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Proposal for new EU habitats associated with coastal dune fields of the Macaronesian region. A case study in the Canary Islands (Spain)

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Abstract The aim of this work is to identify habitats of European interest for the existing dunes in the Canaries, in order to provide data for their proper management. Dune systems considered were the following: aeolian sedimentary systems that cover both most of the island of La Graciosa and also the dune fields of Maspalomas (Gran Canaria) and Corralejo (Fuerteventura). The methodology consisted of overlapping layers of habitats and vegetation by using geographic information systems, so the correspondence between habitat and plant community are analyzed. The results indicate that dune habitats in the Canary Islands have not been well defined. The habitat "2110 embryonic shifting dunes" is associated with several situations incompatible with their biotic and abiotic characteristics. Meanwhile, habitat "2130 fixed dunes with herbaceous vegetation (grey dunes)" is linked, among others, to the phytosociological association *Traganetum moquinii*. However, embryonic dune formation in the Canaries is mainly done by this community, which is inconsistent with its inclusion in the grey dunes habitat. The proposed habitats of European interest associated with dunes in the Canaries are the following: Coastal shifting dunes with *Traganum moquinii*, dunes with *Tamarix canariensis*, Macaronesian aeolian sand sheets and humid dune slacks. It is also suggested the need for a comprehensive study of dune habitats existing in the Canaries and Macaronesia, covering the whole of aeolian sedimentary systems, performing a proper identification, characterization and detailed mapping of these habitats, based on both the existing vegetation and also on the associated landforms and geomorphic processes.

Keywords Dune vegetation · European dune habitats · GIS · Embryonic shifting dunes · Fixed dunes with herbaceous vegetation

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Introduction

The habitats of European interest were declared by the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (EU Habitats Directive). This Directive compiles the habitat types corresponding to different ecosystems, including those related to the "coastal sand dunes and inland dunes" (Table 1). Each country of the European Union made the mapping of these habitats in their respective territories, based on the criteria established by this Directive and by the Interpretation Manual of European Union Habitats (European Commission 2007). In

Table 1 Types of habitats of European interest associated with dunes (European Commission 2007)

2. COASTAL SAND DUNES AND INLAND DUNES	
21. Sea dunes of the Atlantic, North Sea and Baltic coasts	2110 Embryonic shifting dunes
	2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)
	2130 Fixed coastal dunes with herbaceous vegetation (grey dunes)
	2140 Decalcified fixed dunes with *Empetrum nigrum*
	2150 Atlantic decalcified fixed dunes (*Calluno-Ulicetea*)
	2160 Dunes with *Hippophae rhamnoides*
	2170 Dunes with *Salix repens ssp. argentea* (*Salicion arenariae*)
	2180 Wooded dunes of the Atlantic, Continental and Boreal region
	2190 Humid dune slacks
	21A0 Machairs (in Ireland)
22. Sea dunes of the Mediterranean coast	2210 *Crucianellion maritimae* fixed beach dunes
	2220 Dunes with *Euphorbia terracina*
	2230 *Malcolmietalia* dune grasslands
	2240 *Brachypodietalia* dune grasslands with annuals
	2250 Coastal dunes with *Juniperus spp*.
	2260 *Cisto-Lavenduletalia* dune sclerophyllous scrubs
	2270 Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*
23. Inland dunes, old and decalcified	2310 Dry sand heaths with *Calluna* and *Genista*
	2320 Dry sand heaths with *Calluna* and *Empetrum nigrum*
	2330 Inland dunes with open *Corynephorus* and *Agrostis*
	2340 Pannonic inland dunes

the case of Spain, each region determined the habitats existing in their respective territories.

As shown in Table 1, no habitats were determined for the biogeographic region of Macaronesia, a domain that includes the European regions of the Canary Islands, Azores, Madeira and Selvagens Islands, in addition to Cape Verde and the African Macaronesian enclave (Southern Morocco and Western Sahara). The Macaronesian region is generally characterized by its unique flora and ecosystems, displaying numerous halophilic and psamophilic species shared with the northwest coast of Africa (Médail and Quézel 1999; Santos 1993). Therefore, according to the available information, it was considered that dune habitats existing in the Macaronesian region, and in particular in the Canary Islands, were the same as those at the rest of Europe. However, some publications have indicated the uniqueness of the flora at the dune fields of the Canaries in the European context (Doody 1991). Therefore, plant communities associated to dune systems of the Canary Islands do not match those existing in Europe, implying a difficult match in the habitats of European interest established so far (Gracia et al. 2009; Nerilli et al. 2011). Canary dune systems have very different environmental characteristics to those located at the Atlantic European and Mediterranean regions (Alonso et al. 2011; Cabrera et al. 2013; Hernández Calvento et al. 2009; Hernández-Cordero et al. 2012, 2015a). This is mainly due to two factors: first, the arid climate of the Canary Islands coasts which conditions the high mobility of the dunes and determines the existence of transgressive dune systems, which normally exhibits input and output areas for sediment fluxes; a second factor is the existence of plant species and communities with a higher relationship to the northwestern Africa than to the European mainland as well as the presence of some endemic species. Maybe some habitats of European interest located in the Canary Islands are also present in other islands or in the northwest African coast, because the Macaronesian region shares many plant species, and large areas of the region present similar climatic and geomorphological features.

The aim of this work is to identify and characterize the dune habitats of European interest existing in the Canaries, in order to provide data for their proper management. For this, three aeolian sedimentary systems were considered (Fig. 1), which gather all existing dune habitats in the Canary Islands: aeolian sedimentary systems at La Graciosa island and the dune fields of Maspalomas (Gran Canaria) and Corralejo (Fuerteventura).

Material and methods

First, the existing mapping habitats of European interest developed for the Canary Islands were collected (Gobierno de Canarias 2001). This information includes a description of the habitats and the phytosociological associations associated

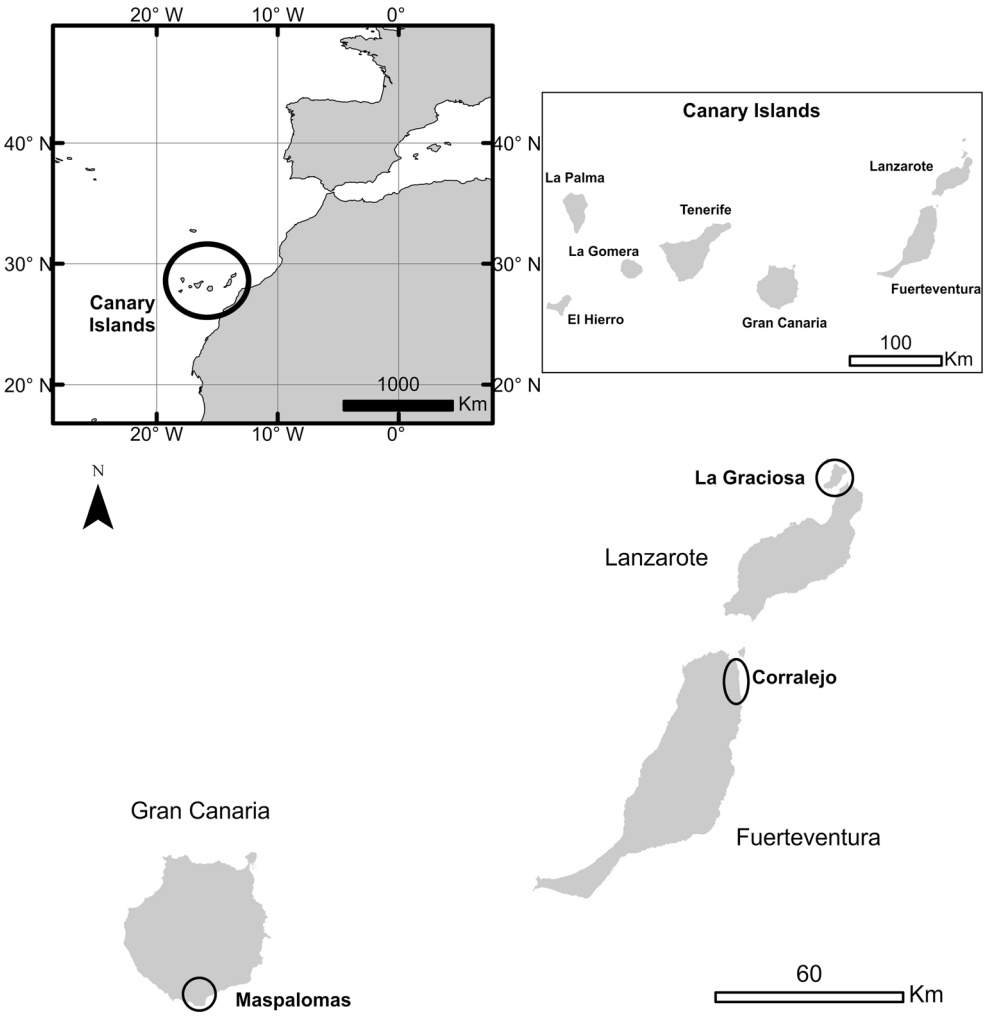

Fig. 1 Location of aeolian sedimentary systems considered

with them, as well as a mapping with GIS vector format (shapefile) containing the delimitation of habitats. The above information is compared with the data obtained in different research projects (Cruz Avero et al. 2009; Fernández-Cabrera et al. 2011; Hernández-Cordero et al. 2015a; Pérez-Chacón et al. 2010, 2012). The following types of vegetation are established based on a methodology different to the phytosociological one. Thus, plant communities were defined according to the dominant species, considering also the environmental variables that determine their distribution (more details in Hernández-Cordero et al. 2015a). These environmental variables, mainly aeolian sedimentary activity and type of landform, were mapped by interpreting digital orthophotos and field work. Subsequently, both maps were overlapping with the layer of plant communities in a geographic information system. This allowed us to associate each plant community with the type of aeolian sedimentary activity (active, semi-stabilized or stabilized areas) and the type of landform (dunes, slacks, sand sheets, etc.). Thus, it was possible to understand the relationship of each plant community with the geomorphological processes and landforms as well as to determine the existence of plant successional stages associated with them. All this information was crucial to analyze the suitability of habitats of European interest associated with dunes defined for the Canary Islands.

To determine the adequacy of plant communities and their associated habitats of European interest the following procedure was followed: 1) the relevés conducted in dune systems of La Graciosa, Maspalomas and Corralejo were collected. Also we have available vegetation layers in GIS vector format for the entire aeolian sedimentary systems of La Graciosa and dune field of Maspalomas, and partly for the Corralejo dune field; 2) these layers are overlapping to the habitats of European interest, so that the correspondence habitat-plant community was analyzed.

Results

European dune habitats identified in the Canary Islands are presented in Table 2. Each habitat is associated with a number

Table 2 Plant communities associated with dune habitats at Canarias (Gobierno de Canarias 2001)

Habitat	Plant communties (phytosociological association)
2110 Embryonic shifting dunes	*Euphorbio paraliasi-Cyperetum capitati* Sunding 1972
	Ononido tournefortii-Cyperetum capitati Wildpret, Del Arco & Acebes 1983
	Polycarpaeo-Lotetum lancerottensis Esteve 1968
2130 Fixed coastal dunes with herbaceous vegetation (grey dunes)	*Chenoleo tomentosae-Suaedetum vermiculatae* Sunding 1972 *typicum*
	atractyletosum preauxianae Sunding 1972
	suaedetosum verae Biondi 1988
	Frankenio-Zygophylletum gaetuli Del Arco & Wildpret 1991
	Traganetum moquinii Sunding 1972

of relevant plant communities corresponding to phytosociological associations.

These habitats are analyzed by comparing the official data with data obtained by our research team:

2110 Shifting dunes with embryonic vegetation

The description of this habitat is as follows (European Commission 2007):

> "*Formations of the coast representing the first stages of dune construction, constituted by ripples or raised sand surfaces of the upper beach or by a seaward fringe at the foot of the tall dunes*".

This habitat is mostly associated with inland fully stabilized aeolian sand sheets of the island of La Graciosa, and therefore away from the area of formation of embryonic dunes, occupied mainly by shrubs of *Salsola vermiculata* and to a lesser extent by *Launaea arborescens* (Table 3; Fig. 2). This type of vegetation does not appear associated with embryonic dune habitat (Gobierno de Canarias 2001; Table 2). This habitat also includes intertidal areas occupied by lava flows and other uncovered inland aeolian sands (Table 3). Furthermore, embryonic dune areas have been excluded from this habitat, as the beaches of Las Conchas and Lambra (west and north of La Graciosa, respectively), which are among the few areas where communities of *Euphorbia paralias* and *Polycarpaea nivea* have been identified, respectively. In the dune field of Corralejo, this habitat has been allocated to mobile dunes without vegetation, located in inland areas, dominated by barchanoid ridges and barchan dunes (Fig. 3). Moreover, contradicting the knowledge we have about the zonation of coastal dune fields, the embryonic dune habitat appears more inland than grey dunes, when it should theoretically be the opposite. In Maspalomas, *Euphorbio paraliasi-Cyperetum capitati* association (represented by the community of *Cyperus capitatus-Ononis serrata*), which is included in habitat 2110, is located on stabilized dunes and to a lesser extent on semi-stabilized ones of the inland areas (Hernández-Cordero et al. 2015a). Therefore, the official information does not consider the existence of this habitat in Maspalomas (Fig. 4).

Table 3 Surface of each plant community associated with habitat 2110 in La Graciosa, obtained by overlay of layers in the GIS

Plant community	Area (ha)	%
Non-aeolian area	126.7	18.6
Astydamia latifolia community	1.6	0.2
Chenoloides tomentosa community	10.8	1.6
Euphorbia regis-jubae community	0.3	0.0
Frankenia ericifolia community	8.8	1.3
Launaea arborescens community	25.1	3.7
Mesembryanthemum nodiflorum community	10.7	1.6
Ononis serrata community	0.1	0.0
Polycarpaea nivea community	3.7	0.5
Salsola vermiculata community	446.0	65.4
Suaeda vera community	2.8	0.4
Traganum moquinii community	2.7	0.4
Bare sand	42.3	6.2
Total	681.6	100

2130 Fixed coastal dunes with herbaceous vegetation (grey dunes)

The Interpretation Manual of European Union Habitats (European Commission 2007) describes the "Fixed coastal dunes with herbaceous vegetation (grey dunes)" as follows:

> "*Fixed dunes, stabilised and colonised by more or less closed perennial grasslands and abundant carpets of lichens and mosses, from the Atlantic coasts (and the English Channel) between the Straits of Gibraltar and Cap Blanc Nez, and the shores of the North Sea and the Baltic. In the case of the thermo-Atlantic coast, it is logical to include Euphorbio Helichrysion (code 16.222 - thermo Atlantic as far as Brittany) and Crucianellion maritimae (code 16.223 - Strait of Gibraltar as far as the southern Atlantic near Cape Prior in Galicia)*".

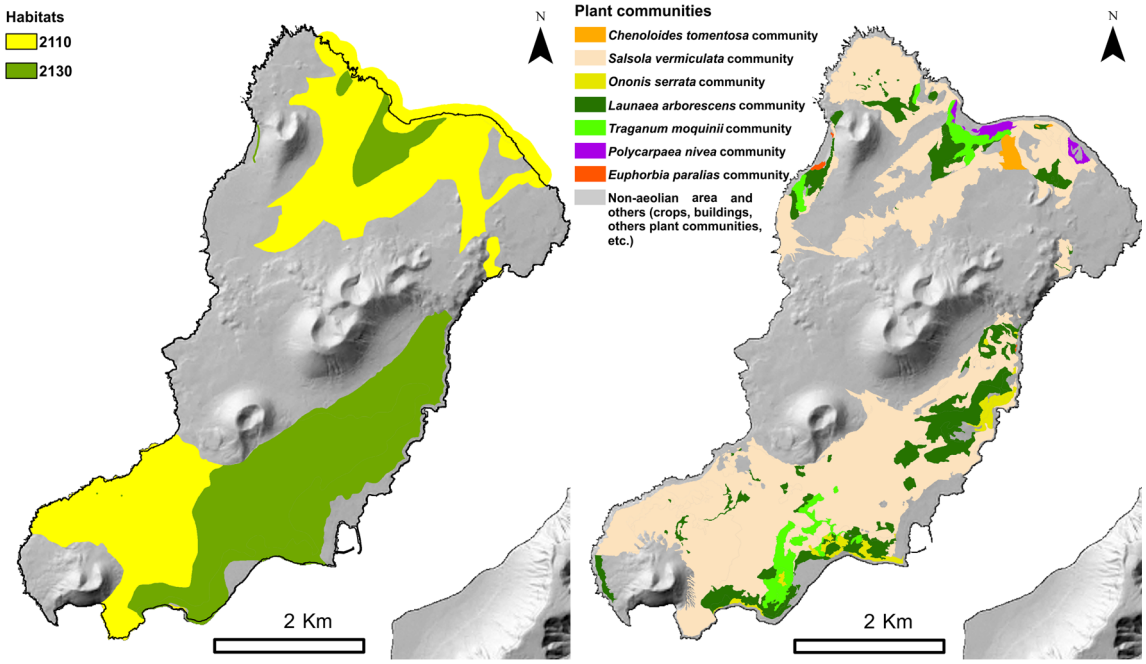

Fig. 2 Distribution of dune habitats (*Source*: Gobierno de Canarias) and plant communities in La Graciosa (only the major communities are represented)

In La Graciosa, more than half of this habitat is associated with the community of *Salsola vermiculata* (Table 4), which correspond to stabilized dunes but with shrubs. However, this habitat also includes *Traganum moquinii* community located in sand input areas and with aeolian sedimentary activity, as in the north of the island, i.e., non-stabilized dunes (Fig. 2). In addition, it is also present in the south of the island, associated with remobilization aeolian sand sheets. Therefore, on the island of La Graciosa *Traganum moquinii* is always associated with areas with active aeolian sedimentary processes. At both Maspalomas and Corralejo, this habitat is located in the area of sediment input to the system, according to the official data (Figs. 3 and 4), which is occupied by the community of *Traganum moquinii*. This is inconsistent with the existence of stabilized dunes, especially considering that big free dunes are located behind this first band. Therefore, in these two dune fields, *Traganum moquinii* community is primarily linked to the foredune. Thus, it is a characteristic plant community of mobile dunes of the Canary Islands, being located besides the foredune, at wet dune slack located between the ridges of free dunes (Hernández-Cordero et al. 2015a) and in aeolian sand sheets.

2190 Humid dune slacks

This habitat is described by the Interpretation Manual of European Union Habitats (European Commission 2007) as follows:

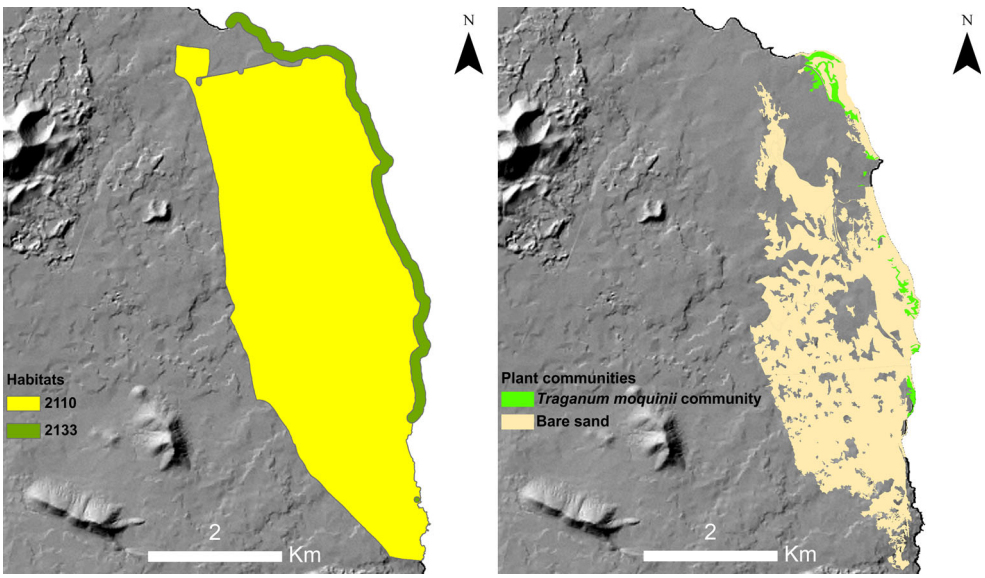

Fig. 3 Distribution of dune habitats (*Source*: Gobierno de Canarias) and *Traganum moquinii* community in the dune field of Corralejo

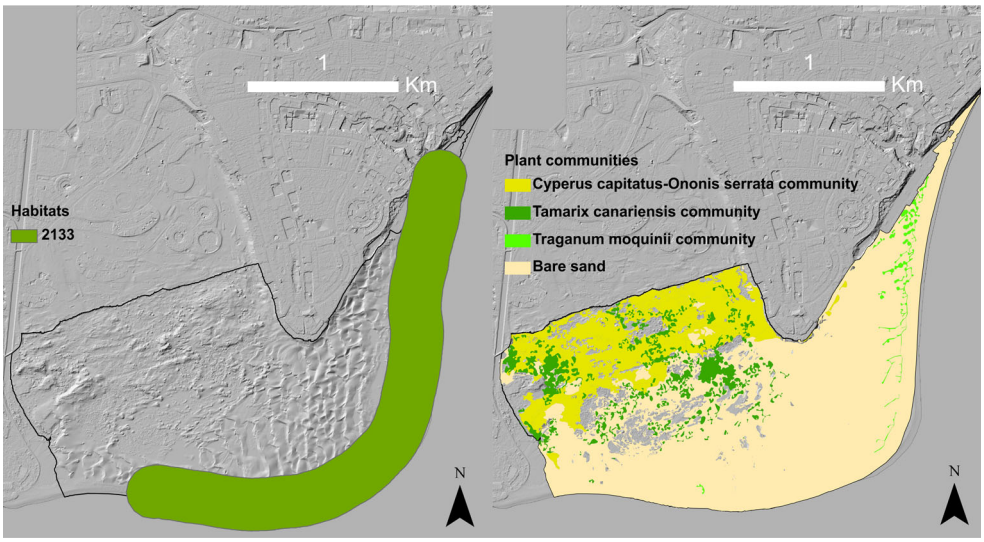

Fig. 4 Distribution of dune habitats (*Source*: Gobierno de Canarias) and plant communities in the dune field of Maspalomas, Gran Canaria (only the major communities are represented; modified from Hernández-Cordero et al. 2015a)

"*Humid depressions of dunal systems. Humid dune-slacks are extremely rich and specialised habitats very threatened by the lowering of water tables*".

European Commission (2007) does not recognize the existence of this habitat in the dunes of the Canary Islands. However, this habitat has been identified in the dune field of Maspalomas (Hernández-Cordero et al. 2015a). In this environment there are wet dune slacks where communities develop, such as *Cyperus laevigatus, Juncus acutus*, *Tetraena fontanesii*, *Traganum moquinii* and *Tamarix canariensis* (Hernández-Cordero et al. 2015a).

Table 4 Surface of each plant community associated with habitat 2130 in La Graciosa, obtained by overlay of layers in the GIS

Plant community	Area (ha)	%
Non-aeolian area	4.1	0.7
Astydamia latifolia community	0.3	0.1
Cakile marítima community	0.4	0.1
Euphorbia paralias community	0.1	0.0
Euphorbia regis-jubae community	0.5	0.1
Frankenia ericifolia community	0.7	0.1
Launaea arborescens community	147.1	24.3
Mesembryanthemum crystallinum community	0.5	0.1
Mesembryanthemum nodiflorum community	1.1	0.2
Ononis hesperia community	4.9	0.8
Ononis serrata community	24.9	4.1
Plantago coronopus community	0.3	0.0
Polycarpaea nivea community	6.0	1.0
Salsola vermiculata community	336.3	55.6
Suaeda vera community	0.1	0.0
Traganum moquinii community	53.9	8.9
Crops	3.4	0.6
Bare sand	20.7	3.4
Total	605.2	100

Discussion

Distinctive features of Macaronesian coastal dunes

Directive of the European Union for Conservation of habitats of European interest (Directive 92/43/EEC) has been a necessary tool for the protection of nature in Europe (Heslenfeld et al. 2004). However, there have been problems in implementing the Directive due to the regional variations in habitat areas, so new habitats based on the new research have been proposed (Evans 2006, 2010; Feola et al. 2011). The habitats of European interest associated with dunes in the Canary Islands were determined solely based on phytosociological criteria, not considering other environmental elements which are fundamental to understand the habitats linked to aeolian sedimentary systems. The landforms or geomorphological processes (sand input areas, types of dunes, dune mobility, etc.) are among those fundamental elements, very important in shaping the dune ecosystems due to their dynamism, especially in arid regions such as the coast of the Canary Islands (Cabrera-Vega et al. 2013). This is a very important issue since a habitat is not defined solely by its vegetation, but also by its landforms and geomorphological processes which are of great importance to understand its configuration and operation (Barrett-Mold and Burningham 2010; Corenblit et al. 2011; Parker and Bendix 1996; Stallins 2006; Swanson et al. 1988).

The method used in this research to characterize vegetation at aeolian sedimentary systems in the Canary Islands is considered more appropriate than the phytosociological one for determining habitats of European interest. Integrating both

biotic and abiotic components for the analysis of vegetation allow us an identification and characterization of the habitats closer to reality; in the case of aeolian sedimentary systems in Canaries these components are mainly aeolian sedimentary activity and type of landform (Hernández-Cordero et al. 2015a). Furthermore, when these habitats were mapped, there was limited available information on the characteristics of the dune vegetation in the Canaries, especially their relationship with environmental factors and patterns of colonization and plant succession, and the processes that control the operation of these systems. Thus, in the three dune fields studied, the habitat "2110 shifting dunes with embryonic vegetation" is associated with several situations incompatible with their biotic and abiotic characteristics: 1) rocky intertidal zones; 2) interior areas without aeolian sands; 3) stabilized aeolian sand sheets occupied by scrub of *Launaea arborescens* and *Salsola vermiculata*; 4) Free dunes without vegetation; 5) grey dunes habitat appears numerous times in a forward position with respect to embryonic dunes.

On the other hand, one of the phytosociological associations that are considered related to embryonic dune habitats is *Polycarpaeo niveae-Lotetum lancerottensis* (Gobierno de Canarias 2001). However, this plant community is more identifiable with habitat "2130 Fixed dunes with herbaceous vegetation (grey dunes)", because it is a type of vegetation that sits on dunes under fixation process (Del Arco Aguilar et al. 2010). Therefore, it is located on areas where formation of dunes embryonic does not occur. We must consider that embryonic dunes are the first stage in the formation of coastal dune fields due to sediment accumulation generated by pioneer plants (Cowles 1899a, b; Hesp 2002). The role of embryonic dune formation is mainly done by the *Traganum moquinii* community (phytosociological association *Traganetum moquinii*), which however is included in the Habitat Directive within the grey dunes habitat. In this context, Sunding (1972) emphasizes the role of *Traganum moquinii* in dune formation. This plant species generates the first dunes, which normally have a hummock morphology. This community is also involved in the later stages of the foredune (Hernández-Cordero et al. 2012). Therefore, *Traganum moquinii* is a species which plays a role similar to *Ammophila arenaria* in the Atlantic and Mediterranean Europe (Sunding 1972). Also, Géhu and Biondi (1996) include the *Traganetum moquinii* association in the mobile dunes habitat and indicate that replaces *Ammophila arenaria* in the formation of dunes on the coast of southern Morocco. In this context, it is inappropriate to consider the community of *Traganum moquinii* as part of grey dunes habitat, being more correct to associate it with a specific habitat similar to "2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)".

On the other hand, there is another habitat that has not been identified in the dunes at Canaries so far (Gracia et al. 2009). It is the case of habitat "2190 Humid dune slacks", which is present in the Maspalomas dune system. It consists of the communities of *Cyperus laevigatus, Tetraena fontanesii* and *Juncus acutus* (Hernández-Cordero et al. 2015a). Consider that plant communities associated with *Molinio-Holoschoenion* class present Maspalomas are those with a higher priority conservation in Spain (García-Madrid et al. 2014).

The knowledge gained in the last decade on aeolian systems of the Canary Islands allows us to propose two new types of habitats not hitherto established by Directive Habitat: the Macaronesian aeolian sand sheets and dunes with *Tamarix canariensis*.

The Macaronesian aeolian sand sheets are formed by wide sandy areas where dune landforms are reduced to the existence of hummock dunes generated by plants (Gutiérrez-Elorza et al. 2013). This habitat would encompass most of the areas included in embryonic dune habitat on the island of La Graciosa and Corralejo dune field. Because of its important extension on the islands of La Graciosa, Lanzarote and Fuerteventura, it is considered a habitat of great importance for the conservation of biodiversity in the Canary Islands, especially because it is the habitat of steppe birds like *Chlamydotis undulata*, *Cursorius cursor* and *Burhinus oedicnemus* among others (Santos 1993), and endemic species of coleptera (García Becerra and Peña Estévez 1995).

The dunes with *Tamarix canariensis* are a characteristic habitat of the dune system of Maspalomas, at Gran Canaria island. The EU Habitats Directive includes *Tamarix canariensis* formations of Maspalomas dune field in the habitat 92D0 *Southern riparian galleries and thickets (Nerio-Tamaricetea and Securinegion tinctoriae)* (European Commission 2007). However, the *Tamarix canariensis* formations of the dunes are singular by their floristic composition and processes ecological succession. It presents a unique formation process, similar to habitat "2170 Dunes with *Salix repens ssp. argentea* (*Salicion arenariea*)" (Hernández-Cordero et al. 2015b; Ranwell 1960). Thus, the juveniles of *Tamarix canariensis* start to colonize the dunes from the wet dune slacks. When the dunes invade the slack, the surviving plants form the dunes with *Tamarix canariensis*.

A correct identification of European habitats is essential for proper management of them. For example, management and protection measures cannot be the same in the habitats of mobile dunes and stabilized dunes, because they present different geomorphological processes and types of vegetation (Martins et al. 2013). In this context, the inclusion of *Traganum moquinii* community in grey dunes habitat could determine management measures and protection aimed at the conservation of stabilized dunes with herbaceous vegetation, as maintaining a maximum of 10 % of bare sand, keep a low presence of trees or shrubs, etc., (Houston 2008), when in fact this plant community develops in areas with active aeolian sedimentary processes (area of sand input, sand mobility, deflation, etc.).

Therefore, dune habitats in the Canary Islands have singularities that must be considered, forming differentiated habitats by their geomorphic processes, by their vegetation types and by the existing plants, unique species in the European context formed by endemic plants or shared with the northwest Africa and other Macaronesian islands. The uniqueness of the flora of the dune fields of the Canary Islands has been shown in previous works (Doody 1991; Sunding 1972). Probably some of the habitats of European interest located in the Canary Islands are present in other areas of the Macaronesian region. For instance, in the Selvagens Islands and the southern coast of Morocco (Costa et al. 2012; Géhu and Biondi 1996, 1998), the presence of the phytosociological association *Traganetum moquinii* has been documented, which could suggest the presence of specific habitat for this plant community.

Proposal of new Natura 2000 Macaronesian habitats

The singularities of dune habitats present in the Macaronesian region produce the need to define a large subgroup, which would be established as follows:

24: Sea dunes of the Macaronesian coasts.

A preliminary characterization of these proposed new habitats, proposing codes for the Natura 2000 list, is made according to the scheme used by the European Directive for the characterization of habitats (European Commission 2007). This scheme includes the codes and names of the Natura 2000 network and the code based on "A classification of Palaearctic habitats" in the 2001 edition; 1) Definition and overview of vegetation, syntaxa, environmental factors and origin; 2) Plants and animals characteristics; 3) Correspondence with other classification systems (Moss and Davies 2002), typical places; 4) Habitat types usually associated in the field (phytodynamic succession, zonation or mosaic); 5) Reference literature. The phytosociological associations are based in Del Arco (2006) and Del Arco Aguilar et al. (2010).

2410 Coastal shifting dunes with *Traganum moquinii* (Macaronesian white dunes)

PAL.CLASS.: a new code is required in this case

1) Active dunes with hummock morphology, which may correspond to both primary stages of dune formation (embryonic dunes) or later stages of the foredune. They can be monospecific communities of *Traganum moquinii*, where the input of sand and dunes mobility is greater, or be accompanied by other plant species when the aeolian sedimentary processes are less intense (Fig. 5). This habitat is also present in remobilized aeolian sand sheets in areas far from the coast, where it also forms hummock dunes (as in some areas of the island of La Graciosa). In transgressive dune fields (as in Maspalomas and Corralejo) this habitat can appear between free dunes colonizing the dune slacks or mobile aeolian sand sheets which generates hummock dunes (in these three cases it would settle the habitat of Macaronesian aeolian sand sheets).
2) Plants: *Traganum moquinii, Tetraena fontanesii, Launaea arborescens, Salsola vermiculata, Atriplex glauca, Polycarpaea nivea*, *Euphorbia paralias, Cakile maritima*.
3) Corresponding categories

   It would correspond to the classification of habitats in Europe EUNIS CLASS: B1.3

   Typical sites: Islands of La Graciosa, Lanzarote, Fuerteventura, Gran Canaria and Tenerife. In addition to the Canary Islands, this habitat is most likely present in the Selvagens Islands, Cape Verde and Morocco.
4) Phytosociological association: *Traganetum moquinii*.
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2420 Dunes with *Tamarix canariensis*

PAL.CLASS.: a new code is required in this case

Fig. 5 Coastal shifting dunes with *Traganum moquinii. Left*: *Traganum moquinii* without associated flora (Maspalomas, Gran Canaria). *Right*: *Traganum moquinii* with companion species such as *Polycarpaea nivea*, *Cakile maritima* and *Salsola vermiculata* (Lambra beach, La Graciosa)

1) Hummock dunes that may be stabilized or have active aeolian sedimentary processes, depending on the state of plant succession (Fig. 6). Its formation begins in wet dune slack of mobile dunes. When the free dunes cover the slack, *Tamarix canariensis* survivors generate hummock dunes. In this case, mobile dunes with *Tamarix canariensis* are formed. Stabilized dunes with *Tamarix canariensis* are formed when the aeolian sedimentary processes are reduced, which presents a more varied companion species. This habitat is found only in the Maspalomas dune system.
2) Plants: *Tamarix canariensis, Cyperus capitatus, Suaeda mollis, Launaea arborescens, Ononis serrata, Heliotropium bacciferum*.
3) Corresponding categories

   It would correspond to the classification of habitats in Europe EUNIS CLASS: B1.7.

   Typical sites: Maspalomas dune system (Gran Canaria Island)
4) Phytosociological association: *Suaedo verae-Tamaricetum canariensis*. The companion species of this plant community varies depending on aeolian sedimentary activity. In mobile dunes, the only one specie present is usually *Tamarix canariensis*. In the semi-stabilized dunes it is present with shrub species as *Launaea arborescens* and *Suaeda mollis*. In stabilized areas, associated flora is richer and has greater coverage, appearing herbaceous species such as *Cyperus capitatus* and *Ononis serrata*, and bushy species as *Heliotropium bacciferum* and *Launaea arborescens*.
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2430 Macaronesian aeolian sand sheets

PAL.CLASS.: a new code is required in this case

1) The sand sheets are aeolian sands with no slip faces and a flat or slightly undulating topography. Stabilized or mobile sand sheets normally present low thickness and large extension, and they can be located at both the immediate area of the shore or at greater distances inward (Fig. 7). Many of them are fed by sediments from fossil dunes. These sand sheets are colonized by different herbaceous and/or shrub plant communities, depending on the distance to the coast, sediment mobility, their thickness and the type of substrate (sand or mixture of sand and volcanic material). Psamophylic, xerophilic and halophytes species are present in this habitat, mostly endemic to the Canary Islands, to Macaronesia or shared with the

Fig. 6 Dunes with *Tamarix canariensis* (Maspalomas, Gran Canaria). *Left*: *Tamarix canariensis* in mobile dunes. *Right*: *Tamarix canariensis* in stabilized dunes

Fig. 7 Macaronesian aeolian sand sheets. *Left*: mobile aeolian sand sheets (El Jabillo, La Graciosa). *Right*: stabilized aeolian sand sheets (Corralejo, Fuerteventura)

northwest Africa. Plants form hummock dunes, whose size is associated with the plant that generates it.

2) Plants: *Convolvulus caput-medusae*, *Atractylis preauxiana*, *Lotus arinagensis*, *Lotus lancerottensis*, *Androcymbium psammophilum*, *Launaea arborescens*, *Salsola vermiculata*, *Polycarpaea nivea*, *Ononis hesperia*, *Traganum moquini*, *Heliotropium bacciferum*, *Euphorbia paralias*, *Ononis serrata*, *Cyperus capitatus*, *Reseda lancerotae*, *Ifloga spicata*.

   Animals: Birds- *Chlamydotis undulata*, *Cursorius cursor*, *Burhinus oedicnemus*, *Bucanetes githagineus*; *Calandrella rufescens*. Invertebrates- *Pimelia granulicollis*, *Pimelia sparsa*, *Pimelia estevezi*, *Pimelia fernandezlopezi*, *Pimelia canariensis*.

3) Corresponding categories

   It would correspond to the classification of habitats in Europe EUNIS CLASS: B1.3, B1.4

   Typical sites: Alegranza, Lobos, La Graciosa, Lanzarote, Fuerteventura, Gran Canaria, Tenerife and La Gomera (Canary Islands). Very probably also in Cabo Verde, Morocco and Porto Santo Island (Madeira archipielago).

4) Phytosociological associations: *Chenoleoideo tomentosae-Salsoletum vermiculatae*, *Chenoleoideo tomentosae-Suaedetum mollis*, *Launaeo arborescentis-Schizogynetum sericeae*, *Cenchro ciliaris-Launaeetum arborescentis*, *Traganetum moquinii*, *Polycarpaeo niveae-Lotetum lancerottensis*, *Euphorbio paraliae-Cyperetum capitati.* Other plant communities that may be present are *Astydamio latifoliae-Euphorbietum aphyllae*, *Lycio intricati-Euphorbietum balsamiferae*.

5) Esteve Chueca F (1968) Datos para el estudio de las clases *Ammophiletea*, *Juncetea* y *Salicornietea* en las Canarias orientales. Collectanea Botanica 7:303–323.

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Other habitats

The following habitat constitute the confirmation of its existence in the Canary Islands:

2190 Humid dune slacks

PAL.CLASS.: subtypes 16.36 to 16.38 are suggested

1) This type of humid dune slack are developed according to two main geomorphological processes. The first one is related to the displacement of the mobile dunes, so that depressions arise between barchanoid ridges by the deflation processes intrinsic to their movement. The second way to originate these depressions is related to the existence of a sediment deficit, which causes the formation of deflation surfaces allowing wet substrates to outcrop by the proximity of the water table.

   Sub-types

   16.36- Dune-slack of mobile dunes: consists mainly of *Cyperus laevigatus* and *Tamarix canariensis* communities. *Cyperus laevigatus* presents a range of strategies to get away from the moving dunes that bury the slack where it develops (Hernández-Cordero et al. 2015b) *Cyperus laevigatus* may be the only one specie, or it could be accompanied by other species such as *Juncus acutus*

and *Tamarix canariensis*.

16.37- Dune-slack of stabilized dunes: formed by the communities of *Juncus acutus* and of *Tamarix canariensis*.

16.38- Dune-slack of saline water: formed by the communities of *Tetraena fontanesii* and of *Tamarix canariensis*.

2) Plants: *Cyperus laevigatus*, *Juncus acutus*, *Tamarix canariensis*, *Tetraena fontanesii*, *Suaeda mollis*, *Frankenia boissieri*, *Limonium tuberculatum*, *Schizogyne glaberrima*.

3) Corresponding categories

It would correspond to the classification of habitats in Europe EUNIS CLASS: B1.8

Typical sites: Maspalomas dune system (Gran Canaria Island, Fig. 8).

4) Phytosociological associations: *Cyperetum laevigati*; *Scirpo globiferi-Juncetum acuti*; *Zygophyllum fontanesii and Suaeda mollis community*, *Suaedo verae-Tamaricetum canariensis*. The community of *Tamarix canariensis* (phytosociological association *Suaedo verae-Tamaricetum canariensis*) starts the process of colonization on dune slacks. Therefore, this community is also temporarily or even permanently a type of vegetation associated with wet dune slacks. When this community sits permanently in a dune slack, it tends to form groves of *Tamarix canariensis* because the dunes not buried it; these groves can be found in mobile, semi-stabilized and stabilized dunes.

5) Esteve Chueca F (1968) Datos para el estudio de las clases *Ammophiletea*, *Juncetea* y *Salicornietea* en las Canarias orientales. Collectanea Botanica 7:303–323.

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Conclusions

The special climatic and ecological characteristics of the Macaronesian Ecoregion favors the development of specific dune habitats, not well known to date. This paper aims to make a contribution to the knowledge of habitats of European interest for the preservation of the Macaronesian coastal dune systems, based on examples of the Canary Islands. The relevance of these habitats is similar to that of other continental European habitats listed as of European interest, and included in international classifications of habitats such as Natura 2000. A new classification of habitats of European interest is thus proposed associated to the Macaronesian dunes establishing the following new habitats. Due to the ecological peculiarities of coastal dune fields in the Canaries this group is suggested to be a subgroup of habitats 24 Sea dunes of the Macaronesian coasts:

2410 Coastal shifting dunes with *Traganum moquinii* (Macaronesian white dunes)
2420 Dunes with *Tamarix canariensis*
2430 Macaronesian aeolian sand sheets

These habitats are defined in the Canary Islands according to their identification, characterization and detailed mapping, based not only on the vegetation but also on landforms and geomorphic processes associated with its generation and development. This study has been completed with the identification of habitat 2190 Humid dune slacks in the Canary Islands, which had not been recognized in this area before.

Fig. 8 Humid dune slack with *Cyperus laevigatus* (Maspalomas, Gran Canaria). *Left*: example with greater floristic richness species such as *Cyperus laevigatus*, *Juncus acutus* and *Tamarix canariensis*. *Right*: humid dune slack only with *Cyperus laevigatus*

On the other hand, some of these habitats have already been identified in other islands of the Macaronesia Ecoregion, although more specific and comprehensive studies are needed as well as detailed maps of these habitats in Madeira, Selvagens and Cape Verde Islands for establishing their actual relevance.

This work includes the characterize of these new habitats, following the official format of the catalog of the Interpretation Manual of European Union Habitats, in order to propose its inclusion as new habitats as presented here, or at least consider the advisability of including them as specific habitats. Although they had been partly recognized in the catalog "A classification of Palaearctic hábitats", its definition was clearly incorrect and incomplete as they did not consider the role of *Traganum moquinii* as a pioneer plant and also a contributor to the formation of the foredune, nor the characteristics of the exclusive Macaronesian dune plant communities. In parallel, the Natura 2000 network does not even recognized their existence. Therefore, we believe that this proposal can be useful to properly complete the catalog of habitats of European interest.

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