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Comparison of two checklist methods for assessment of coastal dune vulnerability

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ABSTRACT

Several northwest and southern European coastal dune systems, including Portuguese case-studies, have been selected, as part of the ELOISE-Dunes Project, to assess the applicability of a checklist method to evaluate and monitor coastal dunes' vulnerability. Parameters such as site and dune morphology, beach condition, surface character of the seaward 200 m of the dune, pressure of use and recent protection measures make good regional comparison of dune systems possible, but provide insufficient information for dune management at the local scale. Therefore, an alternative checklist method was developed. Selected biophysical vulnerability components were selected, including dune erosion, sand input, sand retention by vegetation, and degradation by use, together with dune management and conservation. Variables are characterised and ordered in relation to three vulnerability levels, taking into account the system's level of degradation and the necessity for implementation of management measures. The dunes' tourist attraction and the existence of obstacles to dune transgression are also assessed. Application of the two checklists to the foredune system at Mira, located on the western coast of Portugal, enabled us to compare the two methods. The former checklist's method is basically descriptive, and led to the general conclusion that a higher level of management was needed, taking into account the system's vulnerability. The alternative checklist method makes it possible to easily interpret the system's dynamics and directly identify both the system's highly vulnerable components and appropriate management measures.

Key words: Checklist, dune, management, vulnerability.

RESUMEN

Comparación de dos métodos de lista de control para la evaluación de la vulnerabilidad de las dunas litorales

Diversos sistemas dunares litorales del noroeste y del sur europeos, incluyendo casos portugueses estudiados, han sido seleccionados en el ámbito del Proyecto ELOISE-Dunes para determinar la aplicabilidad de una lista de control a la evaluación y seguimiento de la vulnerabilidad de las dunas litorales. Parámetros como la situación y la morfología dunar, la condición de la playa, las características de la duna en los primeros 200 m, la presión del uso y las recientes medidas de protección permiten una buena comparación regional de los sistemas dunares, pero la información que proporcionan es insuficiente para la gestión de las dunas a escala local. Teniendo en cuenta tal conclusión, se desarrolló una lista de control alternativa. Las componentes de la vulnerabilidad biofísica seleccionadas incluyen la erosión de las dunas, el aporte de arena, la retención de la arena por la vegetación, la degradación por el uso y la gestión y conservación de la duna. Las variables son caracterizadas y ordenadas en relación a tres niveles de vulnerabilidad, teniendo en cuenta el estado de degradación del sistema y la necesidad de implementar medidas de gestión. También han sido evaluadas la influencia de la atracción turística de las dunas y de la presencia de obstáculos a la transgresión

de la arena sobre la vulnerabilidad del sistema. La aplicación de las dos listas de control a las dunas de Mira, localizadas en el litoral occidental portugués, ha permitido comparar los dos métodos. La primera lista de control, muy descriptiva, ha hecho posibles unas conclusiones generales sobre la necesidad de un nivel más elevado de gestión, teniendo en cuenta la vulnerabilidad del sistema. La lista de control alternativa ha permitido interpretar fácilmente la dinámica del sistema e identificar directamente las componentes de mayor vulnerabilidad y las medidas de gestión a tomar.

Palabras clave: *Lista de control, duna, gestión, vulnerabilidad.*

INTRODUCTION

Several researchers from the UK, France, Spain and Portugal collaborated on the EU-sponsored ELOISE-Dunes Project, whose objective was to develop a checklist method to provide managers with a tool for gathering and systematising, in an easy and comparable manner, necessary data regarding

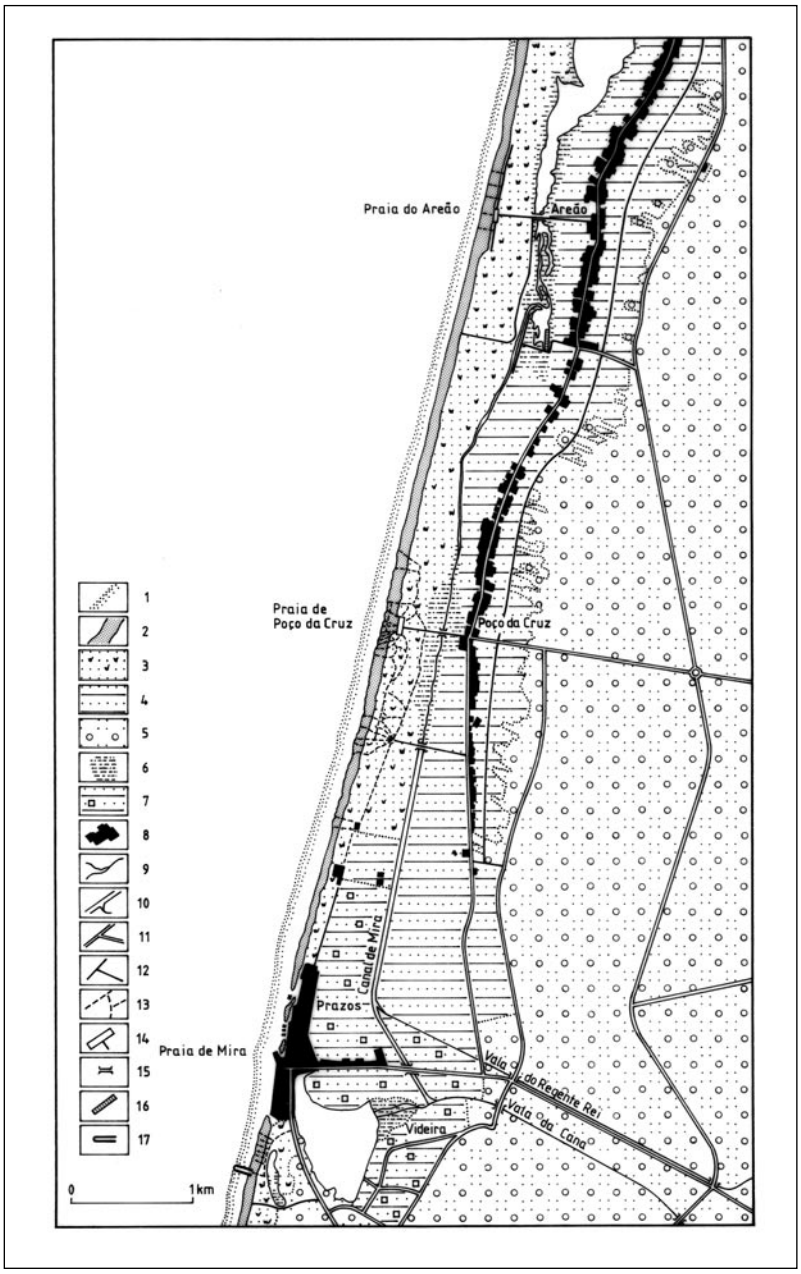

Figure 1. Mira´s study area. Legend: (1): beach; (2): foredune; (3): brushwood (aeolian sand); (4): agriculture (aeolian sand); (5): forested dune field; (6): salt marsh; (7): rural area (aeolian sand); (8): urban area (aeolian sand), (9): lagoon and river; (1): artificial banks; (11): main road; (12): secondary road; (13): path; (14): dock; (15): bridge; (16): parking lot; (17): jetty

coastal dunes' vulnerability and effective dune management. Although each coastal dune system presents a specific combination of problems, phenomena such as wind erosion, wave erosion, deficient sand input, vegetation damage and loss, excessive use and inefficient management measures, are problems common to most dunes. Moreover, many problems of a particular dune system may be related to similar ones experienced by other dune systems, which might not necessarily be adjacent. Therefore, the checklist is a useful tool for dune managers, to be used as a problem delineation procedure in which each problem is listed, rated and evaluated with respect to dune vulnerability (Davies, Williams and Curr, 1995). Coastal dune vulnerability is defined, in the present paper, as the degree of a coastal dune system's susceptibility to experience change and irreversible degradation.

Based on conclusions and criticisms resulting from the application of the original checklist method (referred to, in the present paper, as CHK 1) to several northwest and southern European coastal dune systems, including Portuguese case-studies (many of these outlined in Williams *et al.*, 1994 and Davies, Williams and Curr, 1995), an alternative checklist method for assessing coastal dunes' biophysical vulnerability (referred to as CHK 2) was developed, and results based on a case-study of Mira's dunes were compared with those of CHK 1.

Mira's beach-foredune system, located on the western coast of Portugal (figure 1), is dominated by a very high-energy wave climate, and is becoming very attractive for regional-scale recreation and

Table I. Selected parameters and variables of CHK 1

Parameters	Variables
Site and dune morphology	Orthogonal fetch, surface area, length and width of dune coast, maximum height of dunes, wet slacks, particle size in foredunes
Beach condition	Width of inter-tidal zone, sand supply input, pebble cover, % foredunes cliffed by the sea, dune cliff as % of dune height, breaches in seaward face, width of breaches, seaweed on upper beach, colonisation by vegetation
Surface character of seaward 200 m	Vegetation cover, % blowouts, sand blown inland from system, saltwater invasion of dunes, % new dunes, frontal change and cover change since 1940, relic quarries
Pressure of use	Visitor pressure, road access, on-dune driving, horse riding, path network density, incised paths, camping, housing, owners, sand extraction, grazing, rabbit population
Recent protection measures	Surveillance and maintenance, % area with restricted access, controlled parking, horse riding, controlled on-dune riding, managed paths, sand traps, planting on mobile areas, information boards, protection works, protection by legislation

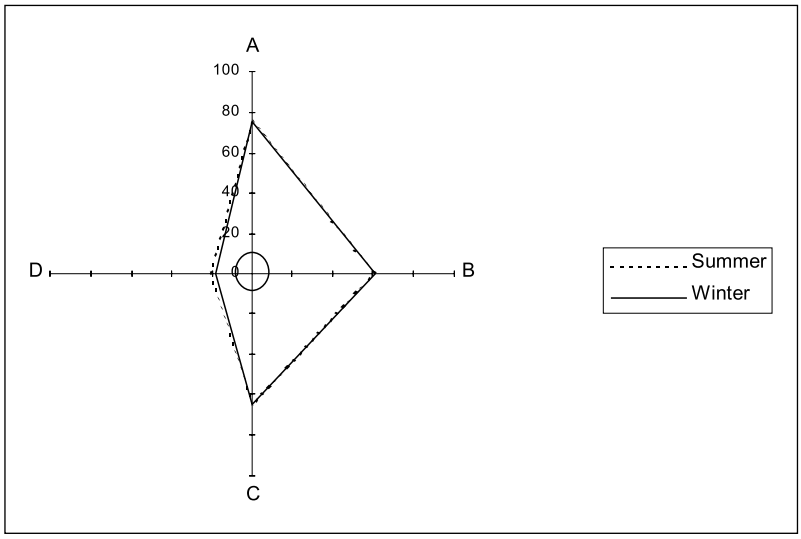

Figure 2. Graphic representation of CHK1-Areão. (A): site and dune morphology; (B): beach condition; (C): surface character of the seaward 200 m of the dune; (D): pressure of use; (Circle): recent protection measures

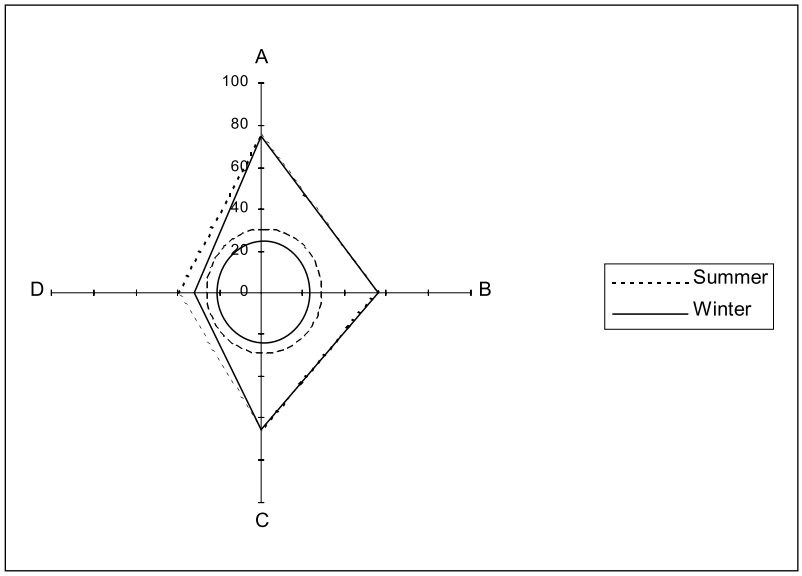

Figure 3. Graphic representation of CHK1-Poço da Cruz. (A): site and dune morphology; (B): beach condition; (C): surface character of the seaward 200 m of the dune; (D): pressure of use; (Circle): recent protection measures

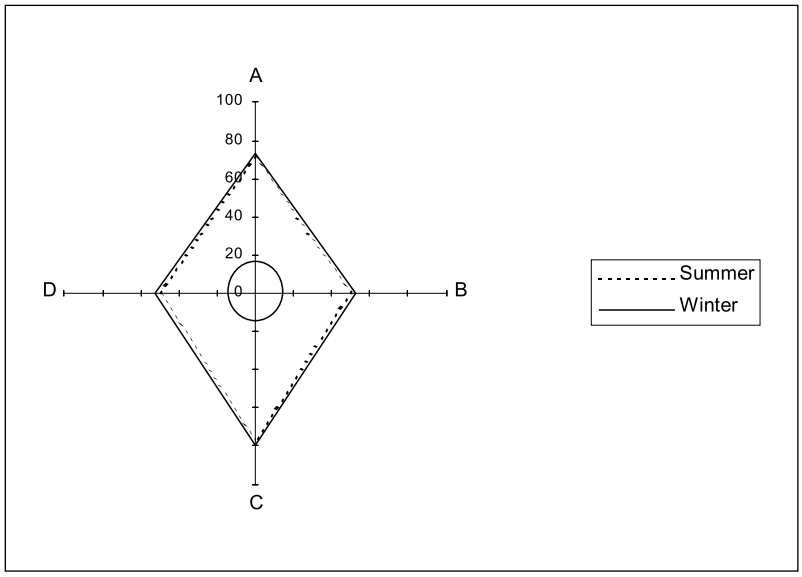

Figure 4. Graphic representation of CHK1-north Mira beach. (A): site and dune morphology; (B): beach condition; (C): surface character of the seaward 200 m of the dune; (D): pressure of use; (Circle): recent protection measures

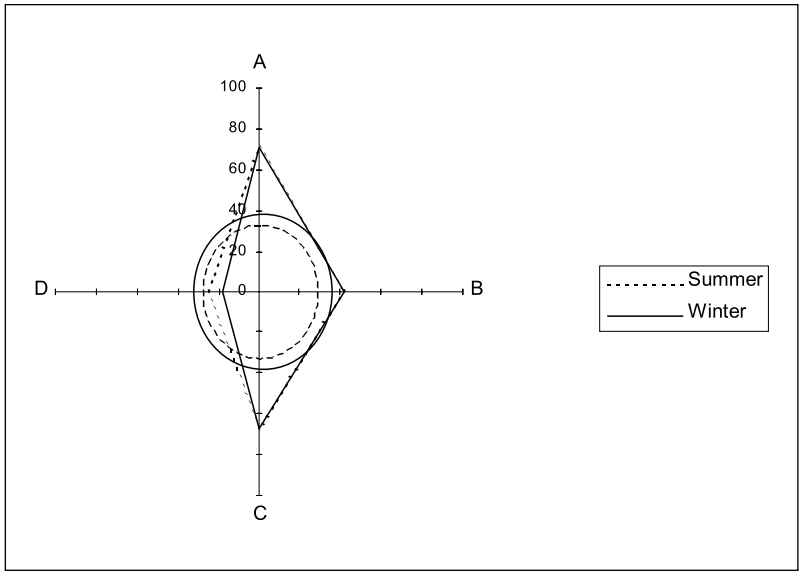

Figure 5. Graphic representation of CHK1-south Mira beach. (A): site and dune morphology; (B): beach condition; (C): surface character of the seaward 200 m of the dune; (D): pressure of use; (Circle): recent protection measures

tourism. Different dynamic conditions, types and intensity of use (recreation, urbanisation and activities related to the traditional fishery), leading to distinct processes of evolution and degradation, pose a variety of problems to managers.

MATERIALS AND METHODS

CHK 1 method

The CHK 1 method for evaluating and monitoring coastal dune vulnerability has been well documented (Bodéré *et al.*, 1991; Davies, Williams and Curr, 1995; Williams and Bennett, 1996). Parameters such as site and dune morphology, beach condition, surface character of the seaward 200 m of dune and pressure of use (table I) were assembled to calculate a vulnerability index (VI). A fifth parameter assesses recent protection measures taken (table I) and gives a protection index (PM).

Variables in each section of parameters are characterised and ordered in relation to five vulnerability levels. These vulnerability levels are not described in the present paper, but can be found in the references cited above. The total score found for each section can be calculated as a percentage of the maximum possible total value (score values from 0 to 4) and plotted as graphs (figures 2-5). These figures present the balance between vulnerability and protection measures for the coastal dune system, which can be numerically calculated by the VI/PM ratio. Equilibrium occurs when the VI/PM ratio is between 0.8 and 1.3. Values lower and higher than this indicate positive and negative disequilibrium, respectively (Davies, Williams and Curr, 1995; Williams and Bennett, 1996). Data is gathered at a particular time, so that each resulting vulnerability checklist only makes it possible to characterise a particular state of the dune system.

CHK 2 method

To characterise biophysical vulnerability components of coastal dune systems, variables which could describe observable signs of degradation or regeneration of the system, as well as the type and necessity of managed response, were determined. Erosion forms originated by wind, waves or man and the evidence of sand blown inland from the system were selected as indicators of the dune system's erosive condition; the presence (or absence) of recent or embryonic dunes was selected as an indicator of a positive (or negative) dune sediment budget; dune vegetation cover and damage state were selected as indicators of sand retention efficiency; signs left by several types of use were selected as indicators of anthropogenic dune degradation; and several measures that could be implemented to manage coastal dune systems were listed as indicators of dune management efficiency and conservation (table II). All

Table II. Selected parameters and variables of CHK 2

Parameters	Variables
Dune erosion	% foredunes cliffed by the sea, dune cliff as % of dune height, recent overwashes, % active breaches in seaward face, % active blowouts, sand blown inland from system
New dunes (sand input)	% recent or embryo dunes along seaward edge, % breaches with new dunes, % overwashes with new dunes, % blowouts with new dunes
Sand retention by vegetation	Vegetation cover, % damaged plants
Degradation by use	Path network density, path incision, on-dune driving degradation, horse riding degradation, camping degradation, housing degradation, sand extraction, degradation by activities related to fishery, sporting installations (e.g., golf courses)
Dune management and conservation	Information boards, managed paths, % area with restricted access, controlled on-dune riding, controlled horse riding, controlled camping, controlled housing, controlled sand extraction, controlled fishery activities, sand traps, planting on mobile areas, sand nourishment (beach and/or dune), protection works
Obstacles to sand transgression	% brushwood, % forest, % agricultural areas, % urban dispersed areas, % concentrated urban areas, camping, roads
Tourist attraction	Level of tourist acommodation, road access and parking, leisure sites, level of development of seaside recreational activities

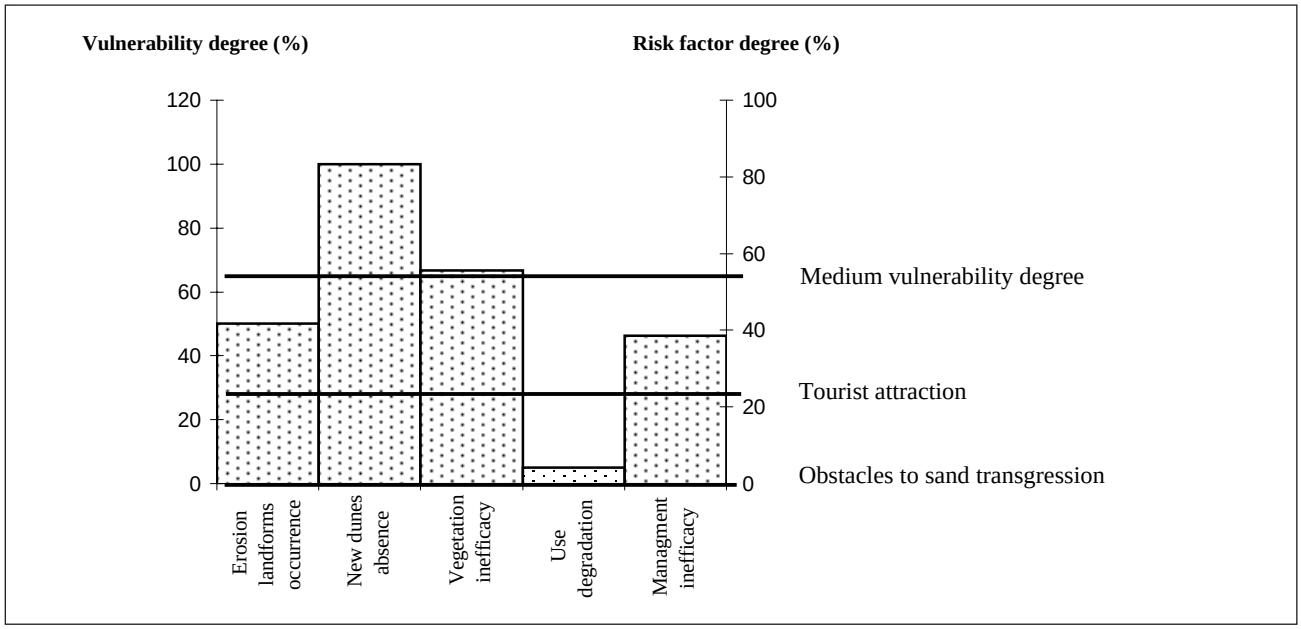

Figure 6. Graphic representation of CHK2-Areão

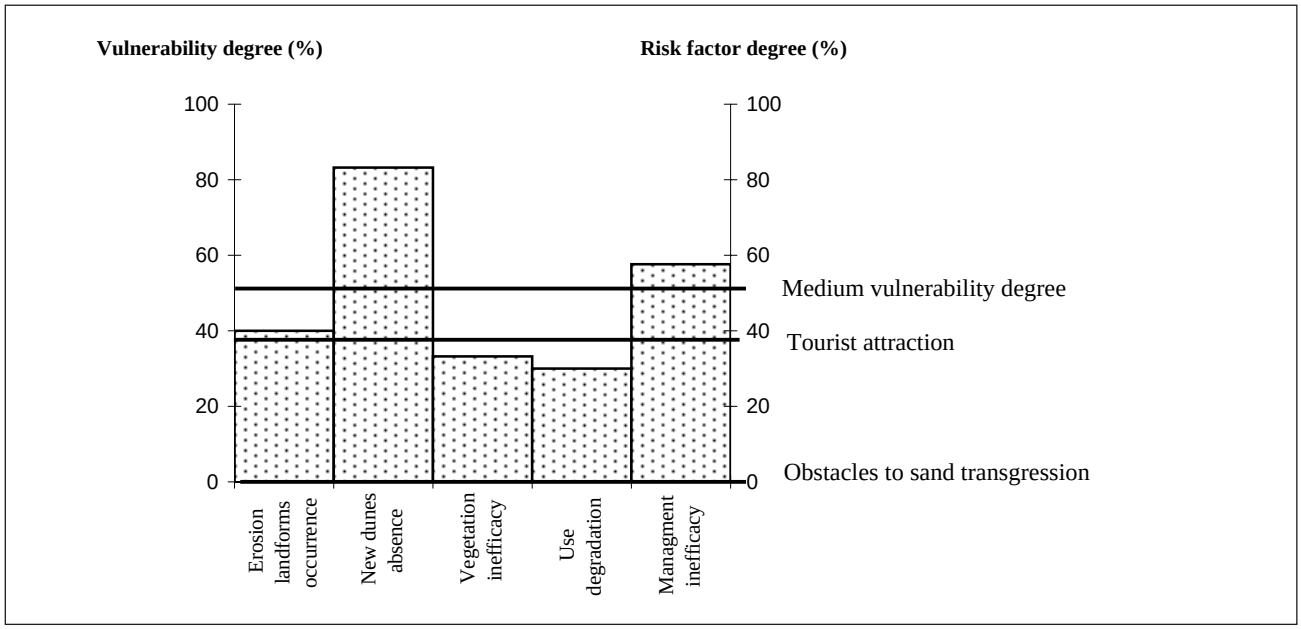

Figure 7. Graphic representation of CHK2-Poço da Cruz

variables selected are related to dune system elements susceptible to management intervention.

Taking the sensitivity (degree of transformation) and resilience capacity of a dune system as determinants of biophysical vulnerability, each variable is rated and evaluated with regard to to three vulnerability levels:

1. low sensitivity, resilience threshold not exceeded
2. variable sensitivity, at the resilience threshold
3. high sensitivity, resilience threshold exceeded, taking into account the system's level of degradation and the desirable level of conservation (e.g. the need to restrict anthropogenic utilisation and implement general or specific management measures).

The impact of tourism on the dune system andd the existence of obstacles to dune transgression

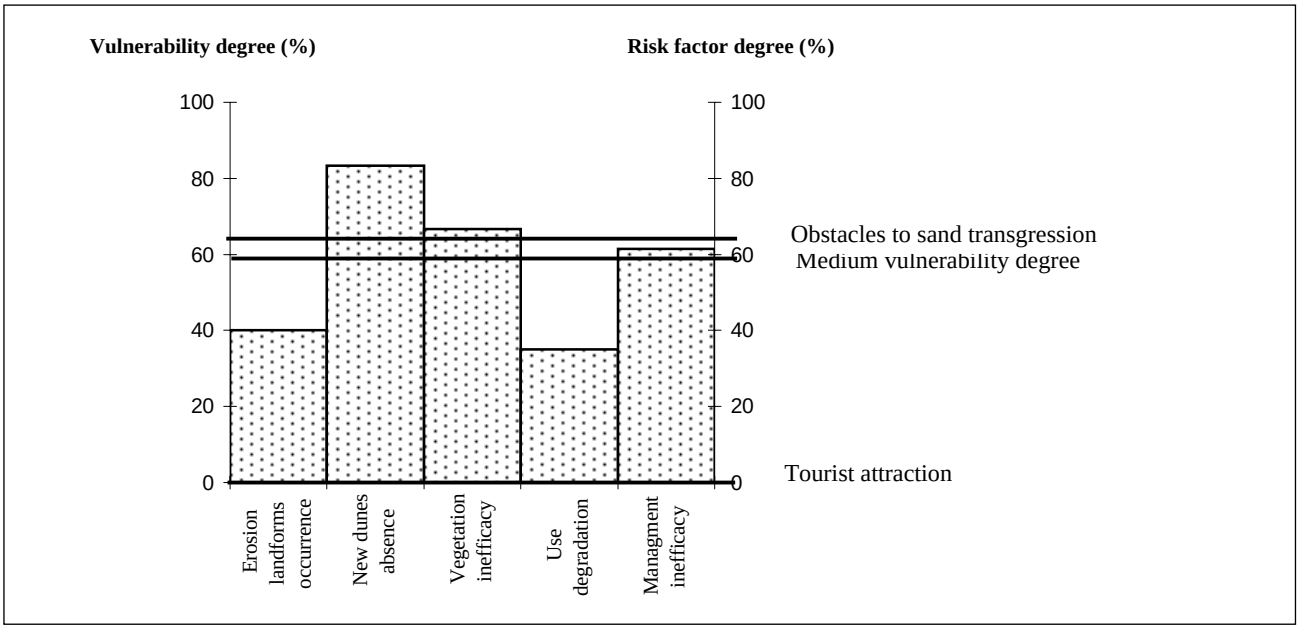

Figure 8. Graphic representation of CHK2-north Mira beach

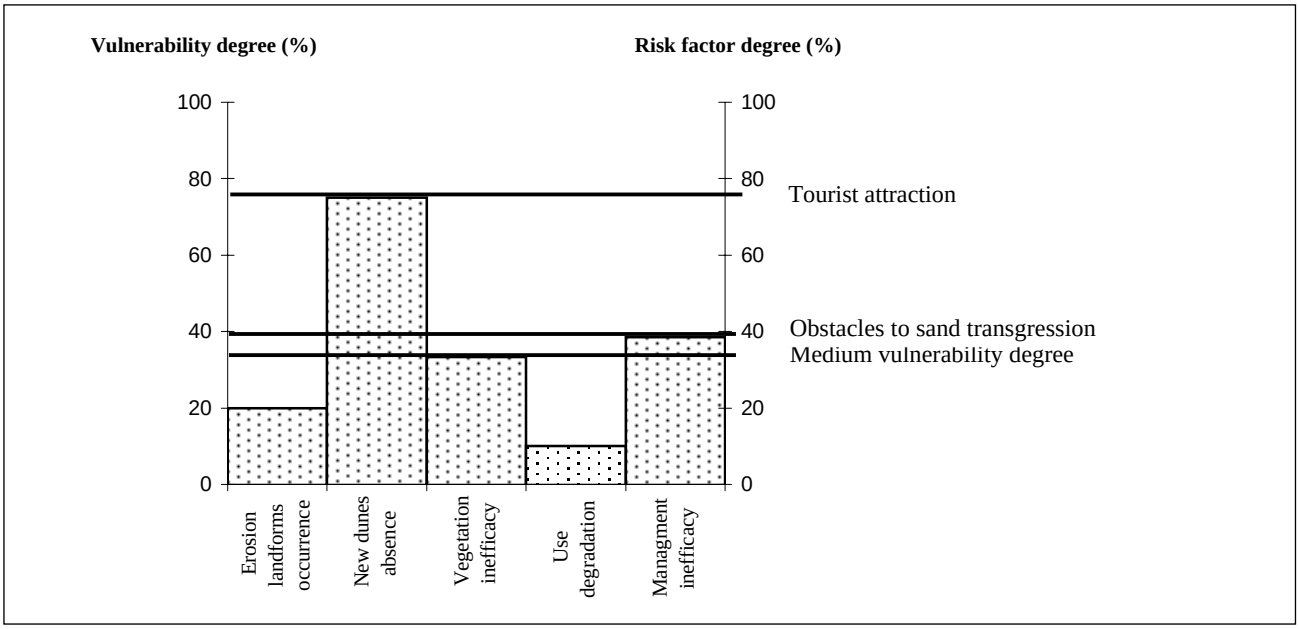

Figure 9. Graphic representation of CHK2-south Mira beach

with respect to dune vulnerability were also assessed (table II). These are considered risk factors associated with dune vulnerability, since they may lead to biophysical, ecological and socio-economic damage.

The total score found for each section of variables can be calculated as a percentage of the maximum possible total value (score values from 0 to 2) and plotted as graphs (figures 6-9). The figures present the relative importance of each vulnerability component to a medium degree of vulnerability of the dune system, and also show the balance between vulnerability and risk factors, such as obstacles to sand transgression and the dune system's tourist attraction. Data should be gathered at the end of a geomorphologic cycle, i.e. late spring or

summer, when sand input, sand retention by vegetation and human pressure reach high values.

Mira's case-study methodology

Selection of Mira's beach-foredune system sectors to apply both checklist methods was based on previous field work and aerial photography (false colour, 1: 20 000, flight CELPA/CNIG/IF, 28-08-1995). Each sector selected corresponded to a homogeneous site, with regard to geomorphologic features, dynamics and human pressure, and to a management unit, defined from the main access to the beach and distance of probable dispersion of visitors from that central point.

Checklist application took place in July 1996 and February 1997.

RESULTS

Areão

At Areão (figure 1), both beach and foredune sediment budgets are negative. The foredune's seaward face was recently cliffed by the sea and there are numerous natural breaches. Despite the fact that visitor pressure is low, degradation is already observable, related to a poorly managed path network. Large (2-6 m) and incised paths (> 1 m) are particularly active deflation corridors (anthropogenic breaches) and associated sand drifts are very characteristic.

CHK 1 showed that dune management intensity is very low (9.1 %) in response to a low level of pressure. However, this response must be regarded as not very effective within the context of the degree of vulnerability which the checklist identified for other parameters (figure 2). The very high VI/PM ratios of 5.6 (26 July 1996) and 5.4 (22 February 1997) indicates how this site is clearly undermanaged.

CHK 2 showed not only the importance of dune management inefficiency (46.2 %) to the medium degree category of vulnerability, but also that such a degree of vulnerability was mainly due to a highly negative sediment budget and poor sand retention by foredune vegetation (figure 6). CHK 2 also showed that properly managed and sign-posted paths and specific dune rehabilitation measures are needed if an increased number of visitors are to be expected. Although relatively vulnerable, the system at Areão is not at risk, since there are not any obstacles to dune transgression and its tourist attraction is still low (figure 6).

Poço da Cruz

At Poço da Cruz, both beach and foredune sediment budgets are negative. The foredune's seaward face is characterised by numerous incipient blowouts, some associated with the main beach-access paths. This is a rural beach, with incipient development. Although visitor pressure is still relatively low, degradation signs are already visible, related to an unmanaged path network, which is deeply incised (> 2 m) and highly dispersed (figure 1). Sand drifts characterise the foredune ridge's inland face, where paths have opened breaches. Sand traps (fences) have been installed in the main blowouts.

CHK 1 showed a slight difference between winter and summer human pressure and a poor balance between vulnerability and protection measures (figure 3). The VI/PM ratios of 2.0 (26 July 1996) and 2.3 (22 Frebruary 1997) indicated a negative disequilibrium.

CHK 2 showed a negative sand supply (83.3 %) together with very low management response (57.7 %) as determinants of dunes' medium degree of vulnerability. Poço da Cruz can be regarded as an under-managed site, but still not at risk (figure 7). CHK 2 has also stressed that properly managed and sign-posted paths, extensive fencing, vegetation planting and access restriction are needed if increasing numbers of visitors are to be promoted.

North Mira beach

North Mira Beach is a site where activities related to the traditional fishery still remain. Warehouses were built on the foredune ridge, and access paths opened to facilitate boat passage, leading to partial destruction of the system. As a result, sand blown inland from the system is invading the adjacent urban area (figure 1). Sand traps were recently installed to partially reconstruct a dune form, but their effectiveness has been low.

CHK 1 showed the importance of permanent human pressure (50 %), and that better beach con-

ditions existed than at Areão and Poço da Cruz (figure 4). The VI/PM ratio of 3.4 (26 July 1996 and 22 February 1997) indicated that this is clearly an undermanaged site.

CHK 2 highlighted the system's degradation, as all vulnerability components presented relatively high values (figure 8). Furthermore, CHK 2 showed the existence of obstacles to sand transgression (62.5 %), due to the presence of the urban concentrated area located inland from the system (figure 1). This leads to a risk situation (figure 8), because during the winter sand invades streets and houses. CHK 2 also highlighted the need to combine existing sand traps with vegetation planting, managed and sign-posted paths and access restriction if rehabilitation of the dune system is to be effective.

South Mira beach

South Mira beach is a site of great interest with regard to seaside summer recreation. This is a sector contiguous to the urban Mira beach (figure 1), where the level of tourist accommodation is high. The beach sediment budget had, more or less, stabilised since construction of a downdrift jetty in the 1970s (figure 1). The foredune's seaward face is characterised by the presence of recent dunes. However, ineffective management of beach access through the foredune ridge (distance between paths of 50 m, no walkways constructed) has produced numerous bare sand areas (sand drifts associated with the path network), which are already invading the inland brushwood. Therefore, the foredune sediment budget is negative. Windbreaks were recently installed at the foredune's seaward face, for sand trapping and to restrict access.

CHK 1 showed a better balance between vulnerability and managed response (figure 5). This is, apparently, a site where the dune system is in equilibrium, as indicated by the VI/PM ratios of 1.3 (26 July 1996) and 1.2 (22 February 1997). However, the dune protection measures are only evaluated and scored in terms of their presence or absence in the system, not in terms of effectiveness, therefore leading, as in this case, to an overestimation of the PM index.

CHK 2 showed that at south Mira beach, the dune system showed lower values of vulnerability, in spite of a somewhat deficient sand supply (75 %). CHK 2 also showed the inefficiency of the management strategy and the poor conservation state of the foredune system (38.5 %), together with the ineffective sand retention by vegetation, as determinants of the system's medium degree of vulnerability (figure 9). Well managed and sign-posted paths and planting programmes are needed. Furthermore, CHK 2 suggested that the system is in a situation of potential risk (figure 9), since proximity of an urban concentrated area justifies a high level of tourist attraction (75 %) and the presence of camping and a somewhat important road may constitute significant obstacles to sand transgression (37.5 %).

DISCUSSION

CHK 1 and the calculated VI/PM ratios make good regional comparisons of dune systems possible, but provide insufficient information for dune management at the local scale. This checklist method is basically descriptive, and leads to a general conclusion that a higher level of management is needed, taking into account Mira's dune system vulnerability in each studied sector. Protection measures need to be considered in terms of their effectiveness if a realistic assessment of them is to be achieved, and of the significance of implementing general measures (surveillance and maintenance, managed paths, information boards) with regard to dune vulnerability or specific measures (restricted access, sand traps, planting programmes). CHK 1 included variables related to factors, conditions and evidence (signs of degradation) of coastal dunes' vulnerability, which means that only some of them are susceptible to management intervention, i.e. have a direct relevance for managers.

The CHK 2 method was developed from a different perspective than CHK 1, and was based on the resilience and carrying capacities of coastal dune systems. CHK 2 may be more useful for managers (usually non-specialists), since coastal dunes' vulnerability can be easily evaluated by direct observation of dune morphology, signs of degradation and managed response, and the checklist is organised so that dune managers can identify in detail which components of the system are more vulnerable and more in need of management intervention. The CHK 2 method made it possible to

easily interpret the dynamics of Mira's dune system and identified directly the system's highly vulnerable components and which appropriate management measures to take in each sector studied. Furthermore, CHK 2 enables managers to assess coastal dune sites from an economic, spatial, and temporal perspective, taking into account the system's tourist attraction and obstacles to dune transgression (with regard to coastline retreat over a time horizon of 50 years). Mira's beach-foredune system is at a point of actual risk, where sand is already invading an inland urban area, and of potential risk, where tourist attraction is very high.

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