-Versión Aceptada-

Mediterranean Dune Vegetation: Study for the Conservation of a Threatened Ecosystem in Southern Spain

José Gómez Zotano, José Antonio Olmedo-Cobo, Jonatan Arias-García

ABSTRACT. This paper investigates the plant diversity and current state of the vegetation of a little-known threatened dune complex located in southern Spain. This littoral fringe has in the past 60 years experienced a continuous process of intensive occupation derived primarily from tourism and agriculture, which has led to the degradation of the fragile and dynamic coastal systems. Its diminished size and lack of legal protection make it vulnerable to a variety of anthropogenic stresses that threaten the survival of the system. Fieldwork has been the primary methodological procedure to conduct research, given the scarcity of previous studies.

The results first of all provide a biogeographical and phytosociological view that elucidates the remarkable plant diversity of the area studied and the complete zonal structure of the communities that comprise the ecosystem. Secondly, a vegetal cartography was created (detail of 1: 2,500) to characterize the distribution of flora. This exploration and mapping of vegetation are effective tools in forming a conservation proposal to combat anthropogenic conflicts that destabilize the system. In this sense, the harmful human activities threatening the plant phytodiversity of the various strips of vegetation forming the dunes have also been identified.

KEY WORDS: Anthropogenic degradation, Costa del Sol, dune, endangered, phytodiversity, preservation.

Introduction

Coastal regions are areas of great geomorphological and biological diversity that have a strong natural dynamism associated with biotic and abiotic changes, natural cyclical dynamics, and fluctuations in sea level, geomorphology, sedimentary and erosive processes, and catastrophic weather events (Angiolini et al., 2013; Christiansen and Bowman, 1986; Lomba, Alves, & Honrado, 2009; Psuty, 2004; Soares de Carvalho et al., 2002; Tüxen, 1975). At present, these zones are subject to great and increasing human pressure, primarily due to urban expansion; the development of various economic activities, such as agriculture, tourism, and industry; and the construction of infrastructure, including roads, ports, and supply networks (Anthony and Psuty, 2014; Fenu, Carboni, Acosta & Bacchetta, 2013; Gómez-Zotano, 2009, 2014; Lemauviel, Gallet & Rozé, 2003). The result of this increasing human occupation of the coastal zone and the urgent necessity of economic development have placed constant pressure on the land-sea interface, which is increasingly destabilized in many countries throughout the world, resulting in alterations of the coast and aggravation of coastal communities' exposures to risks arising from high-energy events, global change, and rising sea levels (Anthony & Psuty, 2014).

Among the various coastal habitats, particular geo-biological diversity is found in coastal dune systems, including embryonic, mobile and fixed dunes, dune scrubs and woodlands, dune slacks and marshes, the last of which are unique habitats because of their ecological diversity and the occurrence of many rare and endemic species (Monserrat, Celsi, and Fontana, 2012; Nairn, 2005; Rodwell, 2000). The conservation of dune systems is especially relevant given the sands contribution to the stabilization of the coastal landscape and the protection of the hinterland, when coastal disasters occur (Choi, Kim, & Jung, 2013). These sandy environments are also fragile and prone to wind and water erosion (Kindermann & Gormally, 2013); moreover, the environments are among the habitats most affected by forestry, tourism, and water extraction, and in many cases, sand dune systems have become transformed to such an extent that they can no longer be considered natural systems (Lemauviel Gallet, & Rozé, 2003; Monserrat, Celsi & Fontana, 2012). Even in areas of less human activity, dune systems are particularly susceptible to destabilization by human activities related to recreational pressures that involve humans, animals and vehicles (Andersen, 1995; Kerbiriou, Leviol, Jiguet & Julliard, 2008; Kindermann & Gormally, 2010; Quigley, 1991; Thompson & Schlacher, 2008; Fenu, Cogoni, Ulian, & Bacchetta, 2013).

Human pressure on these systems especially affects psammophilous vegetation, which has suffered severe degradation in highly populated coasts, given its vulnerability and particular ecological requirements; in many cases, the native and endemic species have been eliminated or replaced by the introduction of non-native invasive species (Monserrat, Celsi, & Fontana, 2012). Endemic plants of the dunes are morphologically, anatomically, phenologically and physiologically adapted to severe environmental stress, high temperatures and lack of available fresh water (García-Mora, Gallego-Fernández, & García-Novo, 1999); thus, any direct anthropogenic alteration of these physical gradients threatens the stability of psammophilous plant ecosystems. This uniqueness limits their migration to different types of ecosystems, resulting in a large number of restricted coastal taxa, endemic and unique plant communities (Acosta, Carranza, & Izzi, 2009).

A specific case is the impoverished Mediterranean dune systems of southern Europe, which in the past 60 years have experienced a continuous process of intensive occupation resulting primarily from two types of apparently conflicting economic activities: tourism and agriculture (Gómez-Zotano, 2014). In direct relation to the first, urban land has led to the most categorical and irreversible transformations produced by humans. According to Brown and McLachlan (1990), McKinney (2006), Rust & Illenberg (1996) and Sanjaume & Pardo-Pascual (2011), this unprecedented littoralisation process has led to the disruption of natural mechanisms of formation and defence of the fragile and dynamic coastal systems and the unexpected mutation of coastal landscapes.

This paper investigates the current state of the vegetation of little-known and threatened dune complex of Matas Verdes (Andalusia, southern Spain). Its diminished size and lack of legal protection expose it to a variety of anthropogenic stresses that threaten the survival of the system. Given the existence of only one previous study, which is found in the work of Gómez-Zotano (2009, 2014), the present study addresses for the first time the biogeographical and phytosociological portrayal of vegetation based on fieldwork. The main objective is to correct the generalized deficiency in public and institutional awareness and knowledge about the composition, structure, distribution and importance of the psammophilous flora and vegetation of the Matas Verdes dunes. It offers a detailed mapping of the various communities studied as well as an enumeration of the harmful anthropogenic activities that threaten the plant phytodiversity of the various bands of vegetation forming the dune system.

Material and methods

Study area

The herein studied dune complex, known as Matas Verdes, is situated on the littoral of the province of Malaga (Andalusia, southern Spain), specifically in the conurbation of the western "Costa del Sol" (Sun Coast) (Figure 1). In this urbanized fringe, Matas Verdes occupies 11.8 hectares, where it is one of the few existing dune complexes. Therefore, a number of the few stabilized and edaphised dunes that have survived the combined activity of tourism and urbanization are located in this space (Gómez-Zotano, 2009). Throughout its 0.5 km of coastline, Matas Verdes configures a complete dune ridge which retain the five morphological stages identifiable in this type of environment (pioneer, embryonic, mobile, semi-fixed and fixed dunes). The dunes reach a maximum height of 8 m, in addition to the interdunal valleys and a slightly more elevated (maximum elevation of 12 m asl) postdune field that extend 200 m inland onto a private estate (Gómez-Zotano, 2009).

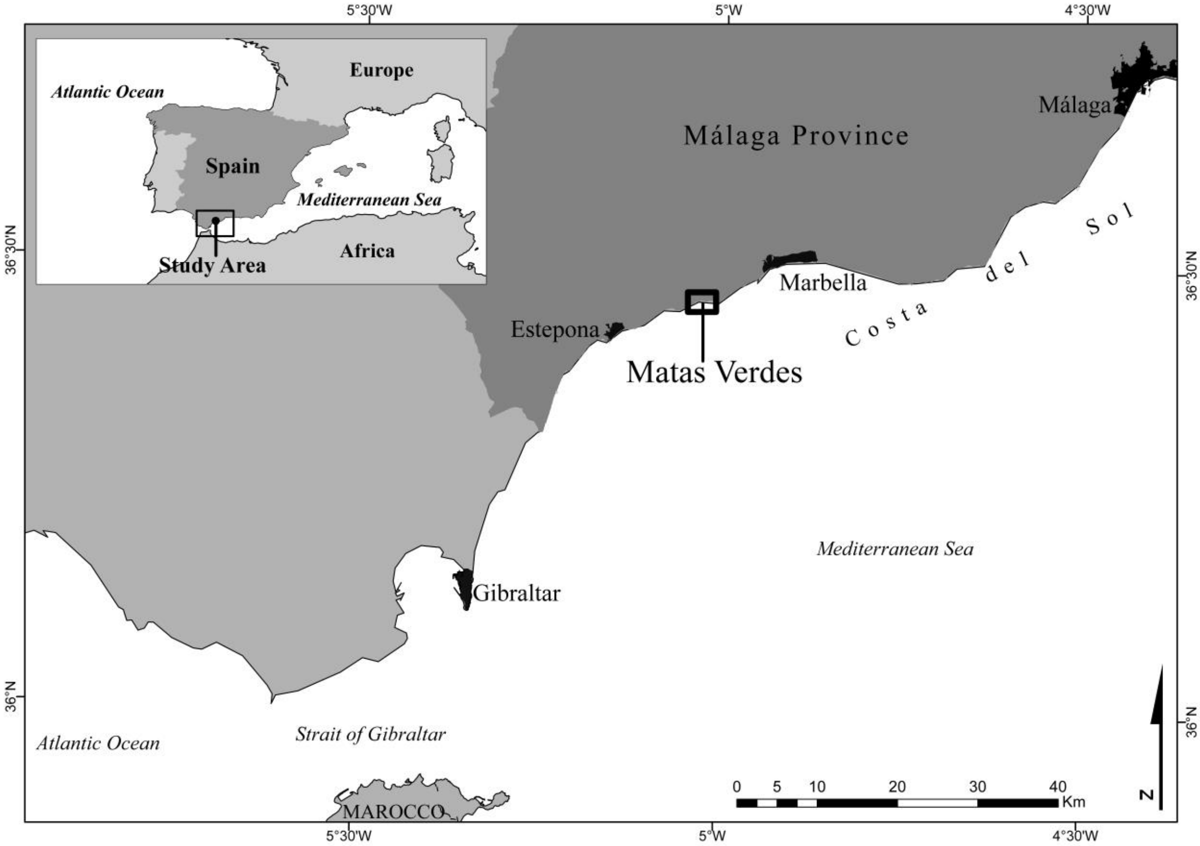

Figure 1. Location of the study area in southern Spain.

The great biological richness of this Mediterranean dune system is in part due to its geographical location at southern Spain, *i.e.*, its position between two continents, Europe and Africa, and two large bodies of water, the Atlantic Ocean and the Mediterranean Sea. This system exhibits characteristics of Atlantic dune systems with the presence of a remaining site of sabulicolous forests of *Quercus suber* in the postdune field. In addition, the fauna of this enclave is rich and varied, with numerous protected species and some, such as the chameleon (*Chamaeleo chamaeleon*), endangered (Gómez-Zotano, 2009). The natural interest of this site is complemented by the presence of numerous archaeological remains, such as Roman baths and two watchtowers in its immediate environment. The variety and uniqueness of these coastal ecosystems, therefore, make this area one of significant eco-cultural value with a considerable biological, geomorphological and landscape diversity (Gómez-Zotano, 2006, 2009).

Methods

Given the lack of previous phytogeographic studies and in conjunction with the advances collected in Gómez-Zotano (2009, 2014), the fieldwork was the primary methodological procedure of this investigation through a systematic and thorough analysis of the study area. This allowed the identification and location of the various communities and its mapping 1:1 with the support of aerial photography latest available (final detail representation to scale 1: 2,500), the detection of singular plant species, and conducting floristic samplings following the Sigmatist methodology of the Zurich-Montpellier School (Braun-Blanquet 1979; Gehú & Rivas-Martínez 1981) to indicate the abundance-dominance of the different taxa that integrate the plant communities identified in Matas Verdes.

The biogeographic references are those established by Rivas-Martínez (2011) and Valle (2003) for the Betic chorological province, and the acquisition of bioclimatic thresholds (thermotypes and ombrotypes), the Itc, Io, T, and P index was that suggested by Rivas-Martínez & Loidi (1999), and Rivas-Martínez (2011) for the Mediterranean region. For floristic and vegetation series taxonomy, syntaxonomical signs were taken as bibliographic sources of support of the works of Bañares, Blanca, Güemes, Moreno & Ortiz (2011), Blanca, Cabezudo, Cueto, Morales & Salazar (2011), Cabezudo & Talavera (2005), Castroviejo (2010), Costa, Peris, & Stubing (1986), Gómez-Zotano (2009), Moreno (2011), Pérez-Latorre (1998), Rivas-Martínez (2011), Valdés, Talavera, & Fernández-Galiano (1987) and Valle (2003). The taxa nomenclature followed the norms of the Phytosociological Nomenclature Code established in Weber, Moravec & Theurillat (2000). The chorological mapping of vegetation was drawn at 1: 2,500 using GIS (ArcGIS 10) from the results obtained from the fieldwork.

The thorough knowledge that authors have of environmental problems regarding this area of southern coastal Spain has provided the focus of the conservation and regeneration proposal presented in this paper. The starting point is the observation that in this type of plant habitats, one must take into account the regional importance, the local rarity and the habitat vulnerability in order to establish conservation priorities of species and plant communities (Gauthier, Debussche & Thompson, 2010). Moreover, the fragility and resilience of dunes, as well as dune structure and ecological dynamics, vary according to different environmental gradients (salinity, substrate mobility, wind exposure, soil xericity and insolation). The conservation of specific flora (and fauna) of dune systems addresses the multiple stresses on the littoral habitats and is also vital for the preservation of the ecological heritage and landscape that make up these systems.

Results

Based on fieldwork and the review of vegetational literature of Mediterranean coast in southern Spain, the present study provides the first biogeographical and phytosociological context for the framing of the Matas Verdes dune system. This knowledge is necessary for the analysis of the plant dynamic (phytosociological sampling and vegetation series) of Matas Verdes. As a graphic result of this study, it presents a chorological mapping of the current vegetation that colonizes the sands and the postdune area.

Biogeography and bioclimatology contexts. Syntaxonomical scheme

The dune complex of Matas Verdes belongs to the Mediterranean Region of the Holactic Kingdom according to the biogeographical distribution proposed for Andalusia by Rivas-Martínez (2007, 2011). It is important to emphasise the transitional nature of this area between the Betica (Rondeño sector) and Lusitano-Andaluza Litoral (Aljibico sector) chorological provinces, Matas Verdes being within the Marbellense district of this latter. The biogeographic ecotone has clear floristic connotations due to the appearance of taxa of both Mediterranean and Atlantic dune systems, highlighting the potential domain corresponding to the Atlantic sabulicolous forests of *Quercus suber*, characteristic of the SW Iberian Peninsula, in the postdune area.

This coastal area is located at the foot of a large sunny hillside (south slope of Sierra Bermeja, Betic Cordillera), where a temperate and humid littoral meso-climate of the Mediterranean nature is predominant, and in direct relation to prevailing western winds. These general orographic and climatic circumstances determine the bioclimatic conditions characterized by the development of lower thermomediterranean thermotype (Itc 411-470; T 18) and sub-humid ombrotype (Io 3.6-6; P 650-750).

In these biogeographic and bioclimatic contexts, there are three areas of potential vegetation in the dune complex of Matas Verdes: the psammophilous communities, the formation of *Juniperus turbinata*, developed in both cases on the dunes, and the sabulicolous forest of *Quercus suber* that occupies the consolidated sands of postdune area. The variations of the ecological conditions in both environments are related to the varying degrees of salinity, mobility of the substrate, wind exposure, soil xericity and insolation, which allow for the identification of a particular plant dynamic. A total of twelve plant associations have been recognized, which have the following syntaxonomical scheme (Class, *-etea;* Order, *-etalia*; Alliance, *-ion*; Sub-Alliance, *-enion*; Association, *-etum*):

Euphorbio paraliae-Ammophiletea australis
- *Ammophiletalia australis*
  - *Ammophilion australis*
    - *Ammophilenion australis*
      - **(1) *Loto cretici-Ammophiletum australis***
  - *Honckenyo peploidis-Elytrigion boreoatlanticae*
    - *Elytrigienion junceae*
      - **(2) *Cypero mucronati-Elytrigietum junceae***
  - *Sporobolion arenarii*
    - **(3) *Sporoboletum arenarii***
- *Crucianelletalia maritimae*
  - *Crucianellion maritimae*
    - **(4) *Loto cretici-Crucianelletum maritimae***
    - **(5) *Malcolmio-Vulpietum alopecuri***

Cakiletea maritimae
Cakiletalia integrifoliae
Euphorbion peplis
(6) *Salsolo kali-Cakiletum maritimae*

Tuberarietea guttatae
Malcolmietalia
Linarion pedunculatae
(7) *Ononidi variegatae-Linarietum pedunculatae*

Cisto-Lavanduletea Stoechadis
Stauracantho genistoidis-Halimietalia calycini
Coremation albi
(8) *Thymo albicantis-Stauracanthetum genistoidis*

Quercetea ilicis
Quercetalia ilicis
Querco rotundifoliae-Oleion sylvestris
(9) *Oleo sylvestris-Quercetum suberis*
Pistacio lentisci-Rhamnetalia alaterni
Asparago albi-Rhamnion oleoidis
(10) *Asparago albi-Rhamnetum oleoidis*
(11) *Asparago aphylli-Calicotometum villosae*
Juniperion turbinatae
(12) *Osyrio quadripartitae-Juniperetum turbinatae*

Phytosociological analysis and Vegetation series: Plant dynamic and floristic sampling

With regards to the phytosociological characterization –vegetation series– of Matas Verdes, the dune habitat is colonized by various communities that are integrated into the psammophilous, Mediterranean-Iberoatlantic, thermomediterranean littoral and edaphoxerophylous geoseries of beaches and dunes. The structure of the geoseries involves the theoretical development of different strips of vegetation roughly parallel to the sea, whose zoning responds to the above factors. The following communities are recognized in Matas Verdes (Figure 2):

Figure 2. Communities of the Mediterranean-Iberoatlantic, thermomediterranean littoral and edaphoxerophylous geoseries of beaches and dunes: a) *Salsolo kali-Cakiletum maritimae*; b) *Cypero mucronati-Elytrigietum junceae*; c) *Loto cretici-Ammophyletum australis*; d) *Loto cretici-Crucianelletum maritimae*. Source: Authors.

Salsolo kali-Cakiletum maritimae (Costa & Manz., 1981, corr. Rivas-Martínez et al., 1992). This pioneer nitro-halophilous therophytic community is seated on pebbles or sand from the edge of the zone of maximum tide to the first dune cordon, where deposited nutrients derived from organic remains of natural and anthropogenic origin are washed away by the sea or in suspension. It is characterized by the pioneer nitro-halophilous species (Sampling 1. Annex I).

Cypero mucronati-Elytrigietum junceae (Br.-Bl., 1933). This hemicryptophytic grassland community of the iberolevantine optimum occupies the embryonic dunes of unstable sand, where vegetation acquires a significant ecological function for the ecosystem to retain and partially fix the substrate. It is characterized by grasses of rapid vertical growth to avoid being buried, and which expand and reproduce quickly, and are specially adapted to withstand the intense sunlight and sea breeze due to sub-succulent organs, dense tomentosus, and leathery leaves, with very deep root systems. The main taxa and their abundance appear in Sampling 2 (Annex 1)..

Loto cretici-Ammophyletum australis (Rivas-Martínez, 1965, corr. Rivas-Martínez et al., 2002). A robust community of grass colonizes crests of the moving dunes; the guiding species is *Ammophila arenaria* ssp. *australis*, although this taxon is currently extinct in the complex of Matas Verdes. The formation is identified by the presence of other taxa with an identical ecological function, which appear in Sampling 3 (Annex I).

Loto cretici-Crucianelletum maritimae (Alcaraz et al., 1989). This camephyte community occupies the semi-fixed dunes and interdunal valleys, under high edaphic xericity conditions. It is a scrub that consists mainly of taxa listed in Sampling 4 (Annex I), and other species of the *Teucrium* and *Thymus* genera. This formation is essential to permanently binding the soil, which can then be colonized by junipers.

Additionally, other communities of annual therophytes with a partly nitrophilous character must be considered, such as *Malcolmio-Vulpietum alopecuri* (Díez-Garretas, Hernández & Asensi, 1975), *Sporoboletum arenarii* Rothmaler 1943, and *Ononidi variegatae-Linarietum pedunculatae* Díez-Garretas, Asensi & Esteve, 1977), which occupy the semi-fixed dunes, the inter-dune valleys and other ruderalised positions.

The formation of *Juniperus turbinata* belong to the dune, littoral Lusitanian-Andalusian thermomediterranean and edaphoxerophylous *Osyrio quadripartitae-Junipereto turbinatae* series, and appear to be considerably degraded in the transition between the last dune cordon and the postdune field. In certain cases, due to their altered state, it is preferable to include the juniper scrub (head of the series) as a permanent community in the psammophilous geoseries described above. Meanwhile, where the series is more recognizable, two stages of vegetation take place (Figure 3):

Figure 3. Communities of the littoral Lusitanian-Andalusian, thermomediterranean and edaphoxerophylous series (*Osyrio quadripartitae-Junipereto turbinatae*) identified in Matas

Verdes: a) *Osyrio quadripartitae-Juniperetum turbinatae*; b) *Thymo albicantis-Stauracanthetum genistoidis*; and communities of the Mediterranean, dry-subhumid-humid thermomediterranean and sabulicolous series (*Oleo sylvestris-Quercetum suberis*): c) *Oleo sylvestris-Quercetum suberis*; d) *Asparago aphylli-Calicotometum villosae*. Source: Authors.

Osyrio quadripartitae-Juniperetum turbinatae (Rivas-Martínez ex Rivas-Martínez *et al*., 1990). Juniper of micro- and nano-phanerophytes of stabilized dunes and paleodunas, over soils with a thin layer of humus and outside the influence of the salt-laden sea winds. Although this vegetation appears considerably degraded in Matas Verdes, a large cohort of species characteristic of the community and other taxa are still detectable (Sampling 5. Annex I).

Thymo albicantis-Stauracanthetum genistoidis (Galán, Sánchez & Vicente, 1997). This sabulicolous community is constituted by camephytes and xerophytic nano-phanerophytes that colonize those paleodunes in which the juniper has been seriously altered or has disappeared. This scrub, known as "jaguarzal", is usually preceded by a stage of dense thickets corresponding to *Rubio longifoliae-Corematetum albi* (Rivas-Martínez et al., 1980), unrecognizable today in Matas Verdes. It is noteworthy that in this dune complex, the scrub *Thymo-Stauracanthetum genistoidis* is enriched with characteristic taxa of the juniper formation and of the postdune field forest, which favours an atypical structure that is explained by its heavy anthropo-zoogenic degradation. Their characteristic elements are listed in Sampling 6 (Annex I).

The postdune field is the potential domain of *Quercus suber* forests of the Mediterranean, dry-subhumid-humid thermomediterranean and sabulicolous *Oleo sylvestris-Querceto suberis* series, whose biogeographical ideal corresponds to the Littoral Lusitanian-Andalusian province. These forests (climax stage, *Oleo-Quercetum suberis* Rivas-Goday, Galiano & Rivas-Martínez ex Rivas-Martínez, 1987), currently have a notably limited distribution in their chorological area (coasts of the Huelva, Cadiz and Malaga provinces, SW Spain) due to their significant alteration by human activities in the last millennium.

But, at present, there is no evidence in Matas Verdes of the theoretical structure of sabulicolous forests in their mature facies (dense cover of trees and understory with abundant thermomediterranean lianas and shrubs sensitive to winter cold). *Quercus suber* patches can still be found between conifer plantations occupying the forest habitat, as well as many of the shadow species in its interior (Figure 3). However, the general configuration departs from the characteristics of well-preserved nemoral strata. Among these strata, the presence of lianas and Mediterranean sclerophyllous shrubs is noteworthy, as well as certain protected species of restricted distribution (Sampling 7. Annex I).

Two substitution stages of the forest are identifiable in Matas Verdes which, like the climatic forest, have a noticeable degradation (Figure 3). First, a thorny fringe can be seen which belongs to *Asparago aphylli-Calicotometum villosae* (Rivas-Martínez, 1975); its characteristics taxa promptly intermingle with lianoid elements of the forest understory and even with bushes accompanying the dune juniper formation. Thus, it is common in Matas Verdes that the degraded and open formations of the forest border have a particular floristic composition (Sampling 8. Annex I).

Furthermore, in the postdune field, coinciding with micro-environments of greater xericity, this thorny scrub is partially replaced by another belonging to *Asparago albi-*

Rhamnetum oleoidis (Rivas-Goday in Rivas-Goday et al., 1960), which is more typical of the degradation stages of thermophilic *Quercus rotundifolia* forests developed in consolidated soils. The main taxa appear in Sampling 9 (Annex I).

The second and last degradation stage of the *Quercus suber* forest recognized in the postdune field coincides with that described as the replacement facies of the juniper formation, thus corresponding to the thickets of *Thymo albicantis-Stauracanthetum genistoidis*, whose floristic composition in the postdune area is listed in Sampling 10 (Annex I).

There is no evidence of the smaller bushes that replace the "jaguarzal", which are typical of the Ibero-Atlantic group corresponding to *Erico scopariae-Ulicetum australis* (Rivas-Martínez et al., 1980).

Chorological mapping of vegetation

The mapping of current vegetation (Figure 4 and Table 1) represents the spatial distribution of psammophilous, riparian and introduced communities identified in the Matas Verdes dune system (*i.e.*, on dunes and postdune field).

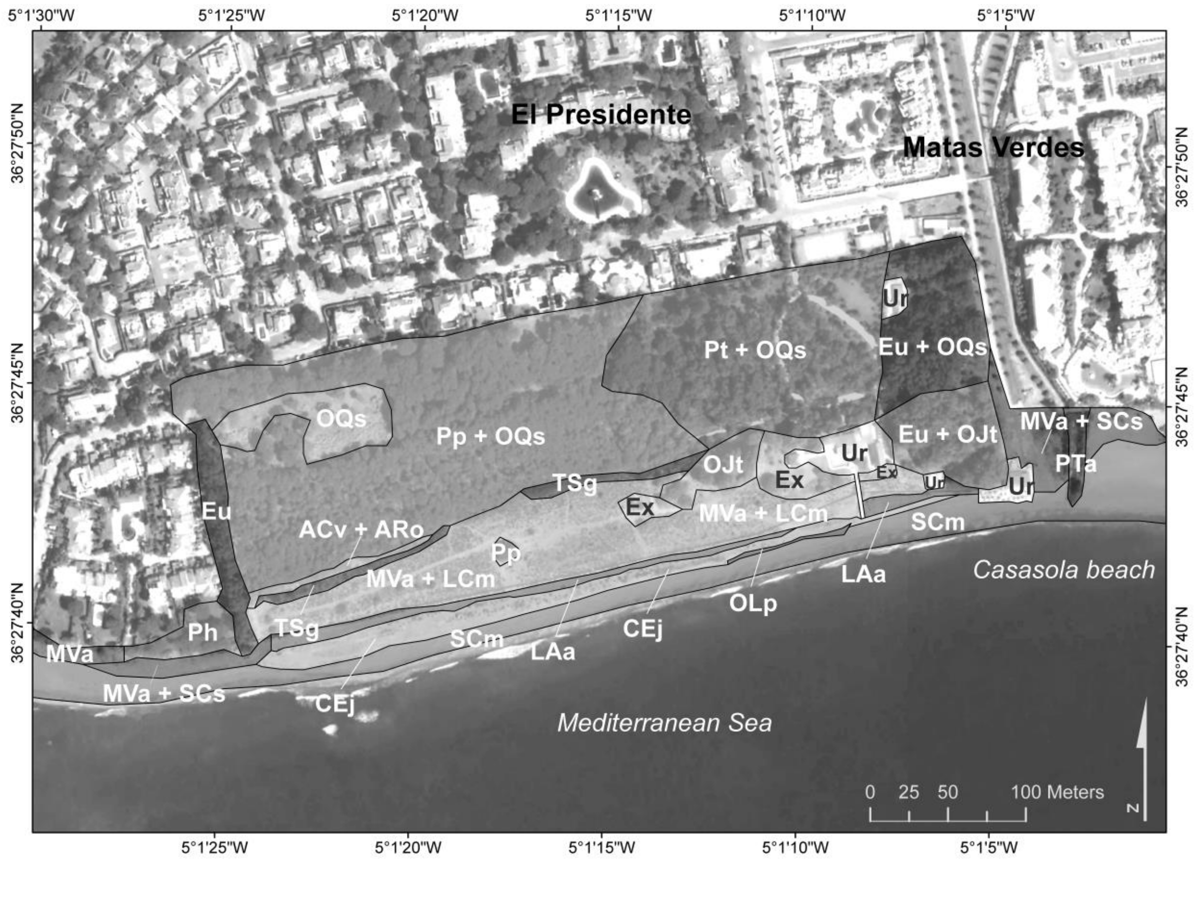

Figure 4. Map of current vegetation of the dune complex of Matas Verdes. Source: Modified from Gómez-Zotano (2009, 2014).

Table 1. Legend of vegetation map of Matas Verdes dune system.

Dune vegetation	
Psammophilous geoseries of beaches and dunes	***Osyrio-Juniperetum turbinatae***
SCm *Salsolo kali-Cakiletum maritimae*	**OJt** *Osyrio quadripartitae-Juniperetum turbinatae*
MVa *Malcolmio-Vulpietum alopecuri*	**TSg** *Thymo albicantis-Stauracanthetum genistoidis*
SCs *Sporoboletum arenarii*	
CEj *Cypero mucronati-Elytrigietum junceae*	
LAa *Loto cretici-Ammophyletum australis*	
LCm *Loto cretici-Crucianelletum maritimae*	
OLp *Ononidio variegatae-Linarietum pedunculatae*	
Postdunar field vegetation	
Oleo-Quercetum suberis	
OQs *Oleo sylvestris-Quercetum suberis*; **ACv** *Asparago aphylli-Calicotometum villosae*	
ARo *Asparago albi-Rhamnetum oleoidis*; **TSg** *Thymo albicantis-Stauracanthetum genistoidis*	
Riparian vegetation	
PTa *Polygono equisetiformis-Tamaricetum africanae*	
Anthropogenic spaces, reforestation masses and invasive alien communities	
Ur Urbanized spaces; **Pp** Reforestation pine of *Pinus pinea;* **Pt** Reforestation pine of *Pinus pinaster*	
Ph Reforestation pine of *Pinus halepensis;* **Eu** Reforestation of *Eucaliptus globulus*, *E. camaldulensis*	
Ex Other invasive exotic plants (*Acacia cyanophylla, Agave americana, Carpobrotus edulis*)	

Environmental problems

The narrow coastal strip suffers most of the environmental problems that affect much of the Spanish Mediterranean coast, all of which are the result of residential and recreational land use which endangers the conservation of the dunes. This territory experienced early and intensive human occupation related to farming, fishing and defence (Gómez-Zotano, 2006), and not until the second half of the twentieth century were these traditional uses minimized by the expansive urbanism associated with mass tourism of the newly named "Costa del Sol". This new activity led to the disappearance of approximately 66% of the sands and dunes between 1942 and 2012; the total sedimentation on marshes and associated wetlands; the channelling of rivers and streams, and the erosion of the shoreline (Gómez-Zotano, 2009); and the synchronous degradation of the postdune area due to its reforestation with conifers (*Pinus pinea*, *P. halepensis* and *P. pinaster*), all of which greatly hinders the regeneration of native sabulicolous forests. All of these issues continue to be problematic and presently have negatives effects on the coastal ecosystems (Figures 5 and 6).

Figure 5. Regression of coastal sands (1942-2012) on the littoral stretch of Matas Verdes. Source: Instituto Geográfico Nacional (Image 1942), and Google Earth (Image 2012).

Figure 6. Detail of degradation experienced in recent decades (1978-2007) by the dune system of Matas Verdes. Sands and reforestation of Pinus pinea are replaced by housing developments as "El Presidente" or "Marriott's". The plot of MatasVerdes, owned by the Opel family, is classified as Developable Soil in the Land-use Planning of Estepona. Source: Paisajes Españoles (Photo 1978), and Gómez-Zotano (Photo 2007).

In addition to the primary environmental conflicts affecting the dune system of Matas Verdes that seriously alter their psammophilous plant ecosystems, the following additional threats should be noted:

1. Construction of dams on adjacent rivers and of breakwaters, harbours and jetties on the rest of the coast, which are infrastructures altering tidal and river systems and, consequently, the coastal sediment regime.
2. Artificial regeneration of sand beach-dune systems as a result of the deposition of sediments, a process that in most cases occurs apart from the geomorphological and biotic structure of the sand ecosystems.
3. Cleaning and raking the beach with heavy machinery, thereby severely degrading the natural dune structure.
4. Dumping of rubbish and other debris of all types in the sea-land interface that constitutes the coast, causing contamination of natural water and soil systems.
5. Mass influx of people and vehicles to the beaches, dunes and its environment.
6. Introduction of exotic/invasive species.

Discussion

The results also indicate that, due to the specific biophysical characteristics of the dune system and its location in a highly urbanized coast, there is little chance of natural regeneration and expansion of vegetation; thus, it is imperative to take urgent and extraordinary measures for the vegetation's future preservation, and its incorporation into the Andalusian Network of Natural Protected Areas (RENPA) is highly recommended.

The Matas Verdes dunes are a stronghold of a continuous dune complex -located on private lands- that has already disappeared. This study demonstrates the existence of major floristic diversity in this dune system and the development of plant communities that respond to a complete zoning scheme in six strips parallel to the sea, which is unique in the Andalusian Mediterranean coast. Stresses impact the appearance of the vegetation series of *Juniperus turbinata* (*Osyrio-Junipereto turbinatae*), of the psammophilous, Mediterranean-Iberoatlantic, thermomediterranean littoral and edaphoxerophylous geoseries of beaches and dunes, and of the vegetation series of sabulicolous forests of *Quercus suber* (*Oleo-Querceto suberis*), the latter characteristic of Atlantic dune systems. The endangered and vulnerable species identified contributes a particular value to the conservation of this widely threatened littoral ecosystem.

The results allow for the formulation of a proposal for the conservationist management of the dune complex to correct the serious environmental problems that threaten its natural balance and compromise the preservation of psammophilous vegetation. Around the planet are numerous examples of dune complexes altered as a result of unsustainable environmental practices. This finding is supported by, among others, authors such as Castro (1992) or De Cabo (2010) in the case of South America, Kelly (2014) for North America, and Bellarosa, Codipietro, Piovesan & Schirone (1996), Curr, Koh, Edwards, Williams & Davies (2000), Del Vecchio, Acosta & Stanisci (2013), Eigaard (1992), Gómez-Zotano (2014), Lousã, Costa, Capelo, Pinto & Neto (1999), Pinna, Cogoni, Fenu & Bacchetta (2015), Provoost, Laurence, Jones & Edmondson (2011) and Van der Zande (1989) for European dune complexes. In this general context, coastal sand dunes are increasingly perceived as areas worthy of sustainable development, so there is a need for the provision of tools suitable for periodic measurement that will help in coastal dune management (García-Mora, Gallego-Fernández, & García-Novo, 2000).

The direct and indirect consequences of human activity seriously threaten the survival of this coastal ecosystem and justify its immediate protection. The erosion of the first line of dunes on the eastern front of the complex in recent years, and the gradual disappearance of the nitro-halophilous pioneer therophytic community (*Salsolo-Cakiletum maritimae*) should both be noted. Additionally, the interdunal valleys are notably altered given their growing use as walkways. Equally altered is the postdune field, which is covered by a dense pine reforestation, under which extensive patches of *Arundo donax* prosper and, conversely, a barely surviving leftover of sabulicolous forest of *Quercus suber* and their replacement facies. The artificial coniferous forest also adversely affects the third dune strip, especially the *Juniperus turbinata* formations, limiting the presence of this taxon to isolated individuals. The conservation of Matas Verdes dunes therefore requires a concerted system of protection referred to in RENPA through the entity of the Concerted Nature Reserve. This statement must be combined with other urgent management measures aimed at curbing the growing anthropogenic degradation (Figure 7) of this biophysical system of singular richness and remarkable ecological values, such as:

1. Cessation of cleaning and raking of the beaches with heavy machinery.
2. Management of human passage along the sands.
3. Design of a strategy for the removal of invasive alien species and communities, among which the following stand out: *Acacia cyanophylla*, *Acacia longifolia*, *Agave americana*, *Agave sisalana*, *Arundo donax*, *Carpobrotus edulis*, *Eucalyptus camaldulensis*, *Eucalyptus globulus*, *Nicotiana glauca*, *Opuntia ficus-indica*, and *Oxalis pes-caprae*.
4. Forest treatment of reforestation pine to favour the regeneration of the *Quercus suber* sabulicolous forest in the postdune area.
5. Special protection of species considered threatened and vulnerable, such as *Gennaria diphylla*, *Linaria pedunculata*, *Epipactis lusitanica*, and *Dipcadi serotinum*.
6. Restocking of currently scarce taxa that are of significant importance to the natural balance of the ecosystem, such as *Quercus suber* and *Juniperus turbinata*.
7. Reintroduction of other absent species that are characteristic of the identified psammophilous communities.

Figure 7. Main consequences of human pressure in Matas Verdes dune system: a), b) The urbanized areas and tourist infrastructures occupy almost the entire dune-beach system in this part of the "Costa del Sol"; c) Cleaning and smoothing of the beach sands and dunes with heavy machinery; d) Erosion and retreat of the coastline; the arrow indicates the level of the beach sands previous to 1960; e) Interdunar valleys converted in walkways; f) A dense reforestation pine mass occupies the postdune field. Source: Authors.

The degradation of the sandy plant communities entails the loss of biological, ecological and landscape value, which must be regarded as priority issues in the environmental policy and management measures for ecological protection of the intensely humanized littorals (Ciccarelli, 2014; Martins, Neto & Costa, 2013; Provoost, Laurence, Jones & Edmondson, 2011). In this regard, numerous studies show the anthropogenic degradation of such biodiverse areas as the dune systems, and require the protection and conservation of threatened psammophilous species and communities in the Mediterranean areas: Ciccarelli (2014, 2015), Del Vecchio, Acosta, & Stanisci (2013), Cogoni, Fenu, Concas & Bacchetta (2013); Fenu, Cogoni, Ferrara, Pinna & Bacchetta (2012), Fenu, Carboni, Acosta

& Bacchetta (2013), Fenu et al. (2016), Nordstrom, Gamper, Fontolan, Bezzi & Jackson (2009), Pinna, Cañadas, Fenu & Bacchetta (2015) and Ruocco, Bertoni, Sarti & Cicarelli (2014) in Italy; or López-Pujol, Orellana, Bosh, Simón & Blanché (2003) in Iberian Peninsula, for example.

The concerted protection system this study proposes will enable the reconciliation of the various public and private interests involved in the management of this territory to achieve a status that allows for maintaining the full ecological functionality of the system and its socio-economic value. This statement is the only one of the recognized entities in RENPA that corresponds to the municipal initiative, which simplifies its legal procedure. However, there are only five precedents in Andalusia (Dehesa de Abajo, Cañada de los Pájaros, Charca Suárez, Laguna de la Paja, and Puerto Moral), which total 803 hectares.

Moreover, the proposed corrective measures in this paper have been implemented successfully in other Mediterranean dune ecosystems in Spain. It is noteworthy that the restoration works of the Mediterranean dunes of Devesa de la Albufera (Valencia, eastern Spain) were developed with different plans of geomorphological morphology restoration and vegetation cover restoration, as sand transfers on the dunes, construction of barriers of reeds and walls of plastic, creation of palisades through planting species such as "espartina" (*Spartina versicolor*) and "caña" (*Arundo donax*), and reforestation of the rest of taxa own of the dune ecosystem (existing or extinct by anthropogenic degradation), in addition to adapting the area for tourism (Benavent et al., 2005). In the Tarifa dunes (Cadiz, southern Spain), measures have also been taken, as transport of sand from inside the dunes to the areas most in need (beaches and dunes embryonic), construction of wooden hurdles, and vegetal reforestation to windward side of the dunes, with different degrees of success to stabilize the sands (Román, Navarro, Muñoz, Gómez & Fages, 2004).

The particular case of forestation is a common problem in many dune systems around the globe, and for this reason numerous dune restoration projects have attempted to transform pine plantations into natural dune landscapes based on a dynamic dune management approach (Rooney, 2010).

Another issue to consider, according to Jones, Akeroyd, Beldean & Tutureanu (2010), is that dune managers can operate only within the limits of natural climatic conditions, and this is a crucial point for those designing and proposing dune restoration and rehabilitation schemes. Additionally, in this case study, the climatic conditions favour the development of tourist, urban and economic activities on the beaches, dunes and their immediate surroundings, which are of great socioeconomic importance in this littoral strip; thus a great effort for sustainable integration of all related territorial variables is necessary for the dune ecosystem conservation. However, in many cases the value of dunes and their ecosystem services are not being properly acknowledged and assessed in decision making, which causes the most valued dunes' qualities (*e.g.*, recreation, cultural, and aesthetic) to paradoxically contribute to their degradation (Lucrezi, Saayman & Van der Merwe, 2014). Furthermore, the number of "soft" and "hard" engineering and restoration interventions implemented to address the problem of coastal dune degradation and loss are extremely costly (Martínez, Hesp & Gallego-Fernández, 2013). The issue generates a greater concern because the effects of human action on coasts are still commonly forgotten or deliberately ignored under the pressures of development (Anthony & Psuty, 2014). Furthermore, the alteration of natural processes resulting from the construction of numerous hydraulic and harbour infrastructures disrupts the regulation of watersheds and the circulation of sediment, in addition to climate change that threatens virtually all of the world's littorals due to rising sea levels (Araújo, Honrado, Granja, De Pinho & Caldas, 2002; Parry, Canziani, Palutikof, Van der Linden & Hanson, 2007; Psuty & Silveira, 2010).

Conclusions

This research represents a significant advance in the knowledge of the phytodiversity of a dune complex threatened by urbanization. The results demonstrate remarkable floristic diversity associated with the complete zonal structure of the Matas Verdes sands. The characterization of the flora and detailed mapping of the vegetation are an effective tool for crafting a conservation proposal addressing the anthropogenic uses that destabilize the system; it is necessary to implement immediate and extraordinary measures for integral and effective conservationist management in order to avoid the loss of the strategic natural heritage and the remarkable eco-cultural and socio-economic values on which these dunes rely.

Given the limited possibilities of natural regeneration and expansion of vegetation in Matas Verdes, implementing a number of management measures is therefore necessary in order for the following to be possible: the halt or regulation of harmful activities affecting the dunes, the removal of invasive species, the application of forest treatments in reforested areas, the protection and population reinforcement of species considered endangered and vulnerable, and the reintroduction of extinct native taxa and characteristic flora of the communities that comprise the dune ecosystem.

Furthermore, given the demonstrated success of different forms of protection at the local level for this type of Mediterranean coastal environment smaller in area and with a rich but threatened geomorphological and biological diversity, developed in highly populated areas, the future preservation of the ecological value of Matas Verdes necessarily depends on its immediate declaration as a Concerted Nature Reserve and its integration into the Andalusian Network of Natural Protected Areas.

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Annex I. Floristic Samplings: dune complex of Matas Verdes (Andalusia, southern Spain)

Sampling (1)	***Salsolo kali-Cakiletum maritimae***	**Sampling (2)**	***Cypero mucronati-Elytrigietum junceae***
Species	Index	Species	Index
Cakile maritima	2	*Sporolobus pungens*	3
Lobularia maritima	1	*Elymus farctus*	1
Salsola kali	+	*Euphorbia paralias*	1
Centaurea seridis	+	*Polygonum maritimum*	1
Suaeda spicata	+	*Cakile marítima*	+
Lotus creticus	+	*Cyperus capitatus*	+
Echinophora spinosa	+	*Eryngium maritimum*	+
Euphorbia paralias	+	*Medicago marina*	+
Echium gaditanum	+	*Otanthus maritimus*	r
Elymus farctus	r	*Crucianlella marina*	r
Data. Location: Matas Verdes. Altitude: 1 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on arenosol of beachfront; Inventoried area: 5 m²; Incline: 2%; Vegetation stratum cover: 20%.		**Data.** Location: Matas Verdes. Altitude: 3 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on arenosol of embryonic dune; Inventoried area: 8 m²; Incline: 0-10%; Vegetation stratum cover: 35%.	
Sampling (3)	***Loto cretici-Ammophyletum australis***	**Sampling (4)**	***Loto cretici-Crucianelletum maritimae***
Species	Index	Species	Index
Eryngium maritimum	3	*Helichrysum stoechas*	4
Medicago marina	1	*Crucianella maritima*	2
Halimium halimifolium	1	*Halimium halimifolium*	1
Pancratium maritimum	1	*Rhamnus lycioides* ssp. *oleoides*	1
Lotus creticus	1	*Ononis ramossisima*	1
Otanthus maritimus	1	*Cistus salvifolius*	1
Pseudorlaya pumila	1	*Pistacia lentiscus*	+
Echinophora spinosa	+	*Delphinium nanum*	+
Cistus salvifolius	+	*Verbascum sinuatum*	+
Elymus farctus	+	*Reichardia tingitana*	+
Crucianella maritima	r	*Eryngium maritimum*	+
Cakile maritima	r	*Echinopora spinosa*	+
		Rubia peregrina	r
Data. Location: Matas Verdes. Altitude: 4 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on arenosol of mobile dune; Inventoried area: 50 m²; Incline: 2%; Vegetation stratum cover: 40%.		**Data.** Location: Matas Verdes. Altitude: 5 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on arenosol of interdunar valley; Inventoried area: 100 m²; Incline: 2%; Vegetation stratum cover: 65%.	
Sampling (5)	***Osyrio quadripartitae-Juniperetum turbinatae***	**Sampling (6)**	***Thymo albicantis-Stauracanthetum genistoidis***
Species	Index	Species	Index
Juniperus turbinata	2	*Halimium halimifolium*	3
Halimium halimifolium	2	*Helichrysum stoechas*	2
Osyris lanceolata	1	*Cistus salviifolius*	2
Cistus salvifolius	1	*Halimium calycinum*	1
Quercus coccifera	1	*Ononis ramossisima*	1
Helichrysum stoechas	1	*Lavandula stoechas*	1
Pistacia lentiscus	1	*Cistus crispus*	+
Cistus monspeliensis	+	*Asparagus aphyllus*	+
Cistus crispus	+	*Cistus monspeliensis*	+
Olea europaea var. *sylvestris*	+	*Chamaerops humilis*	+
Rhamnus lycioides ssp. *oleoides*	+	*Quercus coccifera*	+
Asparagus acutifolius	+	*Pistacia lentiscus*	r
Dittrichia viscosa	+	*Rhamnus lycioides* ssp. *oleoides*	r
Myrtus communis	+	*Aristolochia baetica*	r
Phillyrea angustifolia	+	*Smilax aspera*	r
Daphne gnidium	+	**Data.** Location: Matas Verdes. Matas Verdes. Altitude: 8 m	
Rubia peregrina	+		

Calicotome villosa	r
Aristolochia baetica	r

Data. Location: Matas Verdes. Matas Verdes. Altitude: 8 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on arenosol of stabilized dune; Inventoried area: 50 m²; Incline: 5%; Vegetation stratum cover: 40%.

asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on arenosol of stabilized dune; Inventoried area: 150 m²; Incline: 2%; Vegetation stratum cover: 70%.

Sampling (7)	***Oleo sylvestris-Quercetum suberis***
Species	Index
Quercus suber	2
Quercus coccifera	1
Lavandula stoechas	1
Cistus salvifolius	1
Dittrichia viscosa	1
Asparagus aphyllus	1
Asparagus acutifolius	1
Aristolochia baetica	1
Olea europaea var. *sylvestris*	+
Myrtus communis	+
Chamaerops humilis	+
Phillyrea latifolia	+
Phillyrea angustifolia	+
Daphne gnidium	+
Calicotome villosa	+
Pistacia lentiscus	+
Rubia peregrina	+
Smilax aspera	+
Clematis flammula	+
Gennaria diphylla	r
Epipactis lusitanica	r
Dipcadi serotinum	r

Data. Location: Matas Verdes. Matas Verdes. Altitude: 10 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on consolidated arenosol of postdunar field; Inventoried area: 350 m²; Incline: 0%; Vegetation stratum cover: 55%.

Sampling (8)	***Asparago aphylli-Calicotometum villosae***
Species	Index
Calicotome villosa	2
Asparagus aphyllus	2
Asparagus acutifolius	1
Rubia peregrina	1
Chamaerops humilis	1
Daphne gnidium	1
Cistus salvifolius	1
Asparagus horridus	+
Aristolochia baetica	+
Smilax aspera	+
Pistacia lentiscus	+
Phyllirea angustifolia	+
Rhamnus lycioides ssp. *oleoides*	+
Olea europaea var. *sylvestris*	+
Verbascum sinuatum	+
Ulex parviflorus	r
Ononis ramossisima	r
Juniperus turbinata	r

Data. Location: Matas Verdes. Altitude: 5 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on arenosol of interdunar valley; Inventoried area: 100 m²; Incline: 2%; Vegetation stratum cover: 65%.

Sampling (9)	***Asparago albi-Rhamnetum oleoidis***
Species	Index
Asparagus aphyllus	2
Asparagus acutifolius	1
Rhamnus lycioides ssp. *oleoides*	1
Chamaerops humilis	1
Quercus coccifera	1
Cistus salvifolius	1
Juniperus turbinata	+
Ononis ramossisima	+
Clematis flammula	+
Halimiun halimifolium	+
Helichrysum stoechas	+

Data. Location: Matas Verdes. Matas Verdes. Altitude: 10 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on consolidated arenosol of postdunar field; Inventoried area: 150 m²; Incline: 5%; Vegetation stratum cover: 65%.

Sampling (10)	***Thymo albicantis-Stauracanthetum genistoidis***
Species	Index
Cistus salvifolius	3
Quercus coccifera	3
Ononis ramossisima	1
Halimium halimifolium	1
Asparagus acutifolius	+
Helichrysum stoechas	+
Aristolocha baetica	+
Pistacia lentiscus	+
Juniperus turbinata	+
Rhamnus lycioides ssp. *oleoides*	+
Rubia peregrina	+
Ulex parviflorus	+
Daphne gnidium	+
Lavandula stoechas	r
Clematis flammula	r

Data. Location: Matas Verdes. Matas Verdes. Altitude: 10 m asl; Bioclimatic and edaphic environment: Subhumid lower thermomediterranean, on consolidated arenosol of postdunar field; Inventoried area: 100 m²; Incline: 0%; Vegetation

	stratum cover: 90%.

Annex II. Flora of Matas Verdes

PTERIDOPHYTES
Equisetum ramosissimum Desf.
Pteridium aquilinum (L.) Kuhn

SPERMATOPHYTES, GYMNOSPERMS
Juniperus turbinata Guss.
Pinus halepensis Mill.
Pinus pinaster Aiton
Pinus pinea L.

SPERMATOPHYTES, ANGIOSPERMS, MONOCOTYLEDONS
Ammophila arenaria (L.) Link
Arum italicum L.
Arundo donax L.
Asparagus acutifolius L.
Asparagus aphyllus L.
Asparagus horridus L.
Asparagus offi cinalis L.
Asphodelus albus Mill.
Brachypodium retusum (Pers.) P. Beauv.
Cutandia maritima (L.) Barbey
Cynodon dactylon (L.) Pers.
Cyperus capitatus Vandelli
Chamaerops humilis L.
Dactylis glomerata L. subsp. hispanica (Roth) Nyman
Elymus farctus (Viv.) Melderis
Epipactis lusitanica D. Tyteca
Gennaria diphylla (Link) Parl.
Iris pseudoacorus L.
Juncus acutus L.
Juncus effusus L.
Juncus maritimus Lam.
Lagurus ovatus L.
Lemna minor L.
Pancratium maritimum L.
Panicum repens L.
Phragmites australis (Cav.) Trin.
Piptatherum miliaceum (L.) Coss.
Potamogeton pectinatus L.
Scirpoides holoschoenus (L.) Sojak
Sporobolus pungens (Schreb.) Kunth
Typha angustifolia L.
Urginea maritima (L.) Baker
Vulpia alopecuros (Schousb.) Dumort.

SPERMATOPHYTES, ANGIOSPERMS, DICOTYLEDONS
Aetheorhiza bulbosa (L.) Cav.
Anagallis monelli L.
Anchusa calcarea Boiss.
Aristolochia baetica L.
Cakile maritima Scop.
Calicotome villosa (Poir.) Link
Calystegia sepium (L.) R.Br.
Centaurea seridis L.
Centaurea sphaerocephala L.
Centranthus macrosiphon Boiss.
Cerastium semidecandrum L.
Cistus crispus L.

Cistus monspeliensis L.
Cistus salviifolius L.
Clematis cirrhosa L.
Clematis fl ammula L.
Conyza canadensis (L.) Cronquist
Crataegus monogyna subsp. *brevispina* (Kunze) Franco
Crucianella maritima L.
Chamaeleon gummifer (L.) Cass.
Daphne gnidium L.
Delphinium nanum DC.
Dittrichia viscosa (L.) Greuter
Dorycnium rectum (L.) Ser.
Echinophora spinosa L.
Echium gaditanum Boiss.
Eryngium maritimum L.
Euphorbia paralias L.
Fumaria sepium Boiss. & Reut.
Glaucium fl avum Crantz
Halimium calycinum (L.) K.Koch.
Halimium halimifolium (L.) Willk. subsp. *halimifolium*
Hedera helix L.
Hedypnois rhagadioloides (L.) F.W.Schmidt
Helichrysum stoechas (L.) Moench
Lavandula stoechas L.
Lavatera cretica L.
Linaria pedunculata (L.) Chaz.
Linaria spartea (L.) Chaz.
Lobularia maritima (L.) Desv.
Lonicera periclymenum subsp. *hispanica* (Boiss. & Reuter) Nyman
Lotus creticus L.
Lotus cytisoides L.
Lotus edulis L.
Lythrum junceum Banks & Sol.
Lythrum salicaria L.
Malcolmia littorea (L.) R.Br.
Medicago littoralis Rohde ex Loisel
Medicago marina L.
Mentha rotundifolia L.
Misopates orontium (L.) Raf.
Myrtus communis L.
Nerium oleander L.
Olea europaea L.var. *sylvestris* (Mill.) Lehr
Ononis pinnata Brot.
Ononis ramosissima Desf.
Ononis variegata L.
Osyris lanceolada Hochst. & Steud.
Otanthus maritimus (L.) Hoffmanns & Link
Oxalis pes-caprae L.
Paronychia argentea Lam.
Phillyrea angustifolia L.
Phillyrea latifolia L.
Pistacia lentiscus L.
Polygonum maritimum L.
Populus alba L.
Pseudorlaya pumila (L.) Grande
Pterocephalus intermedius (Lag.) Cout.
Quercus coccifera L.
Quercus suber L.
Ranunculus fi caria L.
Reichardia tingitana (L.) Roth.
Retama sphaerocarpa (L.) Boiss.
Rhamnus alaternus L.
Rhamnus lyciodes ssp. *oleoides* L.
Rosa sempervirens L.

Rubia peregrina L.
Rubus ulmifolius Schott
Rumex bucephalophorus L.
Ruta angustifolia Pers.
Salsola kali L.
Samolus valerandi L.
Scolymus hispanicus L.
Senecio gallicus Chaix
Senecio leucanthemifolius Poir.
Silene littorea Brot.
Silene niceensis All.
Smilax aspera L.
Solanum alatum Moench
Solanum linnaeanum Hepper & P.M. Jaeger.
Solanum nigrum L.
Sonchus tenerrimus L.
Suaeda spicata (Willd.) Moq.
Tamarix africana Poir.
Teucrium fruticans L.
Thapsia villosa L.
Thymelaea hirsuta (L.) Endl.
Tribulus terrestris L.
Ulex parvifl orus Pourret
Ulmus minor Mill.
Urtica urens L.
Verbascum sinuatum L.
Vicia parvifl ora Cav.
Vicia pseudocracca Bertol.
Vinca difformis Pourr. Pervinca,
Vitis vinifera L. var. *sylvestris* Willd.