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Restoration of an ancient dune system enhancing landscape perception

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Abstract

The Doñana National and Natural Parks (SW Spain) present two distinct substrates: the marshes, a silted-up former estuary, and the sands, a Pleistocene detritic formation of gravels, which has been repeatedly covered by dune mantles. The last historical dune-building period occurred during the Little Ice Age (XVI to XIX Centuries) with repeated pulses of dune advance and stability reaching to the El Partido stream watershed to the N of the Parks. The successional response of vegetation developed a cork oak forest with scattered wild olives and elms and dense scrub vegetation. Ashes and willows grew along stream banks. Early in the XX Century scrub was cleared and umbrella pines were planted, although some of the area was reserved for crops. By 1970, to further expand agriculture, most trees in the area had been removed and the old dune morphology was partially erased by wind blow. In 2004, the Spanish Ministry of Environment bought some 4,000 ha of El Partido watershed for ecological restoration in the framework of the Doñana 2005 Project, a large hydrology and landscape plan for the restoration of the Doñana Parks. The landscape restoration of the watershed now under way includes forestation and plantation of native scrub to reconstruct plant communities in order to support threatened vertebrate populations. However, the old dunes are subject to a different treatment with the purpose of recovering their primeval vegetation and to make them more noticeable in the landscape. The paper briefly describes the vegetation, hydrology, and ecological history of the area focusing on the restoration of the ancient dunes and the enhancement of their visual perception.

1 Introduction

1.1 The stabilised dunes of Doñana

The Doñana National and Natural Parks are situated on the southwest coast of Spain to the west of the Guadalquivir River, which flows into the Gulf of Cadiz in the Atlantic Ocean. Littoral currents built up sand deposits in the littoral zone, building a wide spit at the mouth of the Guadalquivir River estuary where marshes evolved during the Holocene. Oncoming winds favoured the transport of coastal sand deposits inland forming sand sheets. The rolling morphology that evolved during alternating episodes of dune activity is recognisable 15-20 km inland (Lario et al. 2002). At present, active dune fields are limited to the coastal strip, and sand substrates with old dune morphology dominate the landscapes to the west and north (García Novo & Merino 1993). Four main land units have been traditionally distinguished in the Doñana National Park: inland marshes, mobile dunes, stabilised dunes, and the Vera, a transition band between the dunes and the marshes (García Novo 1997, García Novo & Merino 1997). At a small scale, the plant composition of the stabilised dunes of Doñana is arranged in parallel bands along dune slopes following local topography (González Bernáldez et al. 1975). Geomorphology controls the vegetation pattern at different scales, through water availability from dune ridges to slacks, exhibiting a sequence of xerophytic scrub, mixed scrub, and heath. Drier crests exhibit *Thymus mastichina*, *Lavandula stoechas*, *Scrophularia frutescens,* and *Halimium commutatum*. Mid slope shrublands are dominated by *Halimium halimifolium* and *Stauracanthus genistoides* and in floodable depressions *Calluna vulgaris*, *Erica scoparia*, *E. umbellata*, and *Myrtus communis* are often associated with *Pteridium aquilinum*. Superimposed, cultural interactions operate as modeller agents at a small scale and a short term (Granados Corona et al. 1988), interacting with succession and climatic shifts at larger scales of time and space (Muñoz Reinoso & García Novo 2005).

Prescribed fire regimes have promoted pyrophytic Mediterranean shrubs, which now dominate the scrub vegetation. Only a few thickets of mature scrub survive, being composed of fruit-bearing species such as *Quercus coccifera*, *Arbutus unedo*, *Phillyrea angustifolia*, *Pyrus bourgaeana*, *Pistacia lentiscus*, *Rhamnus oleoides* ssp. *lycioides*, *Crataegus monogyna* and *Chamaerops humilis*. Close to the coastal zone *Retama monosperma* forms dense stands often becoming the only woody species. A few remnants of the native juniper woodlands (*Juniperus oxycedrus* ssp. *macrocarpa* and *J. phoenicea* ssp. *turbinata*) survive in dunes close to the coastal fringe. *Pinus pinea* plantations started in the Doñana area in 1737, spreading from a single site to become the main woodland of the Parks at present. Retama, oaks, junipers, and pines are now dispersed by wild vertebrates.

1.2 Study area

The area for restoration covers about 2300 ha towards the north-east border of the Doñana National Park, in the floodplain of the El Partido stream, a tributary of the Doñana Marshes (see Fig. 1).

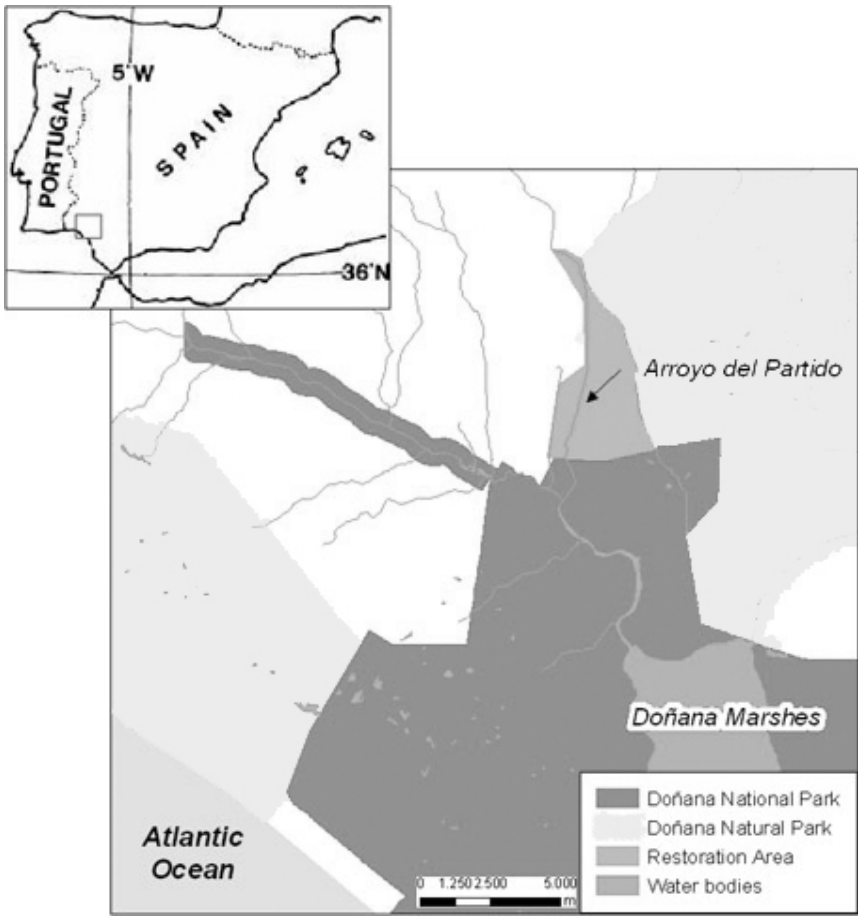

Figure 1: Location of the El Partido stream restoration area.

The El Partido floodplain is covered by sandy sediments deposited by floods. The morphology of transgressive dunes developed during the Little Ice Age (XVI-XIX Centuries) is noticeable (García Novo et al. 2006, Rodriguez Ramirez et al. 2002, Sousa & Sarcía Murillo 2003).

The Mediterranean-type climate receives some oceanic influence. Average annual rainfall is 600 mm, with two peaks: November-December and March with little rain from June to September and a rainless August with high summer temperatures (July and August average temperature: 23 °C). Winter temperatures are mild with a minimum in January (average temperature of 9 °C) and only a few frost days in winter months.

1.3 The El Partido Stream Restoration Project

The Spanish Ministry of the Environment launched in 1998 the Doñana 2005 Project with the goal to restore the hydrology of the Doñana National Park (Saura Martínez et al. 2001) as a basis for conservation. It comprises six key interventions, one of them being the restoration of the El Partido Stream watershed. The stream exhibits a marked torrential regime, due to a rainfall pattern with intense spells. Early in the 1980's the last 7 km of the stream were channelled, and the surrounding flood plain was levelled, tilled and converted into arable land or left as pastureland. Over the last 20 years, the hydraulic impact of collecting the dispersed braided channels of the area into a single straight course led to major erosion of the channel bed and the creation of a large depositional delta (now over 300 ha) on the Doñana National Park marshes (Mintegui Aguirre et al. 2003).

The restoration of the El Partido watershed is being carried out at different spatial levels using an interdisciplinary approach, with the following aims:

1) to prevent the further silting-up of the marsh by avoiding bed erosion and the transport of sand; 2) to recover the former aquatic habitats; 3) to create functional ecosystems for target species (Iberian lynx, imperial eagle and their prey, namely rabbits); 4) to restore some of the original ecosystems of the flooding area, applying the principles of population ecology, community ecology, and landscape ecology (Carotenuto et al. 2006, García Novo et al. 2006).

One of the restoration targets are the former transgressive dunes, which have undergone tree plantation and crop cultivation resulting in dune-field fragmentation and the blurring of dune morphology. This paper describes the restoration of the vegetation in the ancient dune field incorporating landscaping actions aiming at the perception of dunes from the public.

The floristic composition and structure of the vegetation in the stabilised dunes of the nearby National Park have long been studied by many scientists such as González Bernáldez et al. (1971, 1975), Allier et al. (1974), García Novo (1990), Granados Corona et al. (1988) and Muñoz Reinoso (2001), to name a few. The availability of aerial pictures from 1946 onwards, supported the interpretation of ecosystem and landscape changes and the mapping of previous vegetation types.

2 Restoration of an ancient dune system enhancing landscape perception

The first restoration step has been the survey of the vegetation and morphology of the El Partido stream floodplain and the identification of preserved reference ecosystems.

The present day landscapes in the El Partido floodplain are abandoned crop fields, cultivated until 2002-03. Post-cultural grasslands, with ruderal forbs and tall grasses cover the abandoned fields. Some relicts of the former vegetation such as isolated cork oaks, pines, kermes oaks, pear trees and scattered *Chamaerops humilis*, *Pistacia lentiscus* and *Crataegus monogyna*, survived in the fields. Succession to woodland is dominated by scrub, often arranged in dense isolated clusters. A few transgressive dunes retained their geomorphology but are of a low height (0.5-1 m above the surrounding topography). They preserve vegetation similar to the stabilised dunes of the National Park, mainly composed of *Halimium halimifolium*, *Lavandula stoechas,* and *Rosmarinus officinalis*. This vegetation is accompanied by scattered *Quercus coccifera* trees, planted orchards of *Pyrus bourgaeana*, and some *Chamaerops humilis* or *Rubus ulmifolius* stands in the lower part of the dune slopes.

The large distance (almost 10 km) to the sources of seeds of dune shrub species from the National Park, and the scarcity of remnants of mature vegetation, prevents an adequate seed supply to the area, making succession to more mature stages of dune vegetation virtually impossible. In addition, the long-standing human intervention in the area has obliterated the original morphology leaving only a few of the ancient dunes clearly visible.

This explains why it was decided to undertake the ecological restoration of dune vegetation incorporating elements to enhance the visual perception of dune morphology for future visitors of the area. Strictly speaking, the plantation of dune species not found in the area at present cannot be regarded as

ecological restoration. However, two arguments deserved our consideration: the plantation of shrubs meets the restoration objectives of the area in relation to endangered vertebrate populations since their main prey, the rabbit, will be strongly favoured. And secondly, plantation restores the natural dune landscape lost in the area due to past human intervention.

The addition of sand to return dunes to their former height has been dismissed. This artificial sand contribution could drive the system further away from its self-sustained goal and damage the populations of surviving dune species that belong to stabilised dune stages and hence are not adapted to burial. The opening of ditches around the dunes to lower the soil water table and to restrict the root-access to phreatic waters was also considered, but rejected, because it would create an artificially sustained system and affect the actual dune morphology.

2.1 Preservation of visually distinctive dunes

Only those dunes retaining a noticeable morphology and suitable dune vegetation (*Halimium halimifolium*, *Rosmarinus officinalis*, *Lavandula stoechas*, and a few others) have been considered for intervention.

Plantations:

Dune vegetation shows a well-defined pattern according to substrate stability. Where sand movement ceases, succession favours scrub development. In some species, such as *Retama monosperma*, it has been shown that rabbits have a role as active dispersers of the species, which in turn favours the development of dense burrows under *Retama* conopy (Dellafiore et al. 2006).

Table 1 includes the list of species used in plantations. Only a few trees were planted and at specific locations. Other species were planted in clumps with the exception of *Retama monosperma*, which was planted delineating the dune contours and favour its identification in the El Partido stream watershed. In addition, the low-height plantations at the base of dune slopes favours access of rabbits to its fruits and the eventual dispersion of the species in the area.

Table 1: List of dune species to be used in restoration.

Dune species	Distance to phreatic table
Juniperus oxycedrus ssp. *macrocarpa*	Low
Juniperus phoenicea ssp. *turbinata*	High
Halimium halimifolium	Intermediate
Cistus libanotis	High
Lavandula stoechas	Intermediate
Rosmarinus officinalis	Intermediate
Thymus mastichina ssp. *donyanae*	High-intermediate
Retama monosperma	Intermediate

From a landscape perspective, the plantation of these species will be accomplished in a way that enhances the visual perception of the dune and its constituent parts. To favour this perception, the plantation will highlight the different parts of the dune (dry, intermediate and humid) by locating the drier species in the upper parts of the dune (*Juniperus phoenicea* ssp. t*urbinata*) and *Juniperus oxycedrus* ssp. *macrocarpa* and other species along the slopes of the dune and delimitating its perimeter. Figure 2 shows an example of the restoration of one of the remaining dunes.

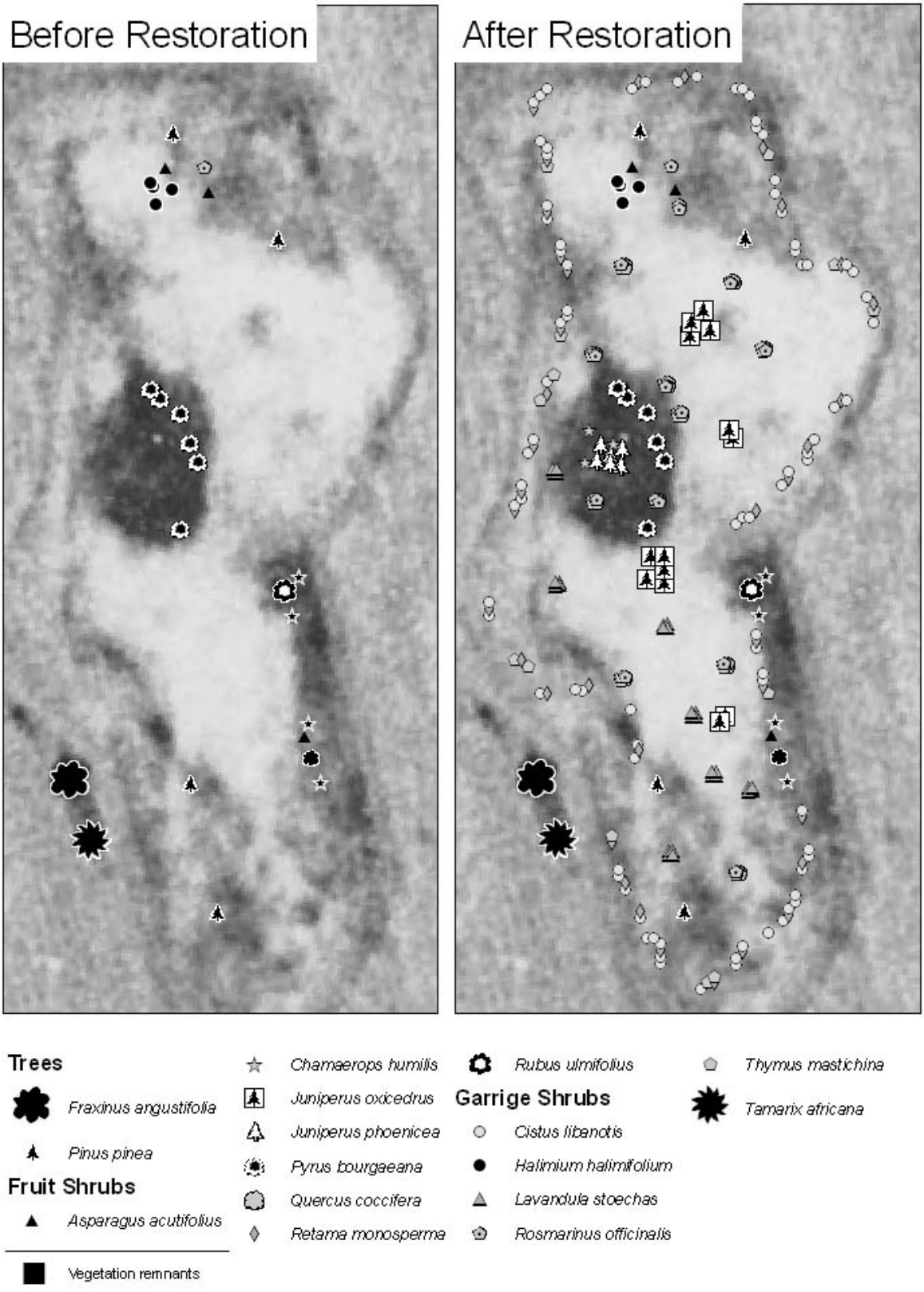

Figure 2: Vegetation present in the dune before and after the restoration.

The plantation of individuals of *Cistus libanotis*, *Thymus mastichina* and *Retama monosperma* along the base of the dune will visually delimit its perimeter. If *Retama monosperma* grows above its desired height, pruning or even elimination of some individuals could be considered once the other dune species have reached their desirable development. *Juniperus oxycedrus* ssp. *macrocarpa* will be

planted on the tallest parts of the dune to add height to dune vegetation and serve as focal points. This pointed-shaped species will be easily differentiated from the rounded shaped umbrella pines present in other parts of the restoration area. Individuals of *Juniperus phoenicia* ssp. *turbinata* and *Chamaerops humilis* will point out the location of the inner depression, and small patches of *Lavandula stoechas*, *Halimium halimifolium* and *Rosmarinus officinalis* will be planted along the intermediate part of the dune.

Besides the difference in the species shape, their flowering colour will also constitute a plant trait that will help in visitors' interpretation of the dune parts during the different flowering seasons.

2.2 Enhancement of perception

On sandy substrates with an almost flat morphology, the aim of restoration was to make the dune remnants more noticeable in the landscape. This will be accomplished by leaving dune borders as bare sand boundaries in sharp contrast amidst scrub; preserving the remaining vegetation (typical vegetation of stabilised dunes), and the plantation of the open vegetation type that prevails in the Doñana sand mantles (see Table 1).

Where the ancient dune landscape has been erased, that is, where there is no dune morphology left, the restoration includes the afforestation and plantation of native Mediterranean shrubland to reconstruct plant communities and to enhance vertebrate populations. Existing remnants of woody vegetation covering about 7.66 ha (2.2 %) will be restored, adding about a 3-fold surface (26.8 ha, 7.8 %) of new plantations. In addition, 545 new vegetation patches, initially covering 20.53 ha (about 6 % of the area) will be planted, following composition and structure of the natural scrub. Each patch combines 5-10 perennial species: a core of a few trees, an inner area with some fruit-bearing shrubs, and the outer fringe with flower-bearing shrubs. Riverbanks will also be vegetated (for further details, please refer to García Novo et al. 2006, García Novo & Marín Cabrera 2006).

Restoration of dune landscapes may be focused on sand transport, geomorphology, coastal vulnerability, biodiversity purposes, visitors use, and many other objectives. This paper suggests how the restoration of vegetation in an ancient dune field can incorporate the perception of the remaining ancient dune landscape, without impairing recovery of the natural ecosystem properties.

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