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Sand dune management problems and techniques, Spain.

Gregorio Gómez-Pina†, Juan J. Muñoz-Pérez‡, Jose L. Ramírez†, Carlos Ley∞

†Dirección General de Costas, Ministerio de Medio Ambiente, Plaza San Juan de la Cruz s/n, Madrid 28071, Spain, pyoggp@m.dgc.mma.es
‡Demarcación de Costas de Andalucía Atlántico, Marianista Cubillo 7, 1106 Cádiz, Spain
∞Ecología Litoral, Príncipe de Vergara 56, 3º,9, 2806 Madrid, Spain

ABSTRACT

Extensive Spanish dune areas were totally altered and destroyed in the course of massive tourist urbanization and road construction projects during the 1960´s-1970´s. Littoral drift interruption by harbour and marinas as well as sand mining for construction and agriculture purposes also contributed to accelerated dune erosion. Furthermore, human trampling, refuse dumping, excessive dune recreational pressure, use of all-terrain vehicles and cropping, are amongst the main causes contributing and accelerating physical and ecological degradation of most Spanish dune systems.

Before 1988, Spanish coastal dunes were totally unprotected. The 1988 Spanish Shore Act ("Ley de Costas") arose with the aim of regulating the coastal activities and preventing littoral destruction. The Spanish Shore Act protects all coastal dunes precludes their destruction by sand mining and any other form of development, . However, this law still does not prevent some of the above negative activities occuring. Furthermore, the complexity of existing boundaries of the different authorities involved in coastal zone management policy makes integrated dune management a difficult task.

The National Spanish Coastal Authority, Ministry of Environment, have been aware of this problem and undertook a strong policy on dune restoration which has been incremented yearly. In this paper the main dune problems found along the Spanish coastline are outlined, paying particular attention to the analysis of certain case studies and an overview of the different dune restoration techniques used is given. Seven representative examples in which the authors were involved are discussed.

ADDITIONALINDEXWORDS: *dune restoration; Spanish coastal dunes; dune damage;; dune management; sand fenc - ing; aeolian transport; Spanish Shore Act*

INTRODUCTION

The sand dunes that fringe the Spanish coastal landscape also serve an invaluable practical purpose. They act as a resilient barrier to the destructive forces of waves and wind. Dunes absorb the impact of high-energy storms preventing or delaying intrusion of waters into inland areas. Beaches and dunes are integral parts of a dynamic cycle in which sand is constantly exchanged. During high-energy storms waves flatten the beach and erode sand, undermining and collapsing the seaward dune. Retreating waves transport the eroded sand offshore and deposit it just seaward of the surf zone in large bars. These sandbars dissipate storm wave energy by causing waves to break further offshore.

On the other hand, the calmer waves carry sand from offshore bars and the surf zone to the beach, causing the beach to gradually accrete. Thus it can be said that dune systems are the most efficient and least expensive defence against shoreline erosion. However, the loss of vegetation that traps and holds sand makes the dunes and beach more susceptible to wind and water erosion. Human activities also take a toll on dunes with tourist urbanisation, road constructions, human trampling, recreation, cropping and grazing animals accelerating or worsening natural damage to the dunes by destroying vegetative cover and promoting development of breaches.

OBJECTIVES

The main objectives of this paper are twofold:

- To demonstrate the main dune problems found along the Spanish coastline.
- To explain different dune restoration techniques and outline the analysis of real case studies

CAUSES OF DUNE DEGRADATION IN SPAIN

Cases of dune degradation in Spain have been analysed by various authors : BONNET FERNÁNDEZ-TRUJILLO (1989), SANJAUME and PARDO (1992),VAN DER MEULEN and SALMAN (1995), RAMIREZ and LEY (1998,1999), GÓMEZ-PINA(1999), COLMENAR (2001), OSORIO *et al*. (2001), MUÑOZ-PÉREZ *et al.* (2001). The main causes for dune degradation in Spain consists of the following:

1. Massive tourist development
2. Road and boulevard constructions
3. Dune mining
4. Littoral drift interruption
5. Dune recreational pressure
6. Inadequate waterfront constructions
7. human trampling
8. off-road vehicles and parking lots
9. agricultural practices and afforestation
10. garbage dumping
11. water extraction
12. civil engineering works
13. Military use

Broadly speaking the most severe damaging causes of dune degradation may be 1 to 4 with intermediate causes, 5 to 9 and the least damaging causes represented by 10 to 12.

In Spain, the large scale urban development carried out on the foredunes during the tourist boom of the sixties and seventies caused the destruction of many Spanish dune systems. As a result of such massive dune occupation, most of the Spanish coastline started to show signs of erosive patterns, particularly in most of the tourist spots.

Before 1988 the Spanish coastal dunes were totally unprotected. The 1988 Spanish Shore Act ("Ley de Costas") was passed with the objective of regulating the coastal activities and impeding as much as possible the littoral destruction. The Spanish Shore Act protects all the coastal dunes, effectively banning sand-mining, development on the public domain, and also changes in land uses. However, this law does not prevent some of the above mentioned negative activities from occurring. Furthermore, the complexity of boundaries of the different authorities involved in coastal zone management policy (State Government, Provincial Government, Municipality, Military) makes integrated dune management difficult.

In general, once the main causes for dune degradation are either eradicated or mitigated, "soft" techniques, such as sand trapping, transplanted vegetation, fencing, dune walkovers and environmental dune information dissimenation, seems to be very efficient against dune degradation. Detailed descriptions of these dune restoration techniques are shown in RAMÍREZ and LEY (1998,1999).

Figures from GÓMEZ-PINA(1999) are representative of dune degradation in La Bota beach (Huelva). Figure 1 shows a typical dune breach caused by off-road vehicles and human trampling. Figure 2 depicts the existing public road, crossing the foredunes longitudinally. The removal of this road is part of a very ambitious integrated dune management project being carried out by the National Spanish Coast Directorate, Ministry of Environment.

Figure 1. Typical dune breaching in La Bota (Huelva, Spain), Gómez-Pina 1997

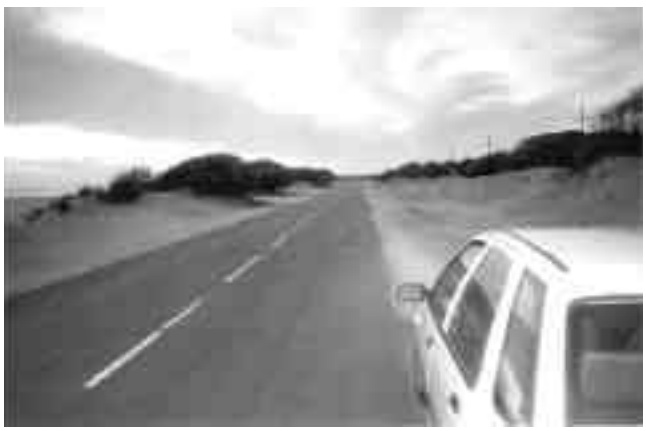

Figure 2. Existing road alongside La Bota beach (Huelva, Spain), Gómez-Pina 1997.

Examples of Dune Restoration Works in Spain.

Although many dune restoration projects have been carried out in Spain in the last ten years (i.e. COLMENAR 2000), only some representative examples in which the authors were involved, are presented below. The cases correspond to the northern maritime façade (Cantabrian sea and North Atlantic ocean) as well as to the Southern façade (Atlantic ocean and Mediterranean sea).

1. Somo spit, (Santander, Cantabrian)

The Somo spit, located in Santander (Cantabrian sea), is a very distinctive spit formation in Santander bay. The spit dimensions are approximately 2,500 m long by 150 m wide,. In the central section a dune system is formed, acting as a buffer against high-energy storm waves, preventing or delaying intrusion of water and sediment into inland areas. This natural spit formation has been subjected to important transformations due to natural processes as well as anthropogenic influences (e.g. Santander harbour, urban development, etc).

Since 1992 dune restoration works have been carried out in several phases consisting of the reinforcement of the deteriorated dune system by using willow sand trappers in conjunction with transplanted vegetation (ammophila arenaria) from the neighbouring dune plant nursery. Fencing was used in sensitive areas to reduce the effects ofhuman trampling. Elevated dune walkovers for access to the beach were conveniently placed near parking areas, beachfront subdivisions and public facilities to avoid damage to the dunes from pedestrian traffic. Finally, information posters were placed in adequate locations to make beach visitors aware of the importance of the dunes and the restoration works in place.

Figures 3 and 4 show aerial views of Somo spit before and after dune restoration. In Figure 5 a detailed perspective of fencing and transplanted vegetation is displayed.

Figure 3. An aerial view of Somo spit (Cantabrian, Spain) before dune restoration.

Figure 4. An aerial view of Somo spit (Cantabrian, Spain) after dune restoration.

2. Liencres spit (Piélagos, Cantabrian)

Liencres spit, located in the mouth of the Pas river and is one of the most important spit formations in the Cantabrian sea, not only for its dimensions but also for its natural and ecological value. The Liencres' wide dune system has suffered a continuous process of degradation due to former extensive sand mining, excessive tourist pressure and also from the occurance of several unfavourable wind, tides and storm events. As a result, the seaward dune face was undermined and collapsed, loosing vegetation and becoming very vulnerable. Dune restoration works ended in 1999 consisting, as in Somo spit, of the use of sand trappers, transplanted vegetation, fencing, walkover construction and educational posters.

Figure 5. Fencing and transplanted vegetation in Somo spit (Cantabrian, Spain).

Figure 6. An aerial view of Liencres spit (Cantabrian, Spain) after breaching.

Figure 7. A detail of dune restoration in Liencres spit (Cantabrian, Spain)

Figure 8. Dune walkover and fencing in Liencres spit (Cantabrian, Spain)

Figure 6 depicts an aerial view of Liencres spit after dune breaching. In Figure 7 sand accumulation caused by willow fences can be seen. Elevated dune walkovers and fencing are shown in Figure 8.

3. Cuchía beach (Miengo, Cantabrian)

As a result of former sand mining, human trampling and disorderly garbage dumping in Cuchía beach, coppice mounds and foredunes lost all kind of dune vegetation presenting a very degrading state. After cleaning operations, foredunes were restored with adequate dredging from the neighbouring inner harbour in Suances estuary ("ría"). Finally, willow sand trappers together with transplanted vegetation were used to stabilise the foredune surface.

Figure 9 shows an aerial view of Cuchía beach and Suances estuary. A panoramic of Cuchía beach after rehabilitation is depicted in Figure 10.

Figure 9. An aerial view of Cuchía beach (Cantabrian, Spain)

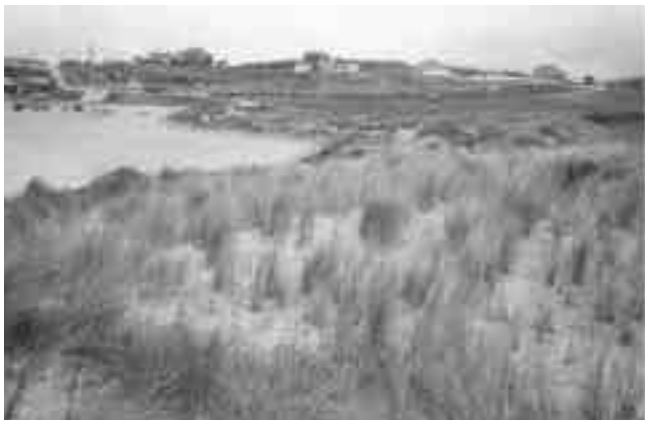

Figure 10. Cuchía beach (Cantabrian, Spain) after dune restoration

4. La Lanzada isthmus (O Grove, Galicean)

La Lanzada isthmus is one of the most emblematic beaches in the province of Pontevedra (North Atlantic façade). The direct burden on the beach caused by tourism and a bad commuting road system on the foredune itself made the whole dune system and beach very vulnerable. The goal of the dune restoration project was very challenging trying to both eliminate the main dune problem (the road) and reinforce the primary frontal dunes. The demolition of the existing public road across the dunes and the construction of an alternative road further inland from dunes was a controversial social issue that was, in the end, well accepted. Willow sand fencing and transplanted vegetation was used to rebuild the dune areas damaged by the road. Damage to dunes from pedestrian traffic was avoided by the use of elevated walkovers constructed parallel and perpendicular to the beach. Selective areas were

Figure 11. La Lanzada beach (Pontevedra, Spain) before dune restoration

Figure 12. La Lanzada beach (Pontevedra, Spain) afterdune restoration

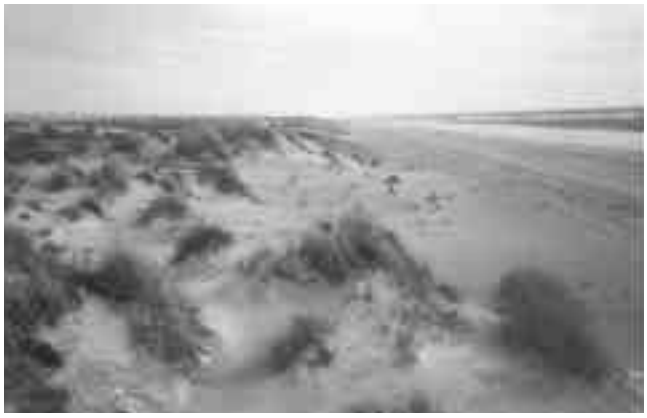

Figure 13. Dune blow-outs in Isla Cristina beach (Huelva, Spain)

Figure 14. Grazing in Isla Cristina beach (Spain).

Figure 15. Dune fencing and revegetation in Isla Cristina beach (Huelva, Spain)

fenced and educational posters were displayed alongside the whole dune restoration work. Presently, local people and visitors can enjoy the beautiful "new" beach landscape.

Figures 11 and 12 show aerial views of La Lanzada beach before and after dune restoration.

5. Isla Cristina beach (Huelva)

The relatively high longitudinal net sediment transport along the Huelva coast (up to 400,000 m^3/year eastward) together with littoral drift interruption by the harbour entrance jetties, decrease sediments by river discharge and urbanisation developed too close to the beach generally expose Huelva beaches and foredunes to high erosive rates. Isla Cristina beach is one of the representative Huelva tourist beaches showing beach and foredune erosion due to the conjunction of the aforementioned causes and in particular to the interruption of the littoral drift (approximately 150,000 m^3/year eastward) by the Carreras and Guadiana entrance river jetties.

As a consequence of the high longitudinal littoral drift rates, it is precluded, in general, to use coastal structures to stabilize Huelva beaches . Only beach nourishment and /or dune restoration are the prefered methods to mitigate erosive coastal processes in Huelva beaches.

Fig.13 shows typical dune blow-outs in Isla Cristina beach. Fig.14 depicts an illustrative grazing scene. Fig.15 shows dune fencing and revegetation.

6. Valdevaqueros Dunes (Tarifa, Cadiz)

The special characteristics of these mobile dunes together with their natural and scenic values confer to Valdevaqueros cove a great attraction. The frequent local Levante wind regimes give rise to high wind speeds of up to 100 km/hr. The high longitudinal aeolian transport is responsible for building up a huge dune at the northern beach side. Wind conditions and low rainfall, together with the direct burden caused by dune visitors, make it difficult to establish permanent vegetation on the dune. As a result the dune became unstable, showing a continuous massive movement towards an adjacent pine grove.

Dune restoration works started with the reshaping of the dune profile in order to obtain a better aerodynamic stability complemented with the experimental use of longitudinal willow sand fences to decrease erosive surface patterns. Also experimental transplanted vegetation techniques were used along certain potentially stable areas.

At present a second phase is being carried out with the aim of re-establishing the natural dune equilibrium based on the experimental results obtained in the first project phase. Also an integrated dune management program is under study in order to minimize human negative impact on the whole dune system.

Figure 16. An aerial view of Valdevaqueros cove (Cádiz, Spain)

Figure 17. A view of Valdevaqueros backdune restoration (Cádiz, Spain)

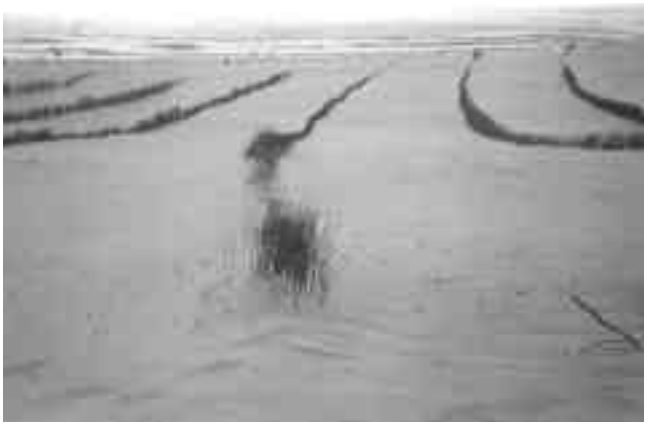

Figure 18. A view of Valdevaqueros accreted foredune after restoration (Cádiz, Spain)

Figure 16 depicts an aerial view of Valdevaqueros cove. Figure 17 shows backdune restoration near the adjacent pine grove. Figure 18 shows foredune accretion after restoration.

7. Guadalquiton Beach (San Roque, Cádiz)

Guadalquitón beach (Fig. 19) is located in the Guadiaro river estuary on the Mediterranean sea, under the influence of the waters from the Gibraltar strait. Coastal dunes at the Mediterranean sea are, in general, less developed than Atlantic dunes due, among other factors, to the almost absence of tides in the Mediterranean sea. Extensive Mediterranean dune areas were totally altered and destroyed in the course of enormous tourist urbanisation projects during the 1960s-1970s (e.g. the beautiful barrier island of La Manga in Cartagena, GÓMEZ-PINA 1999). Furthermore, littoral drift interruption by harbour and marinas contributed to the acceleration of dune degradational proccesses. Although the case of Guadalquitón beach did not escape from this problem its conditions at the time of undertaking the restoration project were not as irreversible as in other Mediterranean beaches.

The dune restoration project was only a part of an integrated plan to improve coastal zone management aspects at the Guadiaro estuary, such as river flushing recovery, garbage cleaning, water quality improvement, wetland restoration, fencing of sensitive areas, public access improvement, sea bird observatories, beach nourishment and dune reinforcement. New sand trapping methods were experimented with as well as native transplanted vegetation under critical climatic conditions (yearly run-off is less than 250 mm)

Figure 19. An aerial view of Guadalquitón estuary after restoration (Cádiz, Spain)

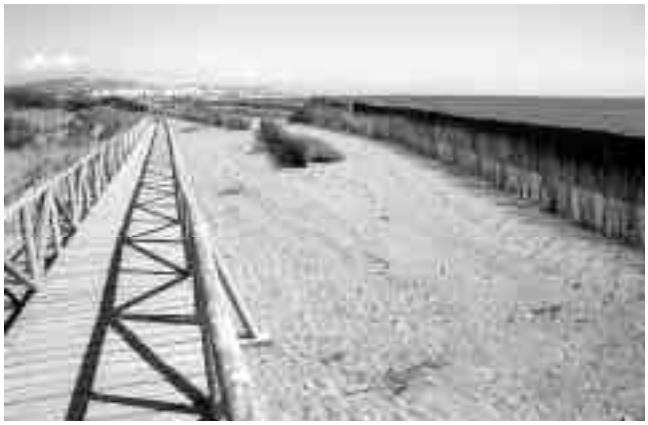

Figure 20. A detailed view of Guadalquitón dune restoration (Cádiz, Spain)

CONCLUSIONS

a) Extensive Spanish dune areas were totally altered and destroyed due to massive tourist urbanisation during the 1960-1970 together with traditional sand mining and road construction. Littoral drift interruption, recreation, off-road vehicles, trampling and cropping also contributed to the acceleration of physical and ecological degradation of most of the Spanish dune systems.

b) Until the 1988 Spanish Shore Act ("Ley de Costas"), Spanish dunes were totally unprotected. Even though this Law protects all the coastal dunes, banning dune sand mining, development and changes in land use, there are still some other negative activities which are not specifically regulated in the Law.

c) The complexity of boundaries of the different authorities involved in coastal zone management policy (State Government, Provincial Government, Municipality, Military) makes integrated dune management challenging but difficult.

d) The National Spanish Coastal Authority, Ministry of Environment, aware of the Spanish dune problems, undertook a strong policy on dune restoration .The budget and number of dune restoration projects have been incremented yearly.

e) "Soft" techniques, as the ones explained in this paper, consisting of sand trapping, transplanted vegetation, fencing, dune walkovers and environmental dune

information seem to be very efficient measures against dune degradation, once the main causes for dune degradation are eradicated or mitigated.

f) The Cantabrian nursery, owned and managed by the National Spanish Coastal Directorate, Ministry of Environment, has proved to be sufficiently productive and economical. In particular dune plant costs have decreased enormously from the first experimental year in 1990 (17.89 € /plant) until presently (0.19 € /plant). New dune nurseries and vegetation techniques are presently under study.

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