Local nature reserve; NNR = National nature reserve; NP = National park; pSA = proposed Special area of conservation; SSSI = Site of special scientific interest.

rather than reactive management can be problematic in such a fragmented framework and simplified management structures are preferable. Further, management based on scientific, conservation and sustainable principles remains rare for dune systems (Ritchie 2001).

If environmental problems are to be solved, management policies should be based on objective and balanced scientific assessment of the environment, with a sound data base integrating information from natural and human systems (Williams et al. 1993). To address this issue a Dune Vulnerability checklist was devised to provide a database capable of being used as a management aid. It is an objective procedure that summarises the condition of a system and is able to identify changes initiated in the past and those induced by contemporary environmental factors. The data can form a useful aid for the development of dune management objectives and strategies aimed at dynamic conservation and sustainable use of the system. This assessment procedure was applied to selected Welsh dune systems with the objective of identifying systems showing an equilibrium, or otherwise, between vulnerability and the level of protection. In addition, an attempt was made to establish whether there was any relationship between vulnerability / protection and the type of conservation designation allocated to the system.

Methodology

Checklists are common in many scientific disciplines e.g. Leopold (1969) and have been applied by the authors and associates to dune systems e.g. Williams et al. (1993), Matias et al. (1998). Additionally, Partridge (int. report 1994) attempted to use dune vegetation as an indicator of dune erosion vulnerability. A series of papers developed the methodological approach utilised in this paper (e.g. Bodéré et al. 1991; Williams et al. 1993; Davies et al. 1995), and this was applied to selected major (> 50 ha) coastal dune systems in Wales. The checklist procedure is a structured approach to assessment of dune conditions, which can be used both spatially and temporally (Williams et al. 1993).

The condition of the system is assessed by utilizing a 0 - 4 scaling procedure for each of 54 parameters. Full details of the checklist used can be found in Davies et al. (1995). The parameters are arranged into five sections: **A.** Site and dune morphology (8 parameters), **B.** Beach condition (9), **C.** Surface character of the seaward 200 m (12), **D.** Pressure of use (14) and **E.** Protection measures (11).

Percentage scores for the ratings in each section are

Table 2. Summary results of checklist surveys of selected Welsh dune systems > 50 ha. See text for definitions of categories.

Site	A %	B %	C %	D %	VI %	PM %	VI/PM
Merthyr Mawr	50	27.8	45.8	32.1	38.4	43.2	0.88
Kenfig Dunes	34.4	75	35.4	28.6	41.3	59.1	0.69
Crymlin	62.5	36.1	47.9	7.1	34.9	40.9	0.85
Baglan	56.3	33.3	47.9	28.6	40.1	59.1	0.68
Pennard Burrows	53.1	47.2	41.7	35.7	42.5	52.3	0.81
Oxwich Burrows	59.4	19.4	37.5	28.6	34.9	54.5	0.64
Hillend	59.4	58.3	64.6	53.6	58.7	56.8	1.03
Broughton	59.4	47.2	31.3	39.3	42.4	37.8	1.33
Whiteford Burrows	46.9	25	45.8	17.9	32.6	31.8	1.02
Pembrey Coast	75	27.8	18.8	7.1	27.3	38.6	0.70
Laugharne	56.3	36.1	39.6	18.6	34.5	36.4	0.95
Pendine	56.3	27.8	33.3	14.3	30.2	36.4	0.83
Tenby Burrows	71.8	44.4	35.4	40.1	42.5	43.2	0.98
Brownslade	56.3	33.3	47.9	17.9	36.6	31.8	1.15
Stackpole	56.3	38.9	52.1	17.9	38.9	29.5	1.31
Freshwater West	62.5	44.4	54.2	46.4	51.2	34.1	1.5
Ynys Las	68.8	52.8	79.2	32.1	56.4	61.4	0.92
Tywyn	43.8	50	20.8	17.9	29.9	40.9	0.7
Morfa Dyffryn	59.4	69.4	75	57.1	65.1	40.9	1.59
Morfa Harlech	46.9	16.7	20.8	17.9	23.8	54.5	0.43
Morfa Bychan	53.1	50	35.4	53.6	47.1	13.6	3.5
Morfa Dinlle	56.6	57.8	45.8	25	42	38.6	1.1
Traeth Crugan	84.4	50	25	25	41.3	50	0.82
Newborough Warren	31.3	38.9	33.3	25	31.4	53.6	0.58
Conway	68.8	63.9	33.3	25	43.1	68.2	0.63
Prestatyn	53.1	38.9	45.8	42.9	44.8	50	0.89

calculated and summation of the scores in sections A-D gives a measure of the overall environmental characteristics of the system coupled with the effects of visitor pressure, this is termed the site Vulnerability Index (VI). The percentage score for the remaining 11 parameters (E) provides an overall indication of the extent of specific procedures applied to the system and is referred to as the index of Protection Measures (PM). Protection in this context being defined as procedures aimed at countering the processes causing loss of diversity within the dune system and which threaten the existence of the system itself. A VI/PM ratio can be obtained to describe the equilibrium relationship at the site. The data can be presented in tabular (Table 2) or graphical (Figs. 2 and 3) form. Systems in equilibrium tend to have a VI/PM ratio between 0.8 and 1.3; systems out of equilibrium either have a ratio of < 0.8 (described as positive) or > 1.3 (described as negative). These indices allow managers to assess changes at a site through time or to compare dune sites on a regional scale.

A simple descriptive classification is also possible where systems in equilibrium are either Low vulnerability - Low response (Category 1) or High vulnerability - High response (2). Out of equilibrium, positive dune systems are those sites described as being Low vulnerability - High response (3) and are highly protected sites. Out of equilibrium, negative systems are those described as being High vulnerability - Low response (4); they are

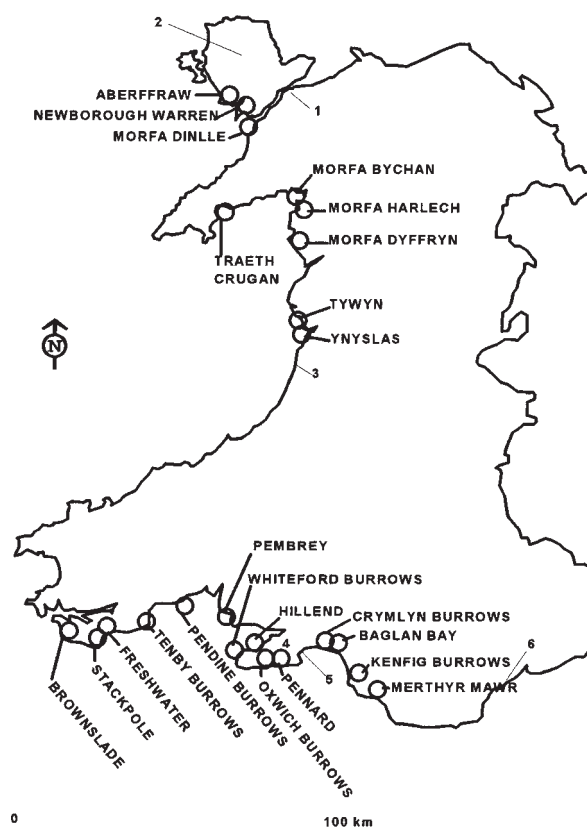


Fig. 1. Location of selected major dune systems (> 50 ha) in Wales. Dune sites: 1. Bangor; 2. Anglesey; 3. Aberystwyth; 4. Gower Peninsula; 5. Swansea; 6. Cardiff.

clearly the most problematic sites with regard to conservation.

26 individual systems in Wales (Fig. 1) were surveyed by the authors between 1998 and 1999 (Table 2) and of these eight representative systems are described more fully to demonstrate the range of possible relationships between the level of vulnerability and the protection measure responses.

Results and Discussion

A. Systems in equilibrium

VI/PM Ratio: 0.8 - 1.3 (Table 2; Figs. 2 and 3).

Descriptive categories: 1 (Low vulnerability - Low response), 2 (High vulnerability - High response).

1. Merthyr Mawr

VI/PM Ratio: 0.88

Descriptive category: 1 (Low Vulnerability - Low response).

Conservation designations: pSAC, proposed NNR, SSSI, HC.

Manager: Countryside Council for Wales.

This system is the most easterly surviving remnant of the once extensive South Wales dune system and covers 341 ha. It has a rock base and dune sands abut against a limestone scarp to a height of ca. 60 m. The dunes are very stable and the area was declared an SSSI in 1953 and now form the western edge of the Glamorgan Heritage Coast. There is evidence that sand accumulation began around 6000 years ago and that there have been periodic changes in the degree of sand influx and stabilization with vegetation. The 15th and 16th centuries in particular have evidence of sand encroachment (Higgins 1933). Further storm periods have seen active sand movement, even into the village of Merthyr Mawr, and in the early 19th century fir plantations were being established west of the settlement at Candleston. In 1840, sea buckthorn (*Hippophae rhamnoides*) was introduced to combat erosion and sand stabilization was achieved in the 1920s. Over the past 40 years, the lack of rabbits due to the spread of myxomatosis has led to expansion of vegetation and dune stabilization. Sites of several foredune blow-outs can still be identified resulting from large-scale sand and gravel extraction, which ceased in the early 1970s. (Williams & Randerson 1989; Williams et al. 1997). Some 1.5 million people live within 2 hours drive of the system but it experiences a comparatively low visitor pressure (32.1%) reflecting the poor road access and the long and difficult walk to the beach through the dune system. Most visitors stay within 250 m of the car park and trampling of this

zone has denuded an area of vegetation. The introduced species, sea buckthorn, has now become a major management problem and is spreading at a rate of ca. 2 ha per year. Trials are currently in progress to test the effectiveness of removing sections of buckthorn using earth moving machines. Pro-active management is needed as the dense buckthorn sward precludes small species regeneration. Although a number of management objectives have been identified for the system to maintain/enhance landscape quality and the range of sand dune habitats/species, to maintain woodland and to encourage appropriate recreational, educational and research activities, little active management *per se* exists. Designation as an NNR could result in the establishment of a more pro-active strategic plan for the system. Whilst the site is not out of equilibrium there are still some environmental problems which remain to be solved.

2. Whiteford Burrows

VI/PM Ratio: 1.02

Descriptive category: 2 (High vulnerability - High response)

Conservation designations: pSAC, AONB, NNR, SSSI, HC.

Managers: Countryside Council for Wales, National Trust.

This system covers ca. 142 ha on the Gower Peninsula in South Wales and is a National Trust property. It was declared an NNR in 1969 (Osborne 1987). Davis (1879) showed that the dunes were in existence in 1661 when tenants were involved in stabilization measures. All major dune forms, i.e. grey, yellow, heath and foredune, can be found in this hindshore system, with the highest dunes reaching 24 m. Ca. 20 ha were afforested with pine plantations between 1955-1964 although most of these trees have now been removed. Grazing by ponies and sheep still occurs. Tourism pressure is light as the area is remote and access is not easy, which is reflected by the checklist low pressure of use index of 17.9%. A range of management objectives have been identified for this site with emphasis on preservation of a range of dune landscape quality and habitats, birds, education and research and controlling visitor access to preserve the nature conservation objectives. The strategy is successful.

3. Ynyslas

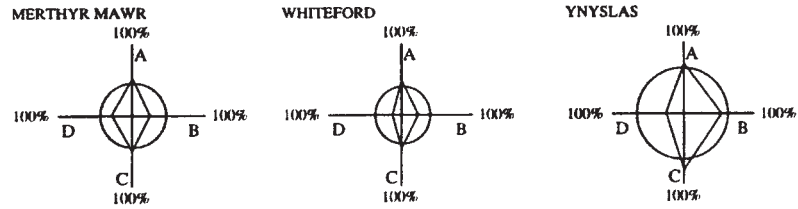
VI/PM Ratio: 0.92, Descriptive Category: 1 (Low Vulnerability - Low response)

Conservation designations: NNR, SSSI.

Manager: Countryside Council for Wales.

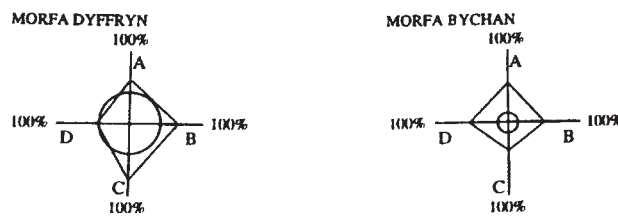
VULNERABILITY AND PROTECTION AT SELECTED SITES

1. IN EQUILIBRIUM

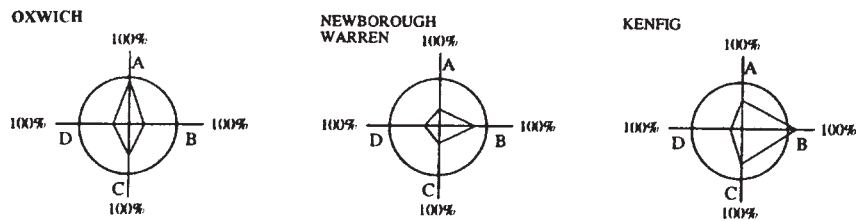


2. OUT OF EQUILIBRIUM

i. LOW PROTECTION - HIGH VULNERABILITY



ii. HIGH PROTECTION - LOW VULNERABILITY



KEY	
AXIS A	SITE AND DUNE MORPHOLOGY
AXIS B	CONDITION OF THE BEACH
AXIS C	SURFACE CHARACTERISTICS OF SEAWARD 200M
AXIS D	PRESSURE OF USE
CIRCLE	RECENT PROTECTION MEASURES

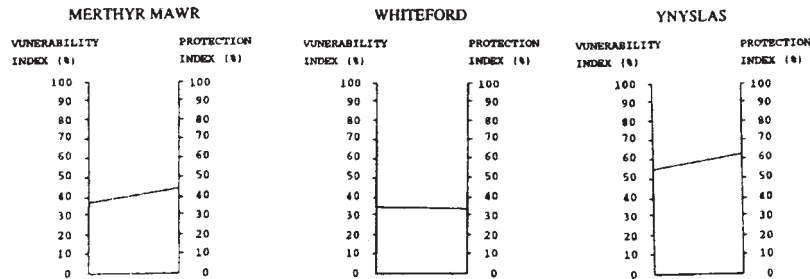
Fig. 2. Vulnerability and protection at selected sites.

This forms part of the Dyfi NNR and covers ca. 68 ha. As at Merthyr Mawr, the growth of the dunes is probably related to the large-scale storms that existed in Europe between the 12th and 16th centuries. The system was grazed but the arrival of the railway in the middle of the 19th century created an influx of visitors. Following World War 2 there was a large increase in the number of visitors (currently > 250 000/yr) which caused pressure of use problems with system deterioration and many blow-outs occurring. This system had the highest value for the surface character of the seaward 200 m zone (79.2%),

indicating a high level of vulnerability in this sector. However, a number of management strategies have been implemented to counter this problem including boardwalks, leaflets and signs and the large visitor numbers and a relatively low pressure of use index (32.1%) now exists. Overgrazing by rabbits still occurs and rabbits are culled most years. In general terms, the site can be regarded as being in equilibrium since the protection index of 61.4% is close to the overall level of vulnerability index of 56.4%.

VULNERABILITY AND PROTECTION INDICES AT SELECTED SITES.

1. IN EQUILIBRIUM



2. OUT OF EQUILIBRIUM

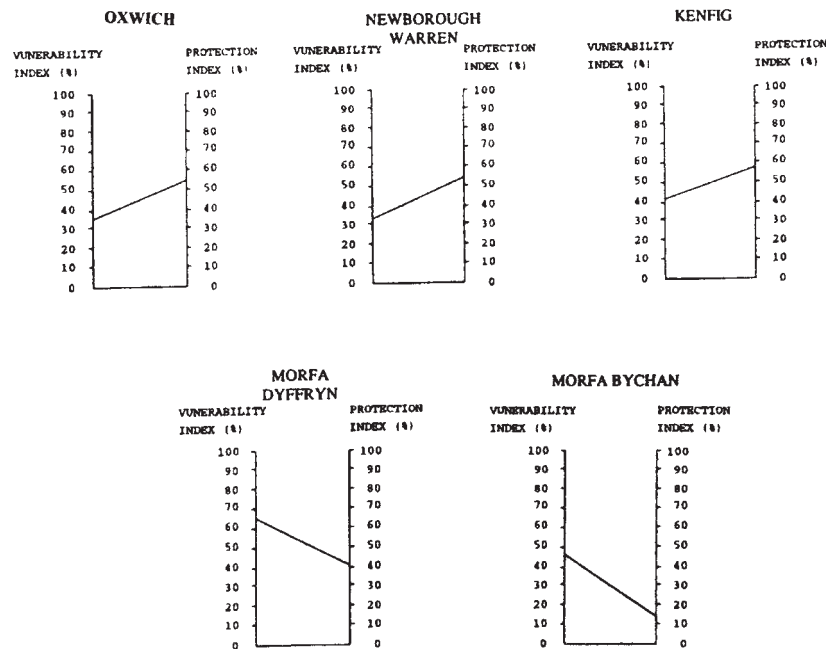


Fig. 3. Vulnerability and Protection Indices at selected sites.

B. Systems out of equilibrium: 'Positive'

VI/PM < 0.8 (Table 2; Figs. 2 and 3).

Descriptive category 3 (Low vulnerability - High response).

1. Oxwich Burrows

VI/PM Ratio: 0.64

Conservation designations: NNR, AONB, SSSI, HC.
 Manager: Countryside Council for Wales.

This dune system (76.2 ha) lies within the boundaries of the Gower Heritage Coast and forms part of the 300 ha Oxwich National Nature Reserve established in 1963. The

dune sand is rich in calcium carbonate and > 300 different flowering species have been recorded (Oxwich Information Sheet, Anon. 1983). The post-Pleistocene sea level rise reworked sand deposits and pushed them shoreward to form a dune system, which developed as a series of parallel waves of sand increasing in height landward. The dunes had assumed their current form by Medieval times. Weather conditions during the 12th to 16th centuries were very stormy (Davies & Williams 1991) and probably caused major blowouts in the system. In the Middle Ages, grazing was common. Military exercises during World War 2 seriously damaged the dune vegetation, which did not recover until the mid 1960s. Management during this period consisted of sand traps, fencing, signs and patrolling (Hughes 1992),

by 1981 stabilization of the frontal dunes had been achieved. Management objectives were dune stability, encouraging diversity and allowing access for recreation (Anon. 1992). The present objectives are maintenance of the sand dune habitats and species populations, encouragement of appropriate recreational and educational uses of the environment. Currently, the dunes exhibit a loss of diversity through over-fixation, partly indicated by a checklist score of 37.5% for the surface character of the first 200 m of dune. The exceptions are where human pressure have maintained a short turf and open sand patches. This loss of habitat diversity has led to an expansion of the policy of limited access within the foredunes rather than exclusion from such areas. Mowing of bracken, goat grazing to control invasive birch and alder in dune slacks, pony grazing and the use of machinery to scrape away vegetation are all current management activities. The area attracts > 300000 tourists per year but has a low Visitor Index (28.6%) and a low Vulnerability Index of 34.9%. Most visitors come for beach activities and a large car park, very close to the beach, accommodates this requirement. The reserve has no highly fragile species requiring intense protection and the public respond well to exclusion zones in specific dune areas through the use of information boards and wardens. The site protection index of 54.5% shows that it is possible to integrate a high standard of visitor facilities without loss of significant conservation interests.

2. Newborough Warren

VI/PM Ratio: 0.58

Conservation designations: pSAC, AONB, NNR, SSSI
Managers: Countryside Council for Wales, Forest Enterprise.

This is the sixth largest system in Britain (1257 ha) and dune development seems to have commenced in the 14th century. Ranwell (1959) and Owen (1953) quote "About one third of the land of the manor was damaged by storm so thoroughly by the sea and inflow of sand as to render it useless for agriculture evermore". Marram grass was used in the 16th century to stabilise the system but the dunes were still mobile during the 19th century when Tutein-Nolthenius (1890) indicated that the whole mass of sand was moving. The spread was the result of wind driven sand moving in a landward direction rather than shoreline pro-gradation. The area was designated an NNR in 1955. Ca. 720 ha of the western edge of the system were planted with conifers between 1947-65. At present the management objectives are to maintain or enhance the sand dune habitats and species allowing natural geomorphological processes to operate. This

system can accommodate large numbers of users due to its large size and effective management policy. The combination of controlled car parking, information boards, signing, limitation of access points and low promotion results in the reserve having a low pressure of use score (25%). Over fixation of the sand, scrub encroachment and encroachment of Corsican pine (*Pinus nigra* var. *calabrica*) are problems which have been exacerbated by the demise of the rabbit population through myxomatosis. Currently one third of the system is grazed by sheep, cattle and ponies and scrub cutting and spraying is common. However, the level of protection (53.6%) far exceeds the existing vulnerability of the site (31.4%). It is likely that existing management objectives and procedures coupled with continuous monitoring will ensure that any increased vulnerability is kept within the parameters of the protection needed.

3. Kenfig Dunes

VI/PM Ratio: 0.69

Conservation designations: pSAC, NNR, SSSI.
Managers: Local Authority, Countryside Council for Wales.

This is the largest hindshore dune system in South Wales and covers ca. 628 ha. It was designated an SSSI in 1954 and an NNR in 1989. The site has the highest checklist score for beach condition (75 %) indicating a shortage of sand supply with a shingle ridge backing an eroding foredune cliff. The area comprises of dune ridges separated by slacks, the foredunes are separated from the rest of the system by a road constructed in the 1960s during extension of the Port Talbot dock system. The site comprises mainly of fixed dunes but each of these extensive units appears to be unique due to differences in local geomorphology, hydrology or successional stage. Ca. 600 species of dune flowering plants and ferns occurs in this system comprising 45 % of the entire British species list; 95 % of the British population of the fen orchid (*Liparis loeselii*) is found here. Man has inhabited the site for at least 4000 years (Jones 1995). The storms so prevalent in Europe in the 12th to 16th centuries caused sand encroachment and by 1607 the old town of Kenfig was completely buried by sand. However, vegetation on the dunes gradually re-established and the area was used for stock grazing. A number of management objectives have been identified for this system ranging from maintenance/enhancement of the sand dune habitats and species to accommodation of visitors for education and recreation without threatening conservation of the system. During the 1970s 250 000 visitors enjoyed the system each year and off-road motorcycle use was a major problem (Jones 1995). In 2000

about the same number of visitors were recorded and the motorcycle problem has diminished to a weather (sunny) and day (weekend) dependent frequency. The system has a low pressure of use (28.6%), well within the confines of the protection level (59.1%). This has been aided by judicious location of the car park at the landward edge of the system. Most people do not walk far from their cars and those that do are dispersed throughout the system as a whole though the northern segment is little visited. The main problem at Kenfig is the limited amount of bare sand and over fixation which has reduced habitat and species diversity, which in some areas is still decreasing. Lack of a significant sand input from the beach and erosion of the foredunes (> 1 m per year) compounds this issue. Management is needed to try to restore the system to its formerly active nature. Grazing will help curtail scrub encroachment but the landowners ban fencing. This is unfortunate because a system of targeted grazing could help alleviate the problem particularly as the present rabbit population is small.

C. Systems Out of Equilibrium: 'Negative'

VI/PM > 1.3 (Table 2, Figs. 2 and 3)

Descriptive category 4, (High vulnerability - Low response).

1. Morfa Dyffryn

VI/PM Ratio: 1.59

Conservation designation: pSAC, NP, NNR, SSSI.

Manager: Countryside Council for Wales.

This system is situated within Snowdonia National Park and covers an area of 313 ha. The whole area has extensive mobile dunes encompassing a range of calcareous sand dune habitats although foredune systems are poorly represented (Morfa Dyffryn Management Plan, Anon. 1991). It was declared an SSSI in 1953 and in 1992 the greater part (220 ha) was declared an NNR. Large amounts of seral change are taking place, verified by the fact that the site had the second highest recorded value for the surface character of the seaward 200 m of dune (75%). Little is known regarding past land usage but it was subject to enclosure by an 1806 Act when the area was incorporated into the Gors-y-Gedol estate, since then low level grazing has been the main use. In 1867 a railway line was built giving tourists easy access to the system, this is demonstrated by the fact that it has the highest recorded pressure of use index. This has been especially noticeable around the access points where the dunes have become de-stabilised and are now subject to considerable restoration works e.g. board walks and fencing. The Protection Index of 40.9% does not compensate fully for the level of Vulnerability (65.1%).

2. Morfa Bychan

VI/PM Ratio: 3.5

Conservation designations: LNR, SSSI.

Managers: National Trust, Estate Trustees, Golf Course.

These sand dunes, located on the Lleyn Peninsula, cover ca. 169 ha and were designated an SSSI in 1957. The dune system, unlike others on the north and west coastline of Wales, is pro-grading rather than eroding and virtually all stages of dune succession can be found, with the fixed dune being the largest in area. This system has long been grazed and parts have been used for growing potatoes (Garland 1993). Grazing is now confined to the Nature Reserve section of the dunes (18 ha) where the stocking density is low (1.77 cattle/ha) although Oosterveld (1985) commented that a density of 1/ha in fixed dune grassland is excessive where the prime objective is nature conservation. Photographic evidence collected since 1958 shows extensive scrub growth occurring at the rear of the system, which could proliferate and cause problems by shading out the smaller dune species. The high recreation index of 53.6% reflects a large number of visitors and associated caravan parks and the presence of a golf course. These are affecting conservation interests and motorcycling and horse riding further exacerbate the problem. This pressure is not addressed by the small protection level offered (13.6%). Analysis clearly suggests that this is a vulnerable system, a condition exacerbated by the existence of a recently installed access ramp on the beach. This is affecting the sand budget by acting as a groyne which reduces sand accretion for the beach/dune system. The location as a whole is not well managed and Morfa Bychan is one of the few Welsh dune systems where no specific management objectives have been identified (Davies 2001). It appears that only the reserve area is directly managed.

Conclusions

Results of the checklist survey suggest:

1. There is a good correspondence between the level of vulnerability and protection measures introduced at the majority of the coastal dune systems of Wales.

2. No regional contrasts could be found between dune vulnerability and protection within the surveyed dune systems.

3. No significant difference seemed to exist between the type of conservation designation, the nature of the manager and level of vulnerability/protection afforded to the dune system. It appears that, within a country of this small size, the frequency of officer meetings, discussion and negotiation operates successfully to share expertise and strategies to resolve most dune conservation problems.

4. Some sites still give cause for concern, e.g. Morfa Bychan is an SSSI and LNR yet further responses are required by the site managers so that the level of protection more closely matches the level of vulnerability identified by the survey. As yet this system has no clearly identified management objectives and suffers from fragmented ownership and administration.

5. Results of the checklist analysis suggest that this approach to environmental assessment could be applied to larger national surveys with a high level of confidence. This particularly applies to objective measures of temporal change within dune systems in a regional/spatial context.

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