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EVOLUTION OF THE BEACH-DUNE SYSTEMS IN THE BALEARIC ISLANDS FROM THEIR GEOMORPHOLOGICAL MANAGEMENT (2000-2021)

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ABSTRACT. In order to restore, maintain and protect the beach-dune systems of the Balearic Islands different management techniques have been applied. They have been based on the artificial emulation of natural processes to favour the recovery of the system, on the installation of elements that prevent the frequenting and on trampling of the dune systems. Some techniques are positive while others have aggravated erosive processes due to a lack of geomorphological criteria. This work analyses good and bad practices on beach-dune systems of the Balearic Islands between 2000-2021.

Evolución de los sistemas playa-duna en las Islas Baleares a partir de su gestión geomorfológica (2000-2021)

RESUMEN. Para restaurar, mantener y proteger los sistemas playa-duna de las Islas Baleares se han aplicado diferentes técnicas de gestión. Se han basado en la emulación artificial de procesos naturales para favorecer la recuperación del sistema y en la instalación de elementos que impidan la frecuentación y el pisoteo de los sistemas dunares. Algunas técnicas son positivas mientras que otras han agravado los procesos erosivos por falta de criterios geomorfológicos. Este trabajo analiza las buenas y malas prácticas en los sistemas playa-duna de las Islas Baleares entre 2000-2021.

Key words: Balearic Islands, beach-dune systems, erosion, restoration, management, recovery.

Palabras clave: Islas Baleares, sistemas playa-duna, erosión, restauración, gestión, recuperación.

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1. Introduction

Coastal dunes represent fragile and dynamic morphological systems fundamental in the balance of the sandy coastline, providing protection functions against erosion. However, these morphologies are located in fragile environments threatened by natural and human factors, with degradation processes that involve the loss of their geo-environmental values and the goods and services they represent.

In recent years there has been awareness of the constant deterioration of natural ecosystems, among which the coastal systems stand out. The stability and balance of dune morphologies are determined by different factors, such as the supply of sand, sedimentary transport rate (Delgado-Fernández, 2011), waves and wind forces (Walker *et al*., 2006), the long-term condition of the beach (Davidson-Arnott *et al*., 2005), the occurrence and magnitude of storms, and vegetation (Miot da Silva *et al*., 2008). The anthropic impact on these morphologies has been widely studied and described, pointing out the causes of their degradation to massive tourist development, construction of promenades, high anthropic pressure, installation of services and the incorrect planning and management that they generate impacts on the system (Carter, 1988; Nordstrom, 2008; Gómez-Piña *et al*., 2002).

To reduce these processes, focused on the loss of beaches, morphologies and vegetation, mitigation strategies have historically been applied through the management and/or defence of the coast, which have conditioned its evolution over the last decades (Lithgow *et al*., 2013). According to Roig-Munar (2011), interventionist actions are determined by the genetic conditions of each space, highlighting:

1. *Hard actions*: structures to resist wave energy, such as breakwaters, in order to retain sediment and prevent coastal erosion.
2. *Soft actions*: they are based on "respect" for the environment, such as artificial beach regeneration (Charlier and Meyer, 1989). These methods generate erosive impacts in the loan sedimentary areas, either submerged or emerged ones (Schooler *et al*., 2019), and imbalances in the area of action (Rodríguez-Perea *et al*., 2000).
3. *Sustainable actions*: they are based on emulating the natural processes with the aim of restoring the dynamic balance between the emerged beach and the dune sector. They need spaces that allow the development of dune morphologies and plant colonization (Roig-Munar *et al*., 2005).

Restoration takes place through the emulation of natural processes that affect the functionality and resistance of the ecosystem (Lithgow *et al*., 2013). According to Psuty and Silveira (2013) the objective is to restore the characteristics in the natural context, being the most suitable to preserve and recover the beach-dune system, since their stability determines the balance of the system as a whole (Roig-Munar *et al*., 2018). Although lately, greater dynamism has been advocated to improve diversity through dune mobility (Arens *et al*., 2013; Delgado-Fernandez *et al*., 2019; Castelle *et al*., 2019).

The structure of the beach-dune systems of the Balearic Islands ranges from the submerged to the emerged area (Figure 1), and can be described based on five sectors described by Servera (1997), Rodríguez-Perea *et al*. (2000), Balaguer and Roig-Munar (2016) and Roig-Munar *et al*. (2018).

Submerged beach is where the *Posidonia oceanica* meadows develop (offshore, 1) and where a redistribution and sediment transport to the emerged beach takes place (nearshore, 2). In the case of the Balearic Islands, the origin of the sediment is a conditioning factor, with a sediment production from biological origin greater than 80%, associated with the *Posidonia oceanica* meadows (Rodríguez-Perea *et al*., 2000; Gómez-Pujol *et al*., 2013).

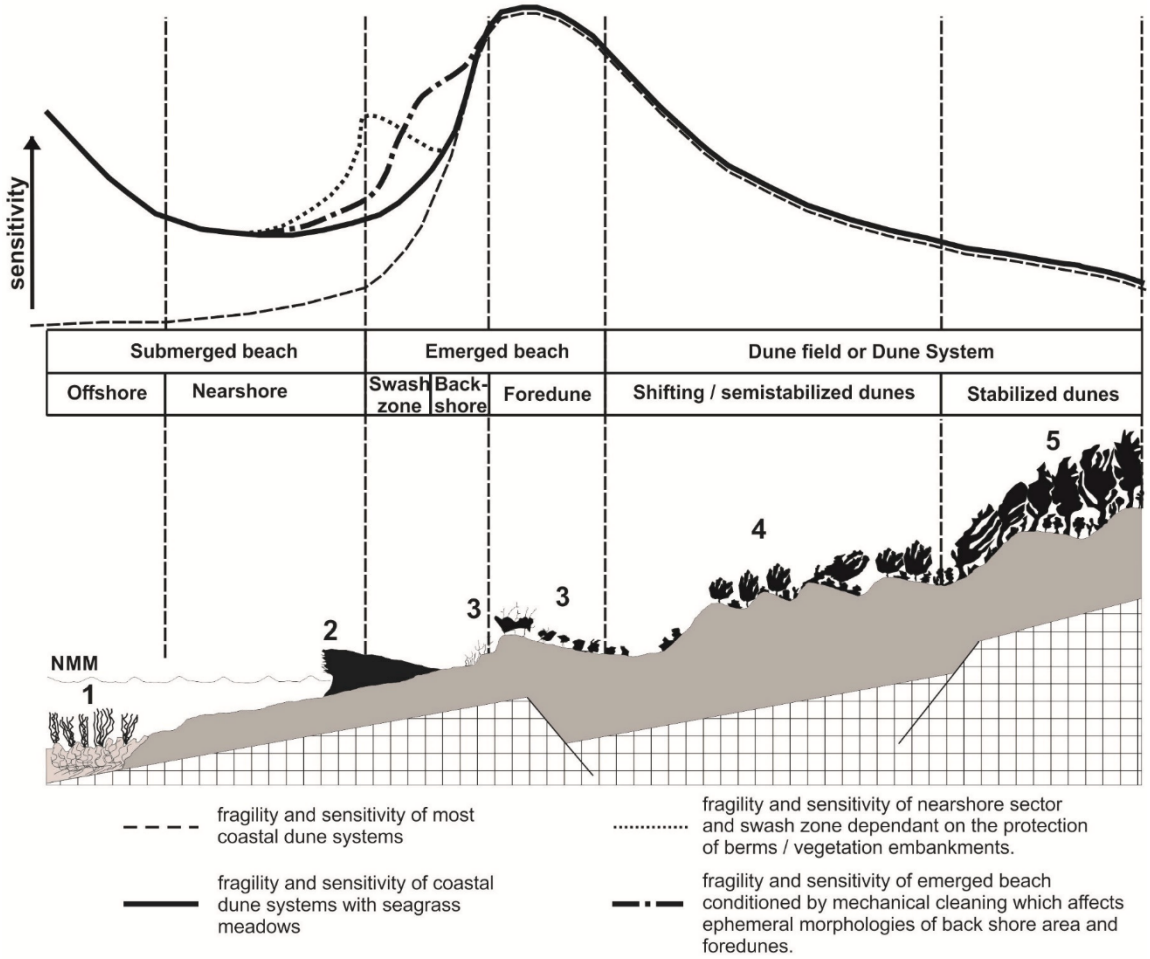

Figure 1. Beach-dune sectors and their different degrees of geo-environmental sensitivity. Source: Roig-Munar et al. *(2018).*

Backshore is the area that shows the sedimentary balance between the submerged and the emerged area. (Woodroffe, 2002). Most of the remains of *Posidonia oceanica* meadows accumulate in the swash zone). Most of the management and maintenance actions are carried out in this area to ensure a good state of the beach.

Foredunes (3 in fig. 1) are characterized by wind processes, only affected by marine processes during episodes of great storms. The first ephemeral morphologies develop with pioneer vegetation. Any alteration of its vegetation can cause rapid destabilization and erosion, giving rise to lobes of deflation (Hesp, 2002; Bouma *et al*., 2013). Foredunes ensures the balance of the beach against strong storms allowing the natural recovery of the beach (Martín-Prieto *et al*., 2009). They also make less strong the force of the wind and marine spray, allowing the development of tree vegetation.

Dune systems are built by a mobile and semi-stabilized area (4 in fig. 1) followed by a stabilized dune area (5 in fig. 1). Behind the foredunes are the mobile dunes fixed towards the interior by the vegetation, configuring the area of semi-stabilized dunes. The extension of this area is usually conditioned to the state of conservation/degradation of the foredune (Hesp, 1988). Edaphic soil increases inland, where the wind deflation processes are lower, and the morphologies are estabilized by shrub and forest vegetation. There is little contribution of sand, and this only takes place during episodes of strong winds, according to the environmental state of the foredune (Lynch *et al*., 2010). Often the vegetation of these areas is shaped by human action for agricultural purposes (Mayol, 2006; Roig-Munar *et al*., 2009).

The degree of sensitivity of the beach-dune systems has been established for those areas where planning and management take place through the sensitivity curve. The first sensitivity curve is located on the *Posidonia oceanica* meadows as a sediment-producing habitat, stabilizer of the submerged beach and dissipator of wave energy (Rodríguez-Perea *et al*., 2000). The second sensitivity curve is located on *Posidonia oceanica* remains deposited on the swash. It works as a buffer against the force of wave storms. The mechanical removal of these vegetal berms gives rise to the continuous erosion of the backshore (Roig-Munar and Martín-Prieto, 2005; Roig-Munar *et al*., 2019). The third sensitivity curve is on the emerged beach, where the mechanical cleaning actions affect the ephemeral morphologies and the destabilization of dune slopes (Roig-Munar, 2004). The fourth one is located on the foredune, which defines their weakening, erosion and/or disappearance of the beach-dune system (Brown and McLachan, 1990; Rodríguez-Perea *et al.*, 2000; Hesp, 2002; Martín-Prieto *et al*., 2009). It is affected by the urbanization, frequentation of users, presence of services and by the degradation of the dune vegetation.

In this way, we can differentiate four critical points in the degree of sensitivity of the beach-dune profile being the front dune sector which gives the stability of the system (Hesp, 2002; Martín-Prieto *et al*., 2007). Not taking these points into account has led to the loss of areas and volumes of the beach-dune, and even their disappearance. Reversing these trends through efforts based on the application of geomorphological criteria has allowed the recovery of several systems in the Balearic Islands (Roig-Munar *et al*., 2017). Working without criteria has aggravated erosive processes, either due to errors in management, monitoring or maintenance.

The goal of this work is to analyse the management carried out over the last two decades (2000-2021) on the front dune sector in 10 dune systems of the Balearic Islands (Table 1, Figure 2). Its geomorphological and its spatio-temporal evolution has been based on the morpho-ecological classification of Hesp (2002). These work analyses the different restoration techniques considered sustainable on the foredune sensitivity curve. Six beach-dune systems have been analysed in Menorca: La Vall, Es Bot, Tirant Son Saura N and Es Grau in the northern coast and Son Bou in the southern coast. Three beach-dune system was analysed in Mallorca: Cala Mesquida at the northeast and Es Trenc-Sa Rapita and Es Carbó in the south. And finally, one system, Es Cavallet, in south Ibiza.

Table 1. Relationship of values for each variable.

Variable	**1**	**2**	**3**	**4**	**5**
Beach state	Erosion		Sedim.		Equilibrium
Foredune (Hesp, 2002)	1	2	3	4	5
Neo-morphologies in the foredune	Yes		Medium		No
Inner deflation channels	Yes		Medium		No
Beach	C		B		A
Revegetation	Yes				No
Cordoning	Yes				No
Walkways	Yes				No
Wind fences	Yes		Some		No
***Posidonia oceanica* removal**	Yes	No			
Mechanical cleaning	Yes	No			
Natural area (ANEI)	Yes	No			
Natural park	Yes	No			
Management measures	Yes	No			
Degree of frequentation	Low		Medium		High

Figure 2. Location of the analyzed beach-dune systems.

2. Study area/regional setting

The main source of income for the Balearic Islands comes from tourist activity. Concentrated on its sandy coastline, beaches, "calas" (little pocket beaches) and beach-dune systems, representing an important economic resource (Roig-Munar *et al*., 2015). The lack of knowledge of its natural dynamics by managers has led to aggressive actions causing its alteration (Alonso *et al*., 2002). Since the approval in 2002 of the European Recommendation on the Integrated Management of Coastal Zones (2002/413/CE), both the national administration, as well as the regional administrations with powers on the coast, have developed convergences to consolidate and apply an integrated coastal management (Balaguer, 2012). Over the past decades, different approaches have been applied to the Spanish coastline in order to restore beach-dune systems (Gómez *et al*., 2002; Ley, 2012; Roig-Munar *et al*., 2019). Dune restoration must consider the spatial and temporal scale of their evolution, their different morphologies,

structures and functions (Boak and Turner 2005; Martín-Prieto *et al*., 2010). Restoration plans (Gallego-Fernández *et al*., 2011) must be adapted to the geomorphological and topographic characteristics of each action (Roig-Munar *et al*., 2009, 2017). The correction of the erosive processes is recent, on in many occasions the efforts give positive results until re-naturalization, but in other cases the measures are deficient (Martín-Prieto *et al*., 2007; Roig-Munar *et al*., 2018).

The most widely methods used for restoration are wind interference traps, elevated walkways and perimeter cords of dune fronts. The elimination of recreational use on dunes and/or their revegetation have giving satisfactory results in recent decades (Gómez-Piña *et al*., 2002; Lithgow *et al*., 2013; Roig-Munar *et al*., 2015, 2018). Dune restoration techniques must be carried out after analysing the spatio-temporal evolution of the system, identifying the impacts and their causes and effects, as well as the natural and/or anthropic elements that favour their erosion (Hesp and Walker, 2012; Cabrera - Vega *et al*., 2013). Protective measures require monitoring and maintenance.

Based on experiences of sustainable management carried out at the state level, the Ministry of Agriculture, Food and Environment (MAGRAMA) prepared the Manual for sustainable restoration of the beach-dune systems (Ley *et al*., 2007). Nevertheless, the Manual does not consider the need to limit, regulate the criteria that affect the upper beach and the swash zone (Figure 1), such as removals of *Posidonia oceanica* remains and / or mechanical cleaning throughout the beach extension. These two tasks affect the sedimentary balance between beach and dunes (Roig-Munar *et al*., 2019).

3. Materials and methods

Beach-dune interaction models can be evaluable tools for managers to apply management and restoration strategies (Figure 1). Short and Hesp (1982) studied the beach-dune interaction with emphasis on morpho-dynamics and its response to wind and wave energy. Psuty (1990) models provided a starting point to identify the most important variables, such as the supply of sediment between beach-dunes to predict the behaviour of the foredunes. Hesp (2002) carried out a morpho-ecological classification of foredunes based on different conservation stages, where stage 1 represents maximum stability and naturalness while stage 5 represents erosion with a tendency to disappear of the front dune system.

However, this knowledge is far from being used in coastal planning and management, since managers focus on socioeconomic aspects (Ariza *et al*., 2010). Not taking these considerations into account can lead to poor management, where erosion problems continuously worsen over time (Rodríguez-Perea *et al*., 2000; Roig-Munar, 2011; Roig-Munar *et al*., 2018).

Since 2000, restoration actions have been carried out in different beach-dune systems of the Balearic Islands which work with the environmental sensitivity curve (Figure 1) of the dune system. In order to evaluate those actions, we take as a starting point the studies carried out in the Balearic Islands by Roig-Munar *et al* (2012), who established a classification analysis of beach-dune systems through the use of variables and established a temporal evolution model (1956-2004). This methodology should be a management tool for future actions.

For this study, in order to establish an evolutionary trend from 2000 to 2021, fifteen variables (Table 1, 2) have been identified using physical, geo-environmental parameters, (García *et al*., 2001; McLaughlin *et al*., 2002; Hesp, 1998 and 2002), and parameters of status, use and management (Williams and Davies, 1997; Williams and Morgan, 1995; Leatherman, 1997; Laranjerira *et al*., 1999; Roig-Munar *et al*., 2018), following the criteria established by Laranjeira *et al*. (1999) and Roig-Munar *et al*. (2006, 2012). The variables are classified from 1 to 5, with 1 being a very positive indicator and 5 very negative within each parameter, in order to perform a statistical analysis (Table 1):

Table 2. Hesp (2002) values by dune system and year analyzed.

Beach-dune name		***2000***	***2006***	***2012***	***2017***	***2019***	***2021***
Es Grau	GR	4	2	1	1	1	1
Son Saura N	SS	5	4	3	2	2	1
Tirant	TR	5	4	3	5	5	5
Son Bou	SB	5	3	2	2	3	3
Cala Mesquida	CM	5	3	2	2	2	2
Rápita-Trenc	RT	5	4	4	5	5	5
Es Cavallet	CV	5	4	4	4	4	4
Es Carbó	CB	1	2	2	2	2	3
La Vall	LV	3	3	4	3	3	4
Es Bot	EB	2	2	2	3	2	2
Average value		*4,2*	*3,2*	*2,8*	*2,9*	*3,0*	*3,1*

Geomorphological variables (4): beach state, foredunes state (Hesp, 2002), neo-morphologies in the foredune and internal deflation channels in the dune system.

Variables of use and management (11); degree of beach frequentation, removal of *Posidonia oceanica* accumulations, mechanical cleaning, Natural Area of Special Interest (ANEI), Natural Park, and measures of management, protection and recovery (wind fences, cordoning, revegetation and/or walkways).

4. Geomorphological management background

Different management techniques have been applied in several dune systems of the Balearic Islands (Figures 3 and 4). The main ones are described below.

Figure 3. Dune systems of A.- es Trenc, Mallorca, and B.- Es Cavallet, Ibiza. Both systems located in natural parks.

Figure 4. Dune system of A.- Tirant, Menorca, and B.- Son Bou Menorca. Both systems are located in natural areas of special interest.

4.1. Wind interference barriers

The recovery and stabilization of dunes using artificial barriers is a well-known technique (Lithgow *et al*., 2013; Grafals-Soto and Nordstrom, 2009). It is the most used in most of the systems studied. The lack of geomorphological criteria, wind characterization and monitoring and maintenance can compromise their good morphological results.

4.2. Revegetation

Nowadays, this practice extends to many dune systems (Ley *et al*., 2007). It may imply some fixation of the system, a decrease in biodiversity and even the reintroduction of non-native species, favouring and excessive stability of the systems.

4.3. Enclosures

The placement of perimeter cords to avoid the passage of users to the systems allows a slow but progressive recovery of the dune morphologies and their associated vegetation (Acosta *et al*., 2011). On occasions, when the recovery of the dune front takes place, the enclosure has been moved towards the beach to recover its original space (Martín-Prieto *et al*., 2007).

4.4. Walkways

The purpose of this technique is to concentrate the flow of users over dune morphologies. These walkways are installed in the dune system if there are no other alternatives to access the beaches, but always with elevation and orientation criteria.

4.5. Maintenance and monitoring

In dune restoration works, the results are not immediate, but it takes time for the techniques to work. Then, it is necessary to carry out follow-ups from the beginning of the action with seasonal or annual continuity. This monitoring allows an objective and critical view of objectives and results, as well as the response of the dune systems. For monitoring, it is necessary to develop a specific vulnerability index (Williams *et al*., 2001).

4.6. Passive management

In some dune systems, the procedures have been based exclusively on the control of the beach user and the limitation or elimination of mechanized actions on the dune fronts and beach.

5. Results

Results are based on a principal component analysis (PCA) of a matrix defined by the 15 variables and the 10 beach-dune systems evaluated in the years 2000, 2006, 2012, 2017, 2019 and 2021 (900 values). Each variable can be considered as a different dimension, and PCA reduces the dimensionality of a multivariate data to two. The resulting figure shows graphically (Figure 5) with minimal loss of information, which variables are the main components of the statistical analysis, and according to the distribution of the individuals in the graph, clusters can be established to group and describe the phenomena evaluated.

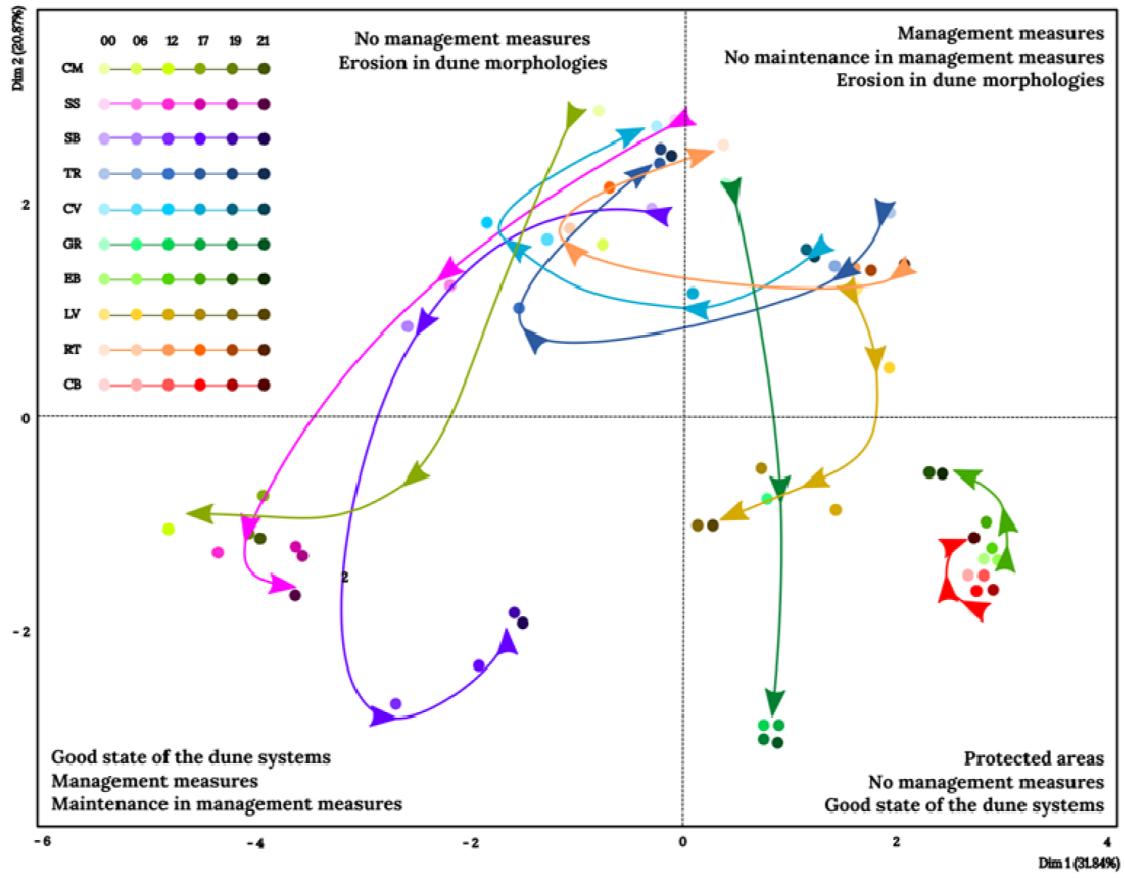

Figure 5. Distribution of dune systems in the factorial space defined for the period 2000-2021.

Components F1 and F2 define a factorial space divided into four quadrants according to the configuration of the values expressed by the set of variables (Figure 5). From the PCA the first two factors explain 52,71% of the variance. The first dimension (31,84% of the variance) is highly positively correlated with protected areas, good status of the foredune according to Hesp (2002) classification and lack of maintenance of management; and negatively correlated with management and maintenance of management.

The second dimension (20,87% of the variance) shows a high positive correlation with the lack of neo-morphologies and bad status of Hesp (2002) classification and presence of some measures (pathways, cordoned areas, mechanical cleaning, sand traps…), whereas the correlation is negative with management and good status of foredune and maintenance of management.

There are four spaces defined by F1 and F2. These quadrants respond to different states of conservation, use and management through their spatio-temporal evolution in the period analysed between 2000-2021:

1. Upper left quadrant: unmanaged beach-dune systems whose dune morphologies show widespread erosion.
2. Upper right quadrant: beach-dune systems where management is applied, but which are not maintained over time and whose morphologies show generalized erosion.
3. Lower right quadrant: these are protected natural areas where a good state of conservation of the dune systems is achieved with few management measures.
4. Lower left quadrant: beach-dune systems with long-term management and maintenance measures that allow optimal geomorphological states of the dune formations.

Throughout the period studied, the beach-dune systems have been analysed through the factorial plane showing a change, both in the management applied, and in their erosive state, always associated with their maintenance. The trend followed by the 10 beach-dune systems are: maintenance of the good state of conservation (CB-Es Carbó and EB-Es Bot), specific changes in the management without improvements in the erosive state of the system and a return to erosive processes (RT-Rapita-Trenc, TI-Tirant and CV-Es Cavallet), and improvement in the erosive state of the dune system linked to comprehensive management actions (CM-Cala Mesquida, SS-Son Saura, SB-Son Bou, GR-Es Grau and LV-La Vall).

The overall trend has been towards the renaturation. Starting from an average value of 4.2 in 2000 the average recovers to 2.9 in 2017 (Table 2). However, some lack of monitoring of measures and their maintenance, in subsequent years, shift the trend towards erosion, with values of 3.1 in 2021. If this management would have been adequate, the recovery trend would have tended towards a value closer to 1 in 2021 in all the analysed dune systems, but the results show us the opposite, a stagnation with a regressive trend. In some cases, like, erosive processes extend towards the interior of the system. Techniques have not been applied adequately in the beach-dune system or not have been adapted for each system.

6. Discussion

The F1 and F2 factors and the distribution of the 10 cases in the factorial space defined for the period 2000-2021, show the importance of the sensitivity curve of the dune system and the Hesp (2002) foredune stages. (2002). The principal component analysis has been able to define beach-dune evolution based on the correct or incorrect procedures carried out and their maintenance. The factorial quadrants express the lack or presence of management and its consequences. Therefore, the resulting evolutionary

model allows to establish a predictive model, associated with the response to the management and planning of the system, mainly to different factors that work on the dune front.

Despite this, the procedures have only been applied in the foredunes, and the lack of maintenance or continuity has generated internal erosive processes of the dune system. Appealing to its evolutionary significance, it is observed that the starting point would be that of a hypothetical state of Hesp (2002) on which action is taken with sustainable techniques to re-establish the balance of the system.

Based on the premise of Hesp (2002), it is unlikely that a stage 5 can migrate to a stage 1 under natural conditions. However, it is reasonable to expect that a stage 5 can return to 4 if the geo-environmental conditions are adequate, with a possible advance towards stage 3. In stages 1, 2 and 3, foredunes continue to develop slowly while stage 5 is highly erosive with a tendency to disappear.

The results obtained for each area, determine that the evolution and trend are associated with management measures, with a rapid recovery with non-interventionist measures. The evolution of the different dune systems (Figure 5), shows three groups of behaviours associated with the management carried out on the front dune system. Group 1 (CM, SS, SB, GR LV): those systems start from a situation of degradation of the front dune and have moved from a morphological stage of 5 to 2. They show specific states of erosion due to poor management or lack of maintenance, as in the case of Cala Mesquida or son Saura N. The case of Cala Mesquida shows a stage of equilibrium that can be questioned since there have been processes of fixing morphologies through revegetation, the system is losing its dynamic function, which affects its biodiversity.

Group 2 (RT, TI, CV): these are systems that initiate with the most erosive stage (stage 5) and that despite the management measures have not been balanced or recovered, reaching an average value of 4 in 2017. Their evolution has been similar to the renaturation processes described by Hesp (2002), therefore, the measures have not favoured their recovery and maintenance. Tirant dune system stands out, which with the use of different management techniques (enclosure and barriers firstly), moved towards recovery, reached stage 3. However, in 2017 Tirant returns to a stage 5, that continues until 2021, due to an abandonment in management. The dune system of sa Rapita-Trenc and es Cavallet, despite the economic efforts in the installation of sand traps and enclosures, they have not recovered the continuity of their dune front. Probably a high frequentation of tourists will move these systems into stages 4 and 5.

Group 3 (GR, LV, EB): These systems have moved through erosive processes from an initial stage to stages 1 and 2in Es Grau and Es Bot and the reversion to 4 in the case of La Vall. The most notable of both is that only passive intervention techniques were used. Only user control measures through enclosures and limitation of mechanized actions were implemented. The absence of barrier installations has facilitated the naturalness of the system. Nevertheless, in La Vall extreme storm events affected the stabilization of the front and reactivation of blowouts.

7. Conclusions

The main conclusion of this work is that the use of principal component analysis (PCA) with a matrix, defined with 15 variables, over 10 beach-dunes systems and along a wide period of time, up to 21 years from 2000 to 2021, is a powerful tool to analyse their evolution and the utility of management actions applied on them.

The recovery trend of the front dune system shows a positive evolution until 2017. Nevertheless, all of them show points of reactivation or weakening, associated with the management carried out. From 2017, there is a return to regressive stages.

Dune restoration requires a significant effort, as well as the combination and integration of different environmental criteria. In this way, the benefits and services they provide are maximized. Dune

restoration attempts have been partially done in the beach-dune systems described in this work. The geomorphological criteria must be taken into account. The main reasons for this poor implementation can be summarized in the following points:

1. Lack of knowledge of wind dynamics has generated erosive processes associated with the techniques applied, such as accesses or interference traps inside erosive morphologies.
2. Installation of wind interference barriers without considering the sectors of each beach, interferences that they may cause, revegetation and/or walkways with the existing morphologies.
3. Wrong location of dissuasive cords, without following the natural line of the front dune morphology and consolidating erosive processes that favour, in the short term, greater beach areas to the detriment of the dune system.
4. Inadequate installation of walkways, which in some cases lead to the fragmentation of the dune front and increase erosive processes and in others to the burial of the infrastructure itself.
5. The lack of monitoring and maintenance, which offers a bad image to users, generates wind distortion and erosive processes.

The beach management techniques used in the Balearic Islands are widely applied and successful if they are based on geomorphological criteria and geo-environmental analysis for each dune system. Its cost is low, easy to apply and reusable in many cases. They use nature for their purpose and even in the case of mistakes, these can be reversible. It is important to bear in mind that, due to the dynamic nature of these systems, the dune morphological restoration on the coast and its associated vegetation may take time to recover in periods of time that can reach and even exceed 10 years. In general, dune restoration based on sustainable criteria is usually a recurring action over time (Hesp and Hilton, 2011), hence the importance of its monitoring and maintenance.

The observation of long periods of time has not been considered in the restoration of the dune systems of the Balearic Islands. It is necessary in order to make a reliable diagnosis of the evolutionary behaviour of the coastline and its relationship with the front dune systems (Boak and Turner, 2005; Martín-Prieto *et al*., 2008).

Finally, measures that have been carried out in recent years have a markedly aesthetic character. As example, the installation and correction of wind interference barriers, not installed or installed just before the tourist season without previous studies of suitability or follow-up. Moreover, they are normally neglected in winter periods. It also has been found that the actions carried out in recent years –where some beach-dune systems show a regressive trend- have been minimal on the geo-environmental sensitivity curves of the system, some justified by the economic crisis (Roig-Munar *et al*., 2017).

Restoration works would have been more effective with the realization of spatio-temporal studies of each beach-dune system. Also, they need to apply geomorphological criteria on the front dune system and a plan for monitoring, maintenance and evolutionary analysis of each restoration.

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