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Annual dune plant communities in the Southwest coast of Europe

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Abstract

This study presents an updated syntaxonomic review of the annual communities from coastal dunes in the Southwest coast of Europe, specifically in the Iberian Peninsula, including both types: directly influenced by the sea salt spray and not affected by this influence. The floristic segregation of the different plant associations was obtained by statistical agglomerative processes (UPGMA, Unweighted Pair Group Method with Arithmetic Mean) plus principal coordinate analysis (PCoA) and discussed based on the interpretation of phytosociological tables. Three new communities in central western Portugal were found and are described: *Pseudorlayo minusculae-Polycarpietum alsinifoli*, *Cerastio diffusae-Vulprietum fontqueranae* and *Omphalodo kunzinskyanae-Evacietum ramosissimae*.

Keywords: *Biogeography, coastal dunes, chorology, syntaxonomy, Iberian Peninsula*

Introduction

A general characteristic of annual plant communities is the fact that they colonize extreme biotopes, within the possible limits for vegetal life (Biondi 2007) where physical conditions hinder the development of most perennials. Globally, the diversity of therophitic communities is enormous, because these communities easily change their floristic combination along ecological gradients such as climatic, soil, topographic and human disturbance-related gradients (Guarino et al. 2005). After the major review from Díez-Garretas et al. (2003), to extensive dune areas, especially in the North of Lisbon (Dividing Portuguese Sector, Sadensean-Dividing Portuguese Sub-province, Lusitan–Andalusian Coastal Province), the available information has been revealed to be scarce. Thus, new complete studies on the annual dune communities in the west of the Iberian Peninsula were needed. Such communities belong to the alliances *Linarion pedunculatae* (*Cutandietalia maritima*), *Anthyllido hamosae-Malcolmion lacerae* (*Malcolmietalia*) and *Thero-Airion* (*Helianthemetalia guttati*). This type of vegetation is threatened by the

invasion of alien plants (Campos et al. 2004; Stanisci et al. 2010; Zedda et al. 2010). Their conservation relevance is supported by the inclusion in the European Union Network “Nature 2000”, with the habitat code “2230 *Malcolmietalia* dune grasslands” (Loidi 1999; Neto et al. 2007).

Materials and methods

The vegetation relevés have been made according to the sigmatist landscape phytosociological approach (Braun-Blanquet 1979; Weber et al. 2000; Rivas-Martinez 2005). Bioclimatic and biogeographic typologic follow Costa et al. (1999) and Rivas-Martinez et al. (2002). A total of 235 relevés were submitted to UPGMA and principal coordinate analysis (PCoA), with Bray–Curtis coefficient using SYNTAX 2000 software (Podani 2001). In addition to these, some other relevés were taken from literature (Rivas Goday 1958; Pinto Silva & Teles 1972; Díaz González & Navarro 1978; Rivas-Martinez et al. 1980; Díez-Garretas 1984; Izco et al. 1988; Costa et al. 1994, 1997, 2000; Díez-Garretas & Asensi 2002; Neto 2002; Lomba 2004) to

compose the synthetic table and run the ordination and cluster analysis.

Results and discussion

The PCoA ordination (Figure 1) separated the relevés of *L. pedunculatae* (relevés 1–123), *Anthyllido hamosae-Malcolmion lacerae* (relevés 124–219) and *Thero-Airion* (relevés 220–242). The performed cluster analysis UPGMA showed a segregation of the communities from *L. pedunculatae* (Figure 2) and *Anthyllido hamosae-Malcolmion lacerae* (Figure 3). Likewise, the new associations described show a fine floristic individuality over the others of the same alliance.

The order *Cutandietalia maritimae* was proposed by Rivas-Martinez et al. (2002) to the Mediterranean annual associations of semi-fixed dunes, including the alliance *L. pedunculatae*, distributed by the west and northwest of the Iberian Peninsula and North of Africa. In the Iberian Peninsula and West Morocco, the order *Malcolmietales* comprises the interior sandy soil communities, namely the Iberian alliance *Anthyllido hamosae-Malcolmion lacerae* which occurs in the clearings of bushes and woodlands in the themediterranean dry belt.

In the central west Portuguese coast, the relevés made in semi-fixed dunes do not show the endemics *Linaria ficalhoana* Rouy or *Herniaria algarvica* Chaudhri, which are present in *Herniario algarvicae-Linarietum ficalhoanae* in the south. Consequently, the communities from the north of Lisbon demonstrate a clear floristic individuality that can be explained by biogeography and climatic reasons.

Both communities are physically separated by an extension superior to 100 km, of rocky cliffs, coastal limestone and granite platforms, between Lisbon and Carvoeiro Cap (Peniche). From a biogeographical point of view, this lithological discontinuity is critical in the distribution of the psammophilic plant communities in the west of the Iberian Peninsula. There are also important climatic differences, like higher number of foggy days in spring and summer, stronger influence of fronts, lower temperatures through the year and higher levels of rainfall, in the north. As a result, thermophilic plants have difficulty in moving north.

When describing the association *Viola henriquesii-Silenetum littoreae* to the dunes of Galicia, Izco et al. (1988) extended its distribution area to the Portuguese western coast. However, the relevés made in this work have revealed that the dune community in the center of Portugal is different from that occurring in the northwest of the Iberian Peninsula (Table I, the bold values mean the type of the association and the values inside the box are the characteristics and the different species of each association). Hence, it is proposed as a new association, *Pseudorlayo minusculae-Polycarpium alsinifolii* (Table II, typus relevé # 8), according to the following arguments: *Viola kitaibeliana* Schultes var. *henriquesii* (Willk.) Beck, *Polycarpon diphylum* (L.) L., *Omphalodes littoralis* Lehm. ssp. *gallaecica* Lainz, *Pseudorlaya pumila* (L.) Grande ssp. *microcarpa* Loret and Barrandon, *Sedum arenarium* Brot. and *Silene scabriflora* Brot. ssp. *gallaecica* Talavera do not occur in the south of Aveiro; *Pseudorlaya minuscula* (Font Quer) Lainz, *Polycarpon alsinifolium* (Biv.) DC., *Hedypnois*

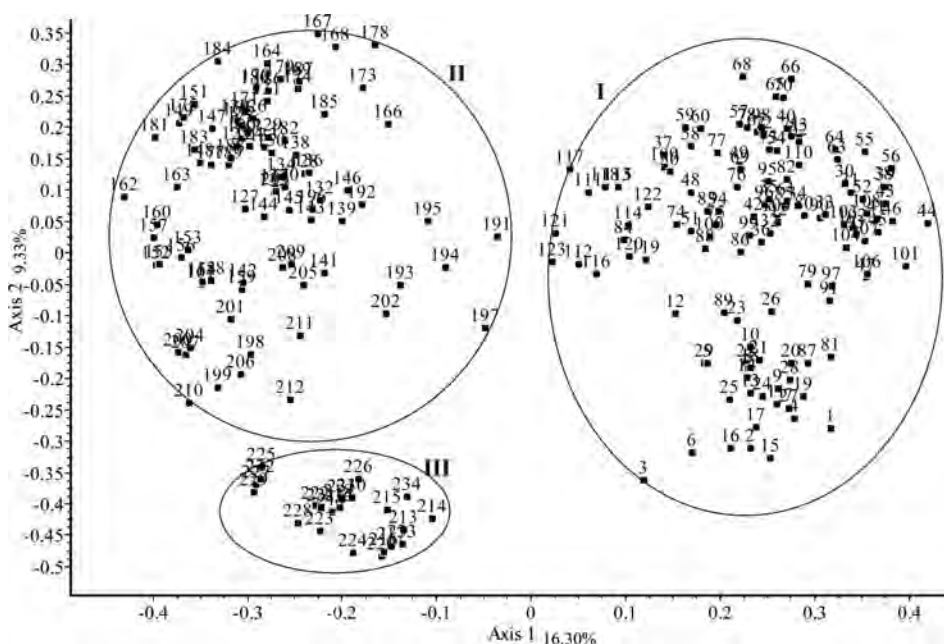


Figure 1. PCoA Bray–Curtis coefficient: I *L. pedunculatae* II *Anthyllido hamosae-Malcolmion lacerae* III *Thero-Airion*.

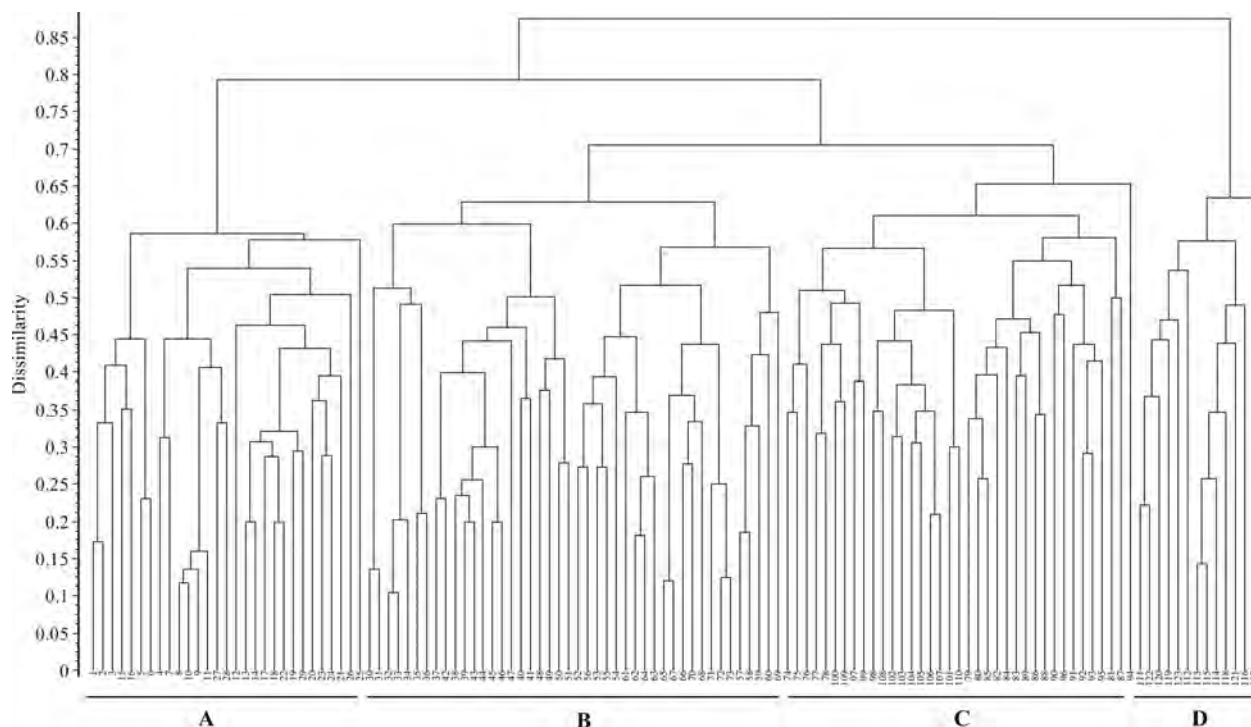


Figure 2. UPGMA with Bray–Curtis coefficient of the association of Iberian Peninsula of *L. pedunculatae*: **A** *Ononido variegatae*–*Linarietum pedunculatae* **B** *Herniario algarvicae*–*Linarietum ficalhoanae* **C** *Pseudorlayo minusculae*–*Polycarpium alsinifoli* **D** *Violo henriquesii*–*Silenetum littoreae*.

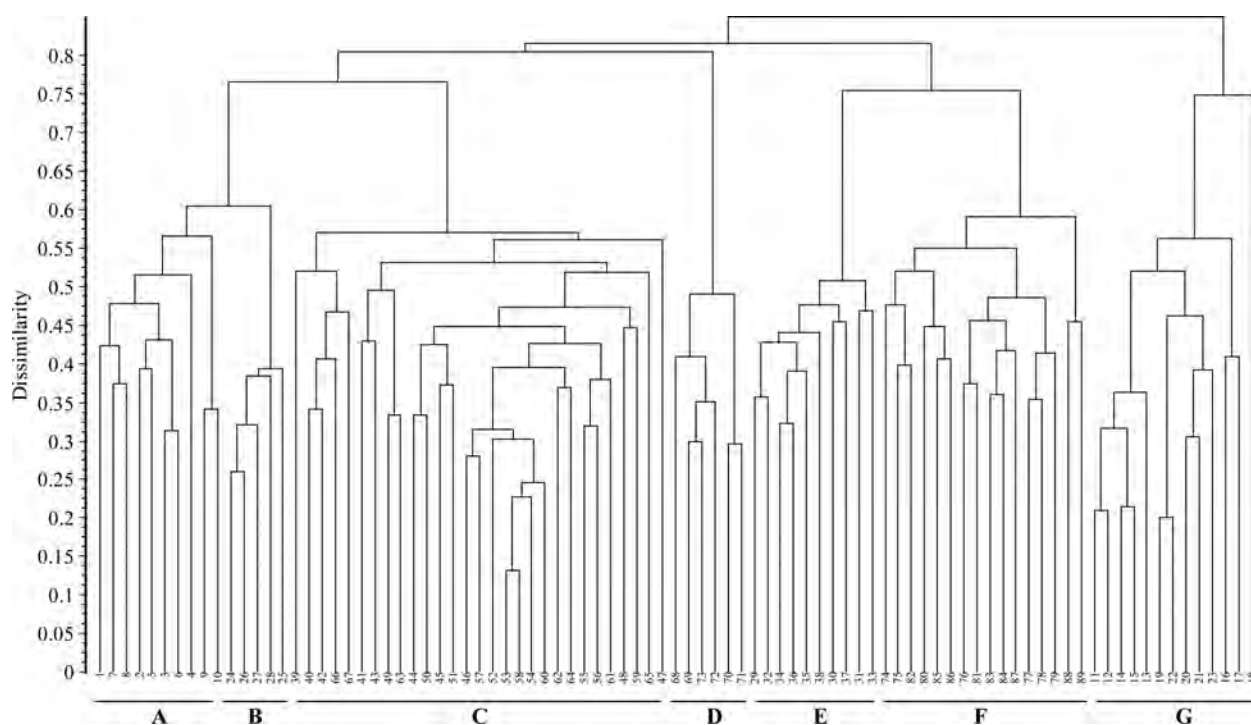


Figure 3. UPGMA with Bray–Curtis coefficient of the association of Iberian Peninsula of *Anthyllido hamosae*–*Malcolmion lacerae*: **A** *Hymenostemmo pseudanthemidis*–*Arenarietum emarginatae* **B** *Malcolmio lacerae*–*Anthyllidetum hamosae* **C** *Corynephoru macrantheri*–*Arenarietum algarbiensis* **D** *Omphalodo kunzinskyanae*–*Evacietum ramosissimae* **E** *Tolpido barbatae*–*Tuberarietum bupleurifoliae* **F** *Cerastio diffusi*–*Vulpietum fontqueriana* **G** *Linario donyanae*–*Loeflingietum baeticae*.

cretica (L.) Dumont-Courset, *Silene nicaensis* All., *Ononis dentata* Sol ex Lowe and *Pimpinella villosa* Schousb. appear as differentials of this new

community, when facing the Galician-Portuguese. *Malcolmia ramosissima* (Desf.) Thell. is differential to *Herniario algarvice*–*Linarietum ficalhoanae*. *Violo*

Table I. Synoptic table of dunes associations of *Linaria pedunculatae*, *Anthyllido hamosi-Malcolmion lacerae* and *Thero-Airion* dunes of the Iberian Peninsula and North Africa.

Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	
Number of relevés	13	7	26	11	7	22	11	4	7	15	15	4	3	10	5	13	10	1	28	6	16	13	10	
Characteristics and differentials of the <i>Linaria pedunculatae</i> associations																								
<i>Viola kitabaliana</i> var. <i>henriquesii</i>	V	II																						
<i>Pseudorlaya pumila</i> ssp. <i>microcarpa</i>	IV																							
<i>Polycarpon diphyllum</i>	I	II																						
<i>Sedum arenarium</i>	II																							
<i>Omphalodes littoralis</i> ssp. <i>gallaecica</i>	II	I																						
<i>Silene scabriflora</i> ssp. <i>gallaecica</i>																								
<i>Malcolmia ramosissima</i>	+	V	III																					
<i>Silene littorea</i>	V																							
<i>Polycarpon alsinifolium</i>					IV	V	V	4											II					
<i>Pseudorlaya minuscula</i>				V	V	V	V	4	IV	V	+	4	3			I			IV					
<i>Silene micaensis</i>				IV	III		III	2	IV	IV		3	3											
<i>Silene nitcaensis</i>				II	II		II		IV	III	V	1	1						+					
<i>Pimpinella villosa</i>				II																				
<i>Ononis dentata</i>				I				1																
<i>Linaria ficalhoana</i>				V	V	V	V	4																
<i>Herniaria algarvica</i>				IV	IV		III	2																
<i>Chaenorhizum serpyllifolium</i> ssp. <i>lusitanicum</i>								4																
<i>Erodium laciniatum</i> (Cav.) Willk.																								
<i>Romulea gaditana</i> G. Kunze																								
<i>Hypocoum littorale</i> Wulfen																								
<i>Ononis variegata</i>					V																			
<i>Linaria pedunculata</i>																								
<i>Linaria munbyana</i> ssp. <i>pygmaea</i>																								
Differentials of the <i>Anthyllido hamosi-Malcolmion lacerae</i> and <i>Thero-Airion</i> associations																								
<i>Hymenostemma pseudanthemis</i>																								
<i>Arenaria emarginata</i>																								
<i>Scilla ramburei</i>																								
<i>Hippocrepis salzmannii</i>																								
<i>Trisetaria difourei</i> (Boiss.) Paunero																								
<i>Anthoxanthum ovatum</i>																								
<i>Evax astenseiflora</i>																								
<i>Hymenocarpus hamosus</i>																								
<i>Malcolmia triloba</i>																								
<i>Loeflingia baetica</i> var. <i>baetica</i>																								
<i>Linaria tursica</i>																								
<i>Arenaria algarbiensis</i>																								
<i>Tuberaria bupleurifolia</i>																								
<i>Scilla odorata</i>																								
<i>Lotus castellanus</i>																								

(continued)

Table I. (Continued).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24			
Number of relevés	13	7	26	11	7	22	11	4	7	15	15	4	3	10	5	13	10	1	28	6	16	13	10			
<i>Corynephorus macrantherus</i>																			I							
<i>Malcolmia gracillima</i>																										
<i>Omphalodes kusinskyanae</i>																										
<i>Jonopsidium acaule</i>																										
<i>Vulpia fontquerana</i>																										
<i>Lotus arenarius</i>																										
<i>Aira praecox</i>																										
<i>Cerastium diffusum</i>																										
<i>Asterolinon linum-stellatum</i>																										
<i>Pterohagia prolifera</i> (L.) P.W. Ball						r																				
<i>Trifolium arvense</i> L.																										
<i>Koeleria albescens</i> DC.																										
<i>Ononis reclinata</i> L.																										
<i>Arenaria serpyllifolia</i> L.																										
<i>Phleum arenarium</i> L.																										
<i>Rumex bucephalophorus</i> ssp. <i>bucephalophorus</i>																										
Characteristics of the <i>Cutandietalia maritimae</i>																										
<i>Medicago litoralis</i> Rohde																										
<i>Cutandia maritima</i>																										
<i>Hedypnois cretica</i>																										
<i>Pseudorhiza pumila</i> var. <i>pumila</i>																										
<i>Hedypnois arenaria</i> (Schousb.) DC.																										
Characteristics of the <i>Malcolmietalia</i> and <i>Anthyllido-Malcolmion lacerae</i>																										
<i>Erodium bipinnatum</i>																										
<i>Rumex bucephalophorus</i> ssp. <i>hispanicus</i>																										
<i>Ononis diffusa</i>																										
<i>Evax ramosissima</i>																										
<i>Coronilla repanda</i>																										
<i>Vulpia membranacea</i>																										
<i>Andryala arenaria</i>																										
<i>Ononis broterana</i>																										
<i>Linaria spartea</i>																										
<i>Silene colorata</i>																										
<i>Leucopodium trichophyllum</i> Schousb.																										
<i>Ononis baetica</i> Clemente																										
<i>Corynephorus fasciculatus</i> Boiss. & Reut.																										
<i>Loeflingia baetica</i> var. <i>micrantha</i>																										
<i>Ornithopus ischnocarpus</i>																										
<i>Agrostis tenerrima</i>																										
<i>Silene scabriflora</i> ssp. <i>scabriflora</i>																										
<i>Ornithopus sativus</i>																										

(continued)

Table I. (Continued).

Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	
Number of relevés	13	7	26	11	7	22	11	4	7	15	15	4	3	10	5	13	10	1	28	6	16	13	10	
Characteristics and differentials of the <i>Helianthemetea guttatae</i>																								
<i>Mibora minima</i> (L.) Dev.						r																		
<i>Hypochoeris glabra</i> L.		I				+											II				+			
<i>Leontodon longirostris</i>		IV	II	IV		+											III				III			
<i>Ornithopus pinnatus</i>		I	+	+				2									IV				III		II	
<i>Tuberaria guttata</i>		III	II	II			I	4									V				IV	V	II	
<i>Trifolium scabrum</i>		I	r																			II		II
<i>Grassula tillaea</i> Lest.-Garl.		III															III							
<i>Teesdalia nudicaulis</i>		I																						
<i>Vulpia myuros</i>			II																			II		II
<i>Logfia minima</i>			I																			III		II
<i>Euphorbia exigua</i>			r																			III		II
<i>Micropyrum tenellum</i>			r																			III		II
<i>Trifolium campestre</i>			r	I																		III		III
<i>Scorpiurus muricatus</i>																						III		III
<i>Briza maxima</i> L.																						I		I
<i>Silene portensis</i> L.																						I		I
<i>Dipicadi serotinum</i>																						I		I
<i>Vulpia bromoides</i>																						II		II
<i>Ornithopus compressus</i> L.																						II		II
<i>Teesdalia coronopifolia</i> (J.P. Bergeret) Thell.																						II		II
<i>Logfia gallica</i> (L.) Coss. & Germ.																						IV		+
<i>Tolpis barbata</i>																						IV		+
<i>Pterocephalus diandrus</i>																						V		+
<i>Perovragia nanthei</i>																						II		+
<i>Lathyrus angulatus</i> L.																						III		+
<i>Paronychia echinulata</i> Chater																						II		+
<i>Plantago bellardii</i>																						II		+
<i>Andryala integrifolia</i> L.																						II		+
<i>Aira caryophyllea</i> ssp. <i>caryophyllea</i>																						II		+
<i>Fasione montana</i>																						II		+
<i>Trifolium angustifolium</i>																						III		+
<i>Linum bienne</i>																						II		+
<i>Medicago lupulina</i> L.																						II		+
<i>Ornithopus perpusillus</i> L.																						II		+

(continued)

Table I. (Continued).

Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24		
Number of relevés	13	7	26	11	7	22	11	4	7	15	15	4	3	10	5	13	10	1	28	6	16	13	10		
Principal companions																									
<i>Vulpia alopecurus</i>	I		IV	II	r	r	I	2	II	I		2	III	1							III				
<i>Paronychia argentea</i>	+	III		I					IV		4	2							+		III				
<i>Lagurus ovatus</i>	+		II											II			IV				IV		III	V	
<i>Anagallis arvensis</i>	+		I	II															I		V	+	III	III	
<i>Senecio gallicus</i>	+		IV	V	V	IV	V	2	II	II		1									II	III		III	
<i>Veronica arvensis</i> L.	I																						+	III	
<i>Catapodium maritimum</i> (L.) C.E. Hubb.	+				I																		+	III	
<i>Centranthus calcitrapa</i>			I	III		+	II	2	IV	IV	4	2							II		V	III	+	II	
<i>Medicago polymorpha</i> L.			I																					+	II
<i>Poa annua</i> L.			I																						III
<i>Sedum acre</i> L.			IV																						I
<i>Reichardia gaditana</i>																									
<i>Papaver setigerum</i> DC.																									
<i>Brassica oxyrrhina</i> Cosson														II	5				II						
<i>Linaria viscosa</i> (L.) Chaz.														II											
<i>Silene longicaulis</i> Pourr.														II											
<i>Alkanna tinctoria</i> (L.) DC.														II											
<i>Catapodium rigidum</i> C.E. Hubb.														II											IV
<i>Chamaemelum mixtum</i> (L.) All.														II	4	II	II		I		+				
<i>Lotus edulis</i> L.																									
<i>Galium murale</i>																									
<i>Blackstonia perfoliata</i> (L.) Huds.																									
<i>Lotus corniculatus</i> L.																									
<i>Aphanes arvensis</i> L.																									

Note: *Viola henriquesii-Silenetum litoreae*: 1 Izco et al. 1988, 2 Lomba (2004); *Pseudorhynchospora misusculae-Polycarpium alsinifoli*: 3, 4 Costa et al. (2000) under the name *Viola-Silenetum litoreae*; *Herniario algarricense-Linariaetum ficallhoanae chaenrhetosum lusitanicae*: 8 Costa et al. (1992); *Herniario algarricense-Linariaetum ficallhoanae chaenrhetosum lusitanicae*: 8 Costa et al. (1992); *Ononido variegatae-Linariaetum pedunculatae*: 9 Diez Garretas (1984), 6 Neto (2002), 7 Costa et al. (1996), 11 Diez Garretas & Ascensi (2002); *Ononido variegatae-Linariaetum pedunculatae linarietosum pygmaeae*: 12 Diez Garretas (1984), 13 Costa et al. (1996); *Hymenostemmo pseudoanthemidis-Arenariaetum emarginatum*: 15 Rivas Goday (1958); *Malcomio lacerae-Anthyllidetum hamosae*: 16 Rivas Goday (1958); *Linario doryanae-Loeffingietum baeticae*: 17 Rivas-Martinez et al. (1980); *Tolpido barbatae-Tubarietum bupleurifoliae*: 18 Costa et al. (1996); *Corynephoru macrantheri-Arenariaetum algarbiensis*: 19 Pinto da Silva & Teles (1972), 20 Neto (2002); *Omphalodo kunztzkyanae-Evacietum ramosissimae*: 21; *Cerastio diffus-Vulprietum fontqueranae*: 22; *Petrorhagio-Trifolietum arenensis*: 23 Diaz González & Navarro Andrés (1978); *Asterolimo limostellait-Rumicetum bucephalophori*: 24 Diaz González & Navarro Andrés (1978).

Table II. *Pseudorhago minusculae*-*Polycarpietum alsinifoli*.

# relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
Sampling area (m ²)	6	4	6	4	4	6	4	4	4	4	6	6	6	4	6	6	6	6	4	4	2	4	6	4	4	4	
Number of species	15	18	21	16	12	20	20	11	14	15	21	22	21	13	17	22	22	19	18	15	18	20	25	19	14	23	
Characteristics of association, alliance and order																											
<i>Polycarpon alsinifolium</i>	+	1	4	3	3	3	2	2	3	2	3	3	3	2	2	1	2	3	2	3	2	3	4	2	2	1	2
<i>Silene litorea</i> Brot.	2	2	1	3	3	2	2	2	1	+	3	2	+	+	+	1	2	2	2	2	2	1	2	2	2	2	2
<i>Erodium bipinnatum</i>	2	2	3	2	2	2	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	2	2	1	1
<i>Medicago littoralis</i> Rohd	1	1	1	3	3	3	1	2	+	+	+	+	+	2	+	+	+	+	+	1	2	2	2	2	2	+	2
<i>Pseudorhago minuscula</i>	2	3	3	2	3	1	1	1	+	+	+	+	+	1	1	1	3	2	1	3	1	1	+	+	+	+	1
<i>Cutandia maritima</i> (L.) W. Barbey								2	2	1	2	1	2	1	1	1	+	+	+	+	2	2	+	+	+	+	1
<i>Silene nitaeensis</i>																											1
<i>Hedypnois cretica</i>	+					+					+	+	+	2	4	+	+										1
<i>Pimpinella villosa</i>																					2	2	2	+	+	+	1
<i>Ononis dentata</i>																					+	1	2	+	+	+	1
<i>Malcolmia ramosissima</i>	1	1			+													+	+								1
Characteristics of <i>Helianthemetea guttati</i>																											
<i>Leontodon longnostris</i> (Finch & P.D. Sell) Talavera	+	1	+															1	+	1	+	+	2	+	+	+	2
<i>Rumex bucephalophorus</i> ssp. <i>hispanicus</i>							2				+	1	+			3	3	1	+	1	2	+	2	+	+	+	2
<i>Vulpia myuros</i> (L.) C.C. Gmel.						1	1	+	2	1	1	1	1	1	1	1	1	+	+	+	+	+	+	+	+	+	1
<i>Tuberaria guttata</i> (L.) Fourr.	+	+	+	1	1					+	1	1	+			1	+	+	+	+	+	+	+	+	+	+	1
<i>Vulpia membranacea</i> (L.) Dumort.								1			1	1	+		+	1	+	+	+	+	+	+	+	+	+	+	1
<i>Logfia minima</i> (Sm.) Dumort.											+	+															+
<i>Coronilla repanda</i> (Poir.) Guss.	1					+					+	+									+						+
Characteristics of <i>Ammophiletea</i>																											
<i>Euphorbia portlandica</i> L.	+	+	+	+																	+	+	+	+	+	+	+
<i>Lotus creticus</i> L.																											+
<i>Crucianella maritima</i> L.	+	+	+				+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Helichrysum picardii</i> Boiss. & Reuter	+	+	+				+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Medicago marina</i> L.	1	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1
<i>Seseli tortuosum</i> L.	+	+	+				+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	1
<i>Armeria welwitschii</i> Boiss.							+																				+
<i>Anagallis monelli</i> var. <i>microphylla</i> (Ball) Vasc.																											+
<i>Calystegia soldanella</i> (L.) R. Br.	1				1	+		+	+		1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Eryngium maritimum</i> L.			+	+																							+
<i>Artemisia erithimifolia</i> L.			+	+																							+
<i>Iberis procumbens</i> Lange			+	+																							+
<i>Aetheorhiza bulbosa</i> (L.) Cass.			+	+																							+
<i>Pancratium maritimum</i> L.			+	+																							+
<i>Malcolmia littorea</i> (L.) R. Br.			+	+																							+
<i>Cyperus capitatus</i> Vandelli																											+
<i>Anchusa calcarea</i> Boiss.																											+

(continued)

Table II. (Continued).

# relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Sampling area (m ²)	6	4	6	4	4	6	4	4	4	4	6	6	4	4	6	6	6	6	4	4	2	4	6	4	4	4
Number of species	15	18	21	16	12	20	20	11	14	15	21	22	21	13	17	22	22	19	18	15	18	20	25	19	14	23
Companions																										
<i>Vulpia alopecuroides</i> (Schousb.) Dumort.	1	1	+			+	1	1	1	1	1	1	2	2	2	2	+	+	+	+	+	1	1			
<i>Senecio gallicus</i> Vill.			+	+	1		+	+	+	+	+	+	+			+	2	+	1	1	1	1	+	+	+	+
<i>Sedum sediforme</i> (Jacq.) Pau		+	+	+	+	+	+																			
<i>Reichardia gaditana</i> (Willk.) Coutinho		+		+		1	1	+																		
<i>Lagurus ovatus</i> L.			1	+																						
<i>Centranthus calcitrapa</i> (L.) Drusf.																										
<i>Plantago coronopus</i> L.																										
<i>Corynephorus canescens</i> (L.) P. Beauv.						+																				
<i>Anagallis arvensis</i> L.											+															
<i>Paraphotis filiformis</i> (Roth) C.E. Hubb.																										

More: Characteristics of *Helianthemetea*: *Lotus arenarius* + in 2, 21; *Silene scabriflora* ssp. *scabriflora* + in 2, 1 in 23; *Ornithopus pinnatus* (Müller) Durc. + in 21, 1 in 26; *Andryala arenaria* + in 22, 24; *Euphorbia exigua* L. + in 3; *Ononis broterana* 1 in 11; *Trifolium scabrum* L. 1 in 14; *Microphyrum tenellum* (L.) Link 1 in 14; *Urospermum picrooides* (L.) Scop. + in 2, 24; *Asteriscus maritimus* (L.) Less. + in 25; Characteristics of *Ammophiletea*: *Leontodon taraxacoides* (Vill.) Merat + in 6, 1 in 11; *Linaria polygalifolia* Hoffmanns. & Link + in 13, 16; + *Euphorbia paralias* L. in 9; + *Matthiola sinuata* (L.) R.Br. in 10; + *Oenanthe maritima* (L.) Hoffmanns & Link in 12; + *Hemiaria maritima* Link; Companions: *Catapodium maritimum* (L.) C.E. Hubb. + in 1, 23, 24; *Lobularia maritima* (L.) Desv. + in 23, 25, 26; *Cakile maritima* Scop + in 22, 23; *Carex arenaria* L. + in 5; + *Bromus rigidus* Roth in 22; *Bromus diandrus* Roth in 24.

Places: 1, 2, 3 South of Pedrogão Beach (Leiria), 4, 5 North of Pedrogão Beach (Leiria), 6, 8 Vieira de Leiria Beach (Marinha Grande), 7, 12 North of Nazaré, 9 S. Pedro de Muel (Marinha Grande), 10, 11 Pedra de Ouro Beach (Marinha Grande), 13 S. Martinho do Porto (Alcobaça), 14 Baleal Sul (Peniche), 15 Peniche, 16 Consolação Beach (Peniche), 17 Areia Branca (Lourinhã), 18 Palheiros de Mira (Mira), 19 Quiaios Beach (Figueira da Foz), 20 Palheiros da Tocha (Cantanhede), 21 Cabo Raso (Cascais), 22 Oitavos (Cascais), 23 Raso Cap (Cascais), 24 Guincho Beach (Cascais), 25 Abano Beach (Cascais), 26 Magoito (Sintra).

henriquesii-Silenetum littoreae have an exclusively Eurosiberian distribution (Galician-Portuguese), in thermotemperate (submediterranean) and upper mesomediterranean bioclimate, occurring in the clearings of *Iberidetum procumbentis* and extending in Portugal until Aveiro. To the south of Aveiro until Cascais (Coastal Portuguese and Olisiponense districts, Dividing Portuguese Sector), the former association is replaced by *Pseudorlayo minusculae-Polycarpium alsinifolii*, occupying the clearings of *Loto cretici-Ammophiletum australis* and *Armerio welwitschii-Crucianelletum maritimae*, in upper thermomediterranean to lower mesomediterranean, upper dry to lower subhumid bioclimate.

The alliance *L. pedunculatae* (Table I) includes the following four associations:

- (1) *Ononido variegatae-Linarietum pedunculatae* (relevés 1–29 in Figure 2): a thermomediterranean association of wide distribution in the southwest of the Iberian Peninsula, between Algarve and

Almeria, also present in Morocco and Algeria (Diez-Garretas & Asensi 2002) (Figure 4), with *Linaria pedunculata* (L.) Chaz. and *Ononis variegata* L. as guideline species. On more stabilized dunes occurs the subassociation *linarietosum pygmaeae*, differentiated by *Linaria munbyana* Boiss. and Reut. ssp. *pygmaea* (Samp.) Rivas-Mart.;

- (2) *Herniario algarvicae-Linarietum ficvalhoanae* (30–73): in Sadensean and Vincentine coastal dunes, in the thermomediterranean dry belt. For lithified calcareous dunes, the subassociation *chaenorhinetosum lusitanicae* characterized by *Chaenorhinum serpyllifolium* (Lange) Lange ssp. *lusitanicum* R. Fernandes is described;
- (3) *Violo henriquesii-Silenetum littoreae* (111–123);
- (4) *Pseudorlayo minusculae-Polycarpium alsinifolii* ass nova hoc loco (74–110).

Concerning the associations in the more interior dunes, belonging to *Anthyllido hamosae-Malcolmion*

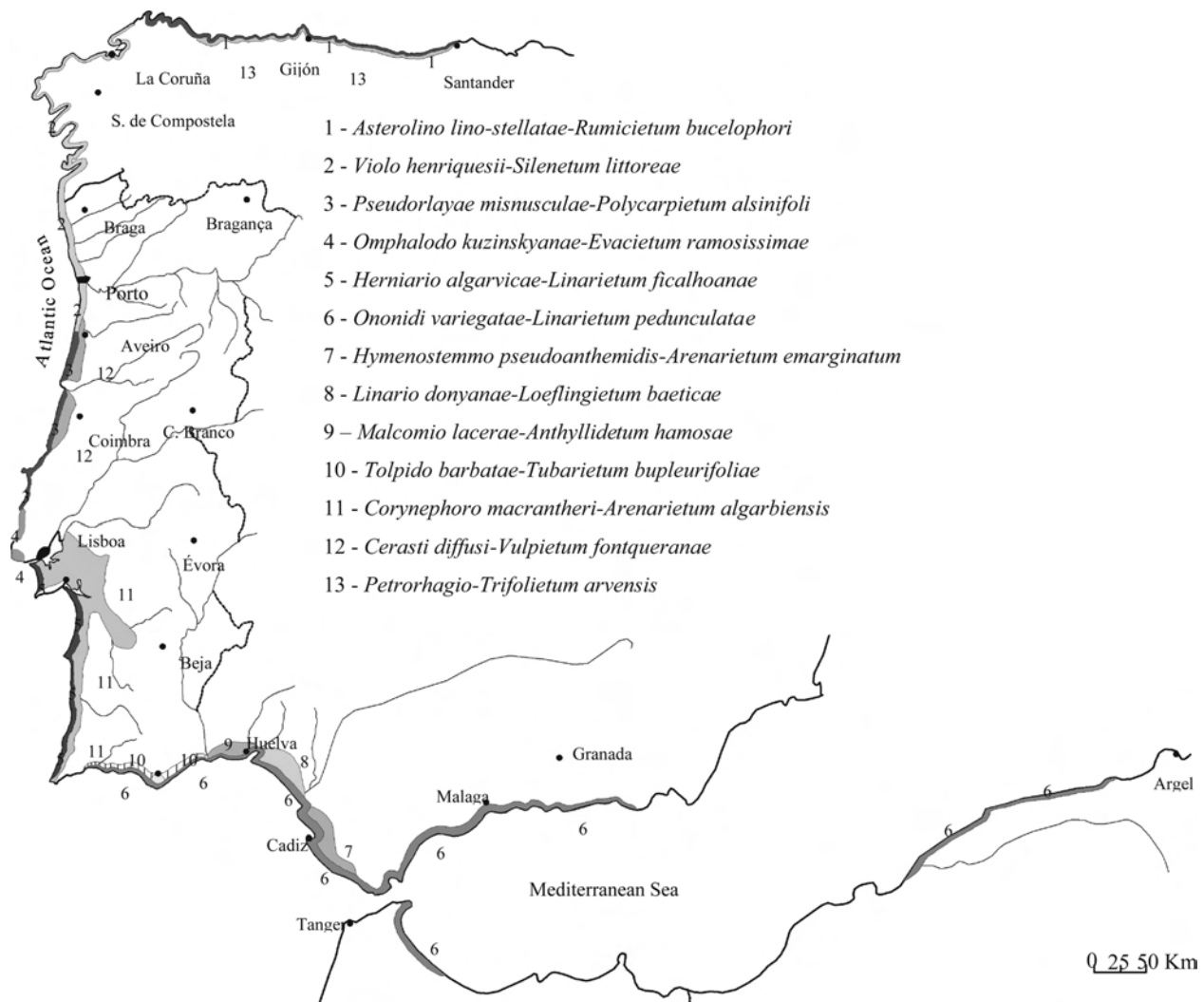


Figure 4. Distribution map of annual dune plant communities in Iberian Peninsula and west of North Africa.

Table III. *Cerastio diffusi-Vulpium fontquereanae*.

# relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sampling area (m ²)	6	6	8	6	6	6	6	14	14	6	6	10	14	6	4	8
Number of species	17	24	24	25	24	27	26	40	31	19	16	21	22	28	22	19
Characteristics of association, alliance and order																
<i>Silene scabriflora</i> ssp. <i>scabriflora</i>	4	3	3	1	3	2	3	3	3	2	3	4	3	3	2	3
<i>Linaria spartea</i>		1	+			+	1	+	1	+	2	1	1	+	1	+
<i>Andryala arenaria</i>	1	1	+	+			1	1	1	1	2	2	+	+	2	
<i>Cerastium diffusum</i>					+	+	1	+	1	1	+	1	+	+	+	1
<i>Aira praecox</i>	3	3	1	1			1	2				1	1	1	1	2
<i>Vulpia fontquereana</i>		1	1	3	2	3	2	1	1	1	+					
<i>Erodium bipinnatum</i>	1				2	+	+	2	+	1		+	+	+		+
<i>Lotus arenarius</i>		1	+		2	+		1	1	+			2			
<i>Vulpia membranacea</i>	+	+	1	1				+	1						+	+
<i>Medicago littoralis</i>	+	+			2	+						1		+		
<i>Coronilla repanda</i>				+		+		2	1	+			1	1		
<i>Rumex bucephalophorus</i> ssp. <i>hispanicus</i>				+		+		+	1	1				3		
<i>Ononis broteroana</i>		2								3			1	1		
<i>Agrostis tenerrima</i>							+						+		1	2
<i>Ornithopus isthmocarpus</i> Coss.				+				+								
Characteristics of <i>Helianthemetea guttati</i>																
<i>Briza maxima</i> L.	1	3	2	2	1	1	2	1	1	1	3	3	+	1	2	1
<i>Tuberaria guttata</i>		+	3		2	+	2	+	1	1	2	2	+	2	2	1
<i>Asterolinon linum-stellatum</i> (L.) Duby		+	2	1	+	+	2	+	+		2	+			1	+
<i>Aira caryophylla</i> L. ssp. <i>caryophylla</i>			3	1	+	1	1		1		2	2			3	2
<i>Leontodon longirostris</i>	+	1	1	+	+	+						+	+	+		1
<i>Logfia minima</i>			1	+	+	+	+	+	+			+	+			1
<i>Tolpis barbata</i> (L.) Gaertn.		+		+	+	+	1	2						2		+
<i>Euphorbia exigua</i>	+			+	+	+	+	+	+		+	+				
<i>Vulpia myuros</i>				2	+	2	1	1	+							1
<i>Trifolium campestre</i> L.		+		+			1		+		1			1	2	
<i>Trifolium scabrum</i>	+				+		1		+	+						+
<i>Linum bienne</i>			+				+	1	+			+		+		
<i>Plantago bellardii</i> All.			1	1			1	1					+			
<i>Vulpia bromoides</i> (L.) S.F. Gray	2	+	1					1					+			
<i>Jasione montana</i> L.				+					+			1				+
<i>Trifolium arvense</i> L.	1			+			+								2	
<i>Teesdalia nudicaulis</i> (L.) R.Br.			+			+						+				+
<i>Ornithopus pinnatus</i>		1		+				1								
Companions																
<i>Lagurus ovatus</i>	1	1	1		1	+	2	1	2	2	1		1	1		
<i>Corynephorus canescens</i> var. <i>maritimus</i>			1			+		1	+			1		+	1	+
<i>Aetheorhiza bulbosae</i>	+				+		+	1				1	1		+	+
<i>Vulpia alopecurus</i>	1	1	+		+		+	1						1	+	+
<i>Centranthus calcitrapa</i>				+	+		+	+	+				+	+		
<i>Senecio gallicus</i>				+	+		+	+		+	+		+	+		
<i>Avena barbata</i> Pott ex Link ssp. <i>barbata</i>				+		+		+	+		+					+
<i>Scilla monophyllus</i> Link				+				+		+			1			
<i>Bromus diandrus</i>				+	1		+									
<i>Sonchus oleraceus</i> L.	+					+		+								
<i>Anarrhinum bellidifolium</i> (L.) Wild.								+					+	+		

More: Characteristics of *Helianthemetea*: *Polycarpon alsinifolium* 1 in 1, + in 8; *Silene littorea* + in 1, 5; *Scorpiurus muricatus* L. + in 2, 4; *Pterocephalus diandrus* (Lag.) Lag. + in 4, 14; *Hedypnois cretica* + in 5, 14; *Silene colorata* Poir. + in 6, 1 in 15; *Trifolium angustifolium* L. + in 6, 9; *Hypochoeris glabra* L. + in 6, 8; *Petrorhagia nanteuillii* (Lag.) Lag. + in 7, 8; *Mibora minima* (L.) Dev. + in 10; Companions: *Herniaria ciliolata* subsp. *robusta* + in 2, 9; *Silene gallica* L. + in 3, 14; *Juncus capitatus* Weigel, + in 3, 16; *Lolium rigidum* Gaudin, + in 4, 9; *Sedum sediforme* + in 5, 9; *Carex arenaria* + in 8, 12; *Vulpia ciliata* Dumort. + in 8, 12; *Dipcadi serotinum* (L.) Medik. + in 8, 13; *Sesamoides purpurascens* (L.) G. López + in 8, 16; *Chamaemelum mixtum* (L.) All. + in 3; +*Seseli tortuosum* + in 5; +*Matthiola sinuata* in 5; *Rumex acetosella* L. ssp. *angiocarpus* (Murb.) Murb. + in 8; +*Anagallis monelli* var. *microphylla*, in 8; +*Helichrysum picardii* (pl.) in 12; +*Senecio vulgaris* L. in 13; +*Urospermum picroides* in 14; +*Odontites tenuifolia* (Pers.) G. Don f. in 16.

Places: 1 Between S. Pedro de Muel and Vieira de Leiria (Marinha Grande), 2 Vieira de Leiria Beach (Marinha Grande), 3 Between Marinha Grande and Vieira de Leiria; 4, 6, 10, 13 Pataias (Alcobaça); 5, 9 Between Vieira de Leiria and Pedrogão Beach (Leiria), 7, 11 Marinha Grande; 8 S. Pedro de Muel (Marinha Grande), 12 Pilado (Marinha Grande), 13 Calhau (Nazaré).

Table IV. *Omphalodo kuzinskyanae-Evacietum ramosissimae*.

Numerical order	1	2	3	4	5	6
Sampling area (m ²)	4	8	2	4	6	6
Altitude (m)	50	60	40	40	60	70
Number of species	18	24	19	21	25	25
Characteristics of association, alliance and order						
<i>Evax ramosissima</i>	2	3	2	2	1	2
<i>Pimpinella villosa</i>	2	3	1	+	2	2
<i>Erodium bipinnatum</i>	+	1	1	1	2	1
<i>Omphalodes kuzinskyanae</i>	4	1	3	4		
<i>Rumex bucephalophorus</i> ssp. <i>hispanicus</i>	1	3			3	2
<i>Ononis broteroana</i>	1	1			2	1
<i>Vulpia membranacea</i>			1	+	1	1
<i>Ononis dentata</i>	2			1	1	
<i>Coronilla repanda</i>		+			2	3
<i>Silene scabriflora</i> ssp. <i>scabriflora</i>		+		+		+
<i>Jonopsidium acaule</i>		1	+			
<i>Ornithopus isthmocarpus</i>					1	+
<i>Ononis diffusa</i> Ten.						1
<i>Ornithopus sativus</i> Brot.						1
<i>Linaria spartea</i>						1
Characteristics of <i>Helianthemetea guttati</i>						
<i>Medicago litoralis</i>	1	+		+	1	+
<i>Euphorbia exigua</i>		+	1	+	1	+
<i>Tuberaria guttata</i>	1	3			1	2
<i>Ornithopus pinnatus</i>		2			2	1
<i>Scorpiurus muricatus</i>			+			+
Companions						
<i>Anagallis arvensis</i>	+	+	+	+	+	+
<i>Centaureum erythraea</i> Rafn	+	+	+	+	+	+
<i>Galium murale</i> (L.) All.	1	+	+	+	+	
<i>Centranthus calcitrapa</i>	+	+	+	+		+
<i>Paronychia argentea</i> Lam.	+				+	1
<i>Lagurus ovatus</i>		+	+			1
<i>Narcissus bulbocodium</i> L.		+	+	+		
<i>Senecio vulgaris</i>		+	+			+
<i>Anagallis monelli</i> var. <i>microphylla</i>		+			+	+

More: Characteristics of *Helianthemetea*: *Polycarpon alsinifolium* + in 1; 1 *Trifolium arvense* 1 in 3; *Asterolinum linum-stellatum* + in 3; *Micropyrum tenellum* + in 3; Companions: *Lobularia maritima* + in 1, 1 in 5; *Armeria welwitschii* + in 1, 5; *Chamaemelum nobile* (L.) All. var. *discoideum* (Willd.) P.Silva 1 in 3, 4; *Dipcadi serotinum* + in 3, 4; *Polycarpon tetraphyllum* (L.) L. + in 3, 6; *Senecio gallicus* + in 4, 1 in 5; *Cerastium glomeratum* + Thuill. in 1; *Bellis annua* L. 1 in 2; *Carlina corymbosa* L. + in 2; *Calendula suffruticosa* Vahl ssp. *algarbiensis* (Boiss.) Nyman + in 2; *Polygomon maritimum* Willd. + in 4; *Geranium molle* L. + in 4; *Centaurea sphaerocephala* L. + in 5; *Seseli tortuosum* + in 5; *Scabiosa atropurpurea* (L.) Greuter et Burdet + in 5; *Lupinus angustifolius* L. + in 6.

Places: 1 Between Ursa and Adraga (Sintra), 2 Samarra (Sintra), 3, 4 Abano (Cascais), 5, 6 Between Adraga and Praia Grande (Sintra).

lacerae, the relevés from the Coastal Portuguese district have revealed an original floristic combination, where elements from *Malcolmietalia* (like *Silene scabriflora* ssp. *scabriflora*, *Vulpia fontquerana* Melderis and Stace, *Erodium bipinnatum* Willd., *Linaria spartea* (L.) Chaz., *Andryala arenaria* (DC.) Boiss and Reut, *Lotus arenarius* Brot., *Ononis broterana* DC., *Coronilla repanda* (Poir.) Guss., *Agrostis tenerima* Trin., and *Rumex bucephalophorus* L. ssp. *hispanicus* (Steinh.) Rechb. f., etc.), the alliance *Thero-Airion* (*Cerastium diffusum* Pers., *Aira praecox* L.), and from the North of the Iberian Peninsula (Cantabric-Atlantic) are mingled. Therefore, for the community occurring on old dunes, in the clearings of *Stauracantho genistoidis-Corematetum albi*, with

upper mesomediterranean and lower subhumid bioclimate, the name *Cerastio diffusae-Vulpietum fontqueranae* (Table III, *typus* relevé # 10) is proposed, distinguishing it from other communities of *Anthyllido hamosae-Malcolmion lacerate*, *Petrorhagio-Trifolietum arvensis* and *Astrolino-Rumicietum bucephalophori* (Table I) described for Asturias (Díaz González & Navarro 1978). A characteristic species of this new association, *Vulpia fontquerana*, possesses a disjoint distribution area, occurring again in the southwest of the Iberian Peninsula, in *Linario doryanae-Loeflingietum baeticae*.

To the Olisiponensean district, in the upper thermomediterranean and upper dry belt, in dunes on calcareous platforms, *Omphalodo kuzinskyanae-*

Evacietum ramosissimae is proposed, which includes *Evax ramosissima* Mariz, *Omphalodes kuzinskyanae* Willk., *Erodium bipinnatum*, *Pimpinella villosa*, *Ononis dentata*, *Ononis broteroana* and *Jonopsidium acaule* (Desf.) Rchb., etc. (Table IV, *typus relevé* # 1). Although near the sea, being positioned in the top of cliffs in the clearings of *Osyrio quadripartitae-juniperetum turbinatae*, these communities do not directly suffer the sea spray influence. The statistic treatments have positioned these communities in the alliance *Anthyllido hamosae-Malcolmion lacerae* (Figure 1).

The alliance is composed as follows (Table I):

- (1) *Hymenostemmo pseudanthemidis-Arenarietum emarginatae* (relevés 1–10 in Figure 3) occurs on sandy soils, in the Gaditanean littoral district, with the differentials *Hymenostemma pseudanthemis* (G. Kunze) Willk., *Arenaria emarginata* Brot., *Scilla ramburei* Boiss. and *Hippocrepis salzmannii* Boiss and Reuter;
- (2) *Malcolmio lacerae-Anthyllidetum hamosae* (24–28) is an association from fossil dunes on deep sandy soils of the Gaditan–Onubensean sector, with *Malcolmia triloba* (L.) Spreng., *Hymenocarpus hamosus* (Desf.) Vis, *Anthoxanthum ovatum* Lag., *Evax asterisciflora* (Lam.) Pers., etc.;
- (3) *Linario donyanae-Loeflingietum baeticae* (11–23) on interior dunes of the National Park of Doñana (Coastal Onubensean District), characterized by *Linaria tursica* Valdés and Cabezudo, *Loeflingia baetica* Lag. var. *baetica*, etc.;
- (4) *Tolpido barbatae-Tuberarietum bupleurifoliae* (29–38) on the littoral sands of the Algarvian district, in the clearings of *Cistetum bourgaeani* and *Tuberario majoris-Stauracanthetum boivini*, with *Tuberaria bupleurifolia*, *Scilla odorata* and *Lotus castellanus* as differentials;
- (5) *Corynephoru macrantheri-Arenarietum algarbiensis* (39–67) on the old dunes of the Sadensean district, characterized by *Arenaria algarbiensis* Willk., *Corynephoru macrantherus* Boiss. and Reut., *Malcolmia gracillima* Samp., *Loeflingia baetica* var. *micrantha* (Boiss. and Reut.) Samp., etc.;
- (6) *Cerastio diffusae-Vulpietum fontqueranae* ass nova hoc loco (74–89);
- (7) *Omphalodo kuzinskyanae-Evacietum ramosissimae* Neto, J.C. Costa, J.P. Fonseca and Lousã ass nova hoc loco (68–73).

Sintaxonomic scheme

HELLANTHEMETEA GUTTATI (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 em. Rivas-Martínez 1978

**Helianthemetalia guttati* Br.-Bl. in Br.-Bl., Molinier & Wagner 1940 em. Rivas-Martínez 1978

***Thero-Airion* Tüxen & Oberdorfer 1958

Asterolino lino-stellati-Rumicetum bucephalophori T.E. Díaz & F. Navarro 1978

Petrorragio-Trifolietum arvensis T.E. Díaz & F. Navarro 1978

**Malcolmietalia* Rivas Goday 1958

***Anthyllido hamosae-Malcolmion lacerae* Rivas Goday 1958 em. Rivas-Martínez 1978

Hymenostemmo pseudanthemidis-Arenarietum emarginatae Rivas Goday 1958

Malcolmio lacerae-Anthyllidetum hamosae Rivas Goday 1958

Linario donyanae-Loeflingietum baeticae Rivas-Martínez, Costa, Castroviejo & E. Valdés 1980

Tolpido barbatae-Tuberarietum bupleurifoliae J.C. Costa in J.C. Costa, Lousã & Espírito-Santo 1997

Corynephoru macrantheri-Arenarietum algarbiensis P. Silva & Teles ex Rivas-Martínez & Izco 2002

Cerastio diffusae-Vulpietum fontqueranae J.C. Costa, Neto, M. Martins & Lousã ass. nova hoc loco

Omphalodo kuzinskyanae-Evacietum ramosissimae Neto, J.C. Costa, J.P. Fonseca & Lousã ass. nova hoc loco

**Cutandietalia maritimae* Rivas-Martínez, Díez Garretas & Asensi 2002

***L. pedunculatae* Díez Garretas, Asensi & Esteve in Díez Garretas 1984

Herniario algarvicae-Linarietum ficalhoanae Díez Garretas 1984

linarietosum ficalhoanae

chaenorrhinetosum lusitanicae J.C. Costa, Espírito Santo & Lousã 1994

Ononido variegatae-Linarietum pedunculatae Díez Garretas ex Izco, P. & J. Guitián 1988

linarietosum pedunculatae

linarietosum pygmaeae Díez Garretas 1984

Violo henriquesii-Silenetum littoreae Izco & Guitián 1988

Pseudorlayo minusculae-Polycarpium alsinifoli J.C. Costa, Neto, M. Martins & Lousã ass. nova hoc loco

All communities from *L. pedunculatae* and *Anthyllido hamosae-Malcolmion lacerae* have specific floristic compositions and biogeographic areas, allowing the characterization of districts. More rarely they correspond to unique thermotype and ombrotype. Considering the alliance *Anthyllido hamosae-Malcolmion lacerae* as an endemic element characteristic from this Province, its distribution to the entire Lusitan–Andalusian Coastal Province is proposed.

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