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AN OVERVIEW OF THE ITALIAN COASTAL DUNE EU HABITATS

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ABSTRACT – In Europe, as in Italy, there is a long phytosociological tradition and a huge amount of vegetation plots has been performed. Considering the critical conservation status of coastal habitats, highlighted by the second Italian Report about the implementation of Habitats Directive (93/42/CEE), we aim to investigate the state of knowledge on Italian coastal dunes vegetation at national level. We built a national database recording 2666 phytosociological relevés concerning 10 dune habitats, most conducted from 1980 to present day. We conducted an explorative meta-analysis through DCA and we described Italian beach and dune EU habitats, focusing on the floristic and coenological information derived from published studies and from interpretation manuals of Habitats Directive. The DCA reflected the gradual turnover of the vegetation, ranging from upper beach habitats to fixed dune habitats. The most part of habitats are widespread throughout the Italian coasts and are represented by a consistent number of samples. Insular areas are characterized by a high number of species and phytosociological associations, often rare or endemic. However, the most part of EU dunes habitats has a bad or inadequate conservation status. This database could be useful for the monitoring and surveillance of EU habitats and species, as required by Habitats Directive.

KEYWORDS: COASTAL DUNE ZONATION, PSAMMOPHILOUS VEGETATION, PHYTOSOCIOLOGICAL RELEVÉS, HABITATS DIRECTIVE, DUNE HABITATS CONSERVATION, NATIONAL DATABASE

INTRODUCTION

By occupying transition zones between terrestrial and marine ecosystems, coastal dunes hold one of the most ecologically relevant ecosystems on earth. The influence of the sea leads to a strong sea-inland environmental gradient related to gradual change in intensity of factors such as salt spray, wind intensity, sand burial, etc. (Miller et al., 2010). Consequently, the vegetation features of coastal dune systems are highly shaped by this gradient and plant communities are often arranged along a compressed sea-inland vegetation zonation (Doing, 1985; Feola et al., 2011). This complex arrangement of plant communities is one of the most interesting features of Mediterranean sandy shores and gives rise to high values of biodiversity in terms of habitat richness and species of interest (Brullo et al., 2001; Acosta et al., 2003; van der Maarel, 2003; Biondi, 2007). Many ecological, environmental and economic benefits are associated with well preserved coastal dune systems (Martínez & Psuty, 2004; Barbier et al., 2011). However, at present, dune environments are considered to be threatened worldwide (McLachlan & Brown, 2006). In Europe, it has been estimated about 70% of dune systems loss during last century, and this loss has been mainly related to urbanization and other human pressures (McLachlan & Brown, 2006). Moreover, biodiversity is highly endangered also in those dune systems still well preserved (van der Meulen & Udo de Haes, 1996; Cori, 1999). The loss of biodiversity and ecosystem functions in coastal dune vegetation may have contributed to the increase in biological invasions, to the decline of water quality and to the decrease of coastal protection from flooding and storm events (Braatz et al., 2007; Cochard et al., 2008, Koch et al., 2009). Nowadays, coastal dune conservation and restoration has become a priority for many European countries (Martínez

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& Psuty, 2004). In this sense, the Council Directive 92/43/EEC, also known as "Habitats Directive" (EEC, 1992), constitutes the most important legal instrument for biodiversity conservation at European level (Mücher et al., 2004; Wätzold & Schwerdtner, 2005).

The last Report of European Commission (Article 17 of Habitats Directive) concerning the implementation of the Directive in the period 2001-2006, showed that dune habitats have very bad conservation status throughout Europe (European Commission, 2008). In particular, the Italian Report highlighted the inadequate or bad conservation status of coastal dune habitats in Italy (La Posta et al., 2008). Currently, most of the EU dune habitats require special attention and conservation actions, so further developments in vegetation science should attempt to address these demands.

There is a long tradition of vegetation survey based on the classical phytosociological approach in Europe (Braun-Blanquet, 1928; Westhoff & van der Maarel, 1973). In Italy at least 150.000 phytosociological relevés have been performed according to Schaminée et al. (2009). On these bases, in this paper we investigate the state of knowledge on Italian coastal dunes vegetation at national level. In particular, through a meta-analysis, we describe Italian beach and dune habitats of European interest, focusing on the floristic and coenological information derived from published phytosociological studies.

MATERIAL AND METHODS

We conducted a detailed bibliographic research on published studies regarding Italian costal dunes vegetation. In addition, some original data (Prisco et al., unpublished) were included in the dataset. We considered only phytosociological relevés regarding plant communities of Holocenic dunes (beach, fore dunes, mobile dunes, transition dunes, fixed dunes and inland dunes).

A database containing phytosociological relevés performed in the last 44 years was built. We used the software TURBOVEG (Hennekens, 1996) developed for storing, editing and selecting phytosociological relevés in virtually unlimited quantities (Hennekens & Schaminée, 2001). For species nomenclature we followed the "Checklist of the Italian vascular flora" (Conti et al., 2005).

Each relevé was paired with the corresponding EU habitat, following the guide lines of the "Italian Interpretation Manual of the 92/43/EEC Directive Habitats" (Biondi et al., 2009) and the "Interpretation Manual of European Union Habitats" (European Commission, 2007). Information about relevés localization (reported in the published articles) allowed us to infer the geographical position of each relevé. Then, using a GIS software (ESRI Inc., 2006), the relevés were georeferenced in order to depict their spatial pattern at national level and, consequently, the distribution pattern of dune habitats.

With the aim of conduct an explorative meta-analysis, the final matrix was analyzed using the software PC-ORD (McCune & Mefford, 2006) through Detrended Correspondence Analysis (DCA). DCA was chosen because it has been proved to be suitable when floristic gradients are relatively wide, i.e. a high turnover of species occurs (Jongman et al., 1987).

For each EU habitat we presented a brief description with the list of diagnostic species based on the European and Italian interpretation Manuals of the 92/43/EEC Habitats Directive (European Commission, 2007; Biondi et al., 2009). We also included the list of most frequent species in the dataset (frequency > 40%) and the complete list of phytosociological associations reported in the articles. We highlighted those phytosociological associations that are endemic or with a particular distribution pattern. In addition, for each habitat we reported the spatial distribution at national scale and their conservation status based on the last Italian Report on the implementation of the Habitats Directive (La Posta et al., 2008). According to these authors a *favourable* conservation status occurs when habitats can thrive without any change of management and strategies currently in place; an *inadequate* conservation status occurs when habitats require a change of management policies, but they are not at risk of extinction; finally, a *bad* conservation status occurs when habitats are in serious danger of extinction, at least locally (La Posta et al., 2008). Finally, for each habitat we included major threats.

RESULTS

The database included 2.666 phytosociological relevés, 2.219 relevés performed in the Mediterranean region and 447 relevés in the Continental one (Fig. 1). Although the time span of the relevés ranged from 1967 to 2011, most of them were conducted after the 80s.

Relevés were performed in different plant communities distributed in 10 EU habitats (Fig. 2). The highest number of relevés were recorded in "Embryonic shifting dunes" (EU habitat 2110; 568 relevés), "Shifting dunes along the shoreline with *Ammophila arenaria*" (EU habitat 2120; 506 relevés) and "*Crucianellion maritimae* fixed beach dunes" (EU habitat 2210; 462 relevés), whereas the highest diversity of phytosociological associations was found in transition dunes habitats 2230 and 2210 ("*Malcolmietalia* dune grassland" -20 associations- and "*Crucianellion maritimae* fixed beach dunes" -17 associations-). For these last two habitats many endemic or very localized

phytosociological associations have been described, particularly in the major islands (Sardinia and Sicily).

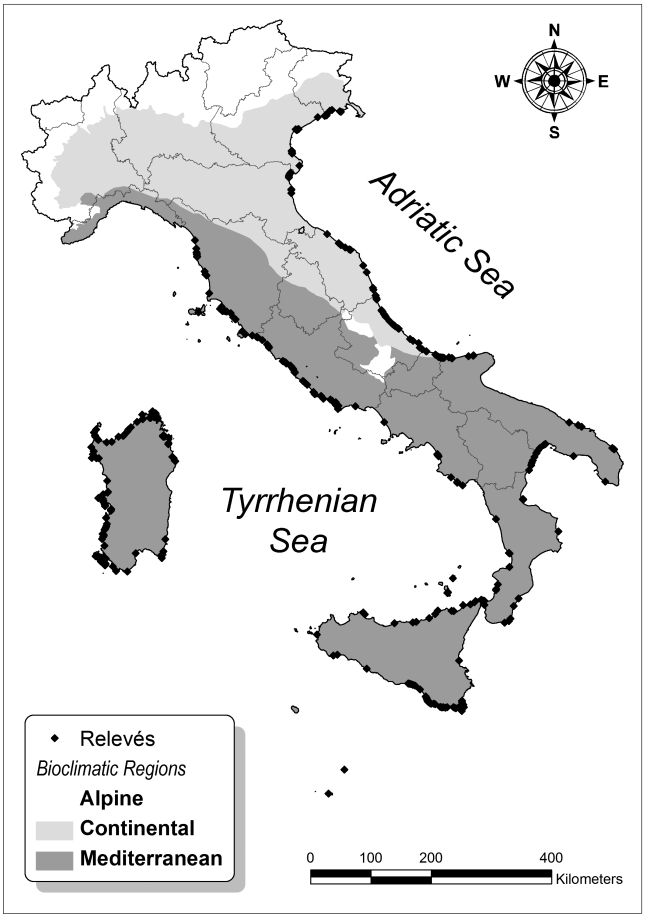

Fig. 1. Geographical distribution of the 2.666 Italian phytosociological relevés. Continental and Mediterranean Bioclimatic Regions are evidenced (sensu Directive 92/43/EEC).Biotopes System codes.

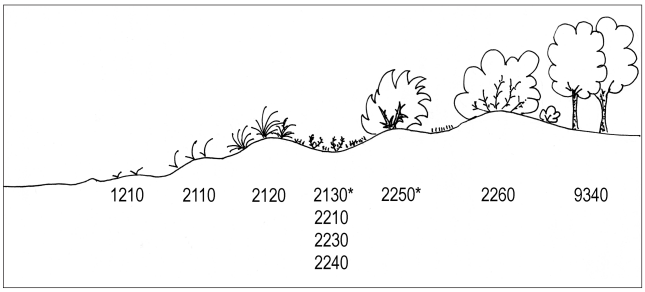

Fig. 2. Scheme of a typical coastal dune zonation evidencing EU habitats: 1210 Annual vegetation of drift lines; 2110 Embryonic shifting dunes; 2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes); 2130* Fixed coastal dunes with herbaceous vegetation; 2210 *Crucianellion maritimae* fixed beach dunes; 2230 *Malcolmietalia* dune grasslands; 2240 *Brachypodietalia* dune grasslands with annuals; 2250* Coastal dunes with *Juniperus* spp.; 2260 *Cisto-Lavanduletalia* dune sclerophyllous scrubs; 9340 *Quercus ilex* and *Quercus rotundifolia* forests.

The first DCA axis reflected the gradual turnover of the vegetation, ranging from upper beach habitats to the fixed dune habitats (Fig. 3). This axis could therefore be assumed to synthesize the sea-inland vegetation zonation along the dune profile, with lower scores indicating habitats closer to the beach and higher scores representing more sheltered habitats further from the sea. We can highlight a clear separation between beach, fore dune and transition dune habitats dominated by herbaceous species and back dune habitats with perennial vegetation. The second axis, instead, showed the variability of transition dune habitats.

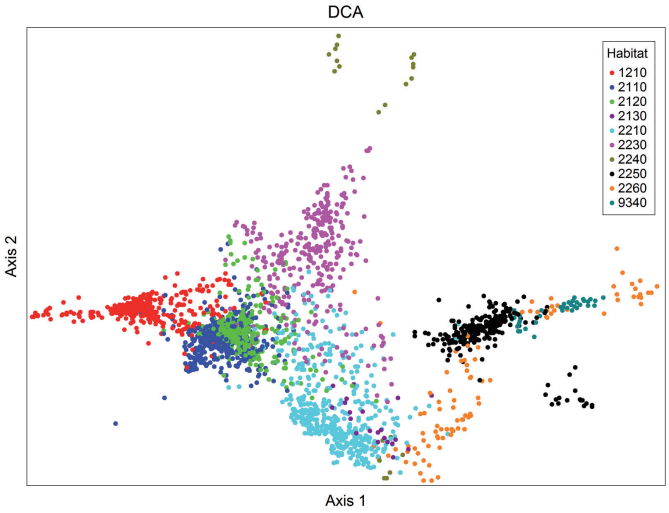

Fig. 3. Detrended Correspondence Analysis of the 2.666 phytosociological relevés. The first axis highlights the sea-inland vegetation zonation from fore dunes to inland dunes, while the second axis shows the variability of transition dune habitats (Total inertia = 70.1150; Axis 1 eigenvalue = 0.9221948385; Axis 2 eigenvalue = 0.7971464396).

Italian coastal dune EU habitats

EU Habitat 1210 Annual vegetation of drift lines

Major features: The habitat includes formations of herbaceous annual plants that start the dune building. It is found on beaches with sand and/or fine gravel near the shoreline, where the organic matter brought by the waves accumulates and decomposes, creating a substrate rich in sea salts and organic matter decomposition. The vegetation cover is generally very low (up to 5% of the total).

Diagnostic species: *Cakile maritima, Salsola kali, Chamaesyce peplis, Matthiola sinuata, Matthiola tricuspidata, Glaucium flavum.*

Most frequent species in the dataset: *Cakile maritima, Salsola kali, Xanthium orientale.*

Phytosociological associations (in order of abundance): *Salsolo kali-Cakiletum maritimae* Costa & Manzanet 1981, *Salsolo kali-Euphorbietum peplis* Pignatti 1952 (only in Sicily), *Atriplicetum hastato-tornabenii* O. Bòlos 1962 (only

in Sicily and Sardinia), *Cakiletum maritimae-Xanthietum italici* Pignatti 1953, *Raphano maritimi-Glaucietum flavi* Biondi, Brugiapaglia, Allegrezza, Ballelli 1989 (only in Marches), *Xanthio italici-Cenchretum incerti* Biondi, Brugiapaglia, Allegrezza, Ballelli 1989 (only in northern Adriatic Sea).

Geographical distribution and conservation status: The 1210 habitat is widespread throughout the Italian coasts (Fig. 4), but its conservation status is inadequate in both Mediterranean and Continental bioclimatic regions. This habitat is highly threatened by coastal erosion and by the mechanical cleaning of the beaches during the summer season.

EU Habitats	N° of relevés		Habitat presence in the Italian Regions
	Continental region	Mediterranean Region	
1210 Annual vegetation of drift lines	97	279	
CONSERVATION STATUS	INADEQUATE	INADEQUATE	
2110 Embryonic shifting dunes	107	461	
CONSERVATION STATUS	BAD	BAD	
2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)	124	382	
CONSERVATION STATUS	BAD	BAD	
2130* Fixed coastal dunes with herbaceous vegetation (grey dunes)	21		
CONSERVATION STATUS	INADEQUATE		
2210 *Crucianellion maritimae* fixed beach dunes		462	
CONSERVATION STATUS		INADEQUATE	
2230 *Malcolmietalia* dune grasslands	72	261	
CONSERVATION STATUS	INADEQUATE	UNKNOWN	
2240 *Brachypodietalia* dune grasslands with annuals		23	
CONSERVATION STATUS	INADEQUATE	UNKNOWN	
2250* Coastal dunes with *Juniperus* spp.	19	219	
CONSERVATION STATUS	BAD	INADEQUATE	
2260 *Cisto-Lavanduletalia* dune sclerophyllous scrubs	7	93	
CONSERVATION STATUS	BAD	INADEQUATE	
9340 *Quercus ilex* and *Quercus rotundifolia* forests		39	
CONSERVATION STATUS	FAVOURABLE	FAVOURABLE	

Fig. 4. Conservation status of the different coastal dune habitats (according to La Posta et al., 2008). The number of relevés for each habitat is reported for the two bioclimatic regions (Mediterranean and Continental).

EU Habitat 2110 Embryonic shifting dunes

Major features: The habitat is characterized by psammophilous perennial plants (geophytes and hemicryptophytes) that give rise to the formation of the first sandy drift, called "embryo dune". These formations, dominated by *Elymus farctus*, represent the first stages of the plant colonization, that make it possible the spread of many other species, feeding the dune construction process.

Diagnostic species: *Elymus farctus, Sporobolus virginicus, Cyperus capitatus, Otanthus maritimus, Echinophora spinosa, Eryngium maritimum.*

Most frequent species in the dataset: *Elymus farctus, Eryngium maritimum, Echinophora spinosa, Cakile maritima, Medicago marina, Otanthus maritimus, Sporobolus virginicus, Pancratium maritimum.*

Phytosociological associations (in order of abundance): *Elymetum farcti* Br.-Bl. 1933, *Echinophoro spinosae-Elymetum farcti* Géhu 1987, *Sporobolo arenarii-Elymetum farcti* (Br.-Bl. 1933) Géhu, Rivas-Martinez, R. Tx. (1972) 1984, *Sileno corsicae-Elymetum farcti* Bartolo, Brullo, De Marco, Dinelli, Signorello, Spampinato 1992 (Sardinian-Corsican endemism), *Cypero capitati-Elymetum farcti* (Kühnholtz-Lordat 1923) Br.-Bl. 1933 (only in Sicily and Calabria), *Sporoboletum arenarii* (Arènes 1924) Géhu & Biondi 1994, *Inulo crithmoidis- Elymetum farcti* Géhu 1979 (only in Veneto), *Elymo farcti-Spartinetum junceae* Vagge & Biondi 1999 (only in Tuscany), *Pancratietum angustifolii* Brullo & Siracusa 1996 (endemic of the Linosa and Lampedusa islands, Sicily).

Geographical distribution and conservation status: The 2110 habitat is widespread throughout the Italian coasts (Fig. 4), but its conservation status is bad in both Mediterranean and Continental bioclimatic regions. This habitat is often fragmented due to different disturbances, mainly related to tourism and recreational activities.

EU Habitat 2120 Shifting dunes along the shoreline with **Ammophila arenaria** *(white dunes)*

Major features: The habitat identifies the more stabilized and inner coastal dunes colonized by *Ammophila arenaria*: these are defined as white dunes and they form the seaward cordons of dune systems of the coasts. This habitat represents a semi-permanent stage and the vegetation cover could reach 50-70% of the total.

Diagnostic species: *Ammophila arenaria*, *Echinophora spinosa*, *Anthemis maritima*, *Eryngium maritimum*, *Euphorbia paralias*, *Medicago marina*, *Cyperus capitatus.*

Most frequent species in the dataset: *Ammophila arenaria, Eryngium maritimum, Echinophora spinosa, Elymus farctus,*

Euphorbia paralias.

Phytosociological associations (in order of abundance): *Ammophiletum arenariae* Br.-Bl. (1921) 1933, *Echinophoro spinosae-Ammophiletum arenariae* (Br.-Bl. 1933) Géhu, Rivas-Martinez, R. Tx. 1972, *Medicagini marinae-Ammophiletum arenariae* Br.-Bl. 1921 corr. Prieto & Diaz 1991, *Sileno cosicae-Ammophiletum arenariae* Bartolo, Brullo, De Marco, Dinelli, Signorello, Spampinato 1992 (Sardinian-Corsican endemism).

Geographical distribution and conservation status: The 2120 habitat is widespread throughout the Italian coasts (Fig. 4), but its conservation status is bad in both Mediterranean and Continental bioclimatic regions. This habitat is strongly influenced by human trampling and by the mechanical levelling of sand dunes.

EU Habitat 2130 Fixed coastal dunes with herbaceous vegetation (grey dunes) [* priority Habitat]*

Major features: This priority habitat is characterized by inland stable dune formations sheltered from salt winds, coastal erosion and sand burial. Fixed dunes are colonised by more or less closed perennial grasslands (hemicryptophytes and chamaephytes) associated with abundant carpets of lichens and mosses. The habitat is principally found along the Atlantic coasts from the Straits of Gibraltar to the North Sea coasts and the Baltic Sea. However, the sub-type "Ibero-Mediterranean grey dunes" is associated with the Adriatic coasts (Houston, 2008).

Diagnostic species: *Tortula ruraliformis, Cladonia convoluta, Cladonia rangiformis, Silene otites, Phleum arenarium.*

Most frequent species in the dataset: *Fumana procumbens, Oenothera biennis, Lomelosia argentea, Teucrium chamaedrys, Teucrium polium, Cyperus capitatus, Silene vulgaris, Ammophila arenaria, Koeleria cristata, Petrorhagia saxifraga, Stachys recta, Helianthemum jonium, Hypochaeris radicata, Tortula ruraliformis, Ambrosia maritima, Calystegia soldanella, Silene otites, Dactylis glomerata, Helichrysum italicum, Sanguisorba minor, Phleum arenarium.*

Phytosociological associations (in order of abundance): *Tortulo ruralis-Scabiosetum gramuntietum* (Pignatti 1953) Géhu & Biondi 1996 (only in Veneto), *Tortulo ruralis-Scabiosetum albae* Pignatti 1952 (only in Veneto and Emilia-Romagna).

Geographical distribution and conservation status: This priority habitat is distributed only along the North Adriatic Sea, in the Continental bioclimatic region (Fig. 4). Its conservation status is inadequate probably due to land use transformations mainly related to agriculture activities and urban development.

EU Habitat 2210 Crucianellion maritimae *fixed beach dunes*

Major features: This habitat (distributed only in the Mediterranean biogeographic region) includes chamaephytic vegetation that develops on the inner slope of sand dunes with a more stable and compact substrate. In general, many phytosociological associations concerning this habitat are often endemic-vicariant: particularly rich in associations related to *Crucianellion maritimae* is Sardinia region.

Diagnostic species: *Crucianella maritima, Pancratium maritimum.*

Most frequent species in the dataset: *Crucianella maritima, Pancratium maritimum, Helichrysum italicum, Lotus cytisoides.*

Phytosociological associations (in order of abundance): *Crucianelletum maritimae* Br.-Bl. 1933, *Centaureo sphaerocephalae-Ononidetum ramosissimae* Br.-Bl. & Frei 1937 (endemic of Sicily), *Helichryso microphylli-Crucianelletum maritimae* Mossa 1992 (endemic of Sardinia), *Helichryso italici-Ephedretum distachyae* Géhu et al. 1987 (endemic of Sardinia), *Armerio pungentis-Scrophularietum ramosissimae* Valsecchi & Bagella 1991 (endemic of Sardinia), *Pycnocomo rutifolii-Crucianelletum maritimae* Géhu, Biondi, Géhu-Franck, Toffetani 1987, *Helichryso microphylli-Armerietum pungentis* Filigheddu & Valsecchi 1992 (endemic of Sardinia), *Artemisio variabilis-Ephedretum distachyae* Brullo, Giusso del Galdo, Siracusa, Spampinato 2001 (endemic of Calabria and Basilicata), *Scrophulario-Crucianelletum maritimae* Géhu & Costa 1984 (endemic of Sardinia), *Scrophulario ramosissimae-Helichrysetum microphylli* Valsecchi & Bagella 1991 (Sardinian-Corsican endemism), *Pycnocomo rutifolii-Seselietum tortuosi* Arrigoni 1990 (endemic of Tuscany), *Seselio maritimi-Helichrysetum microphylli* Brullo, Giusso del Galdo, Siracusa, Spampinato 2001 (endemic of Sardinia), *Astragalo massiliensis-Armerietum pungentis* Filigheddu & Valsecchi 1992 (endemic of Sardinia), *Crucianello-Armerietum pungentis* (Desole 1959) Zevaco 1969 (Sardinian-Corsican endemism), *Thymelaeo tartonrairae-Crucianelletum maritimae* Brullo, Giusso del Galdo, Siracusa, Spampinato 2001 (endemic of Sardinia), *Seselio maritimi-Crucianelletum maritimae* Brullo, Minissale, Siracusa 1998 (endemic of Sicily), *Verbasco phlomoidis-Seselietum maritimi* Brullo, Giusso del Galdo, Siracusa, Spampinato 2001 (endemic of Tyrrhenian coasts of Calabria).

Geographical distribution and conservation status: This habitat is widespread throughout Mediterranean bioclimatic region, however, its conservation status is inadequate (Fig. 4). Anthropic activities have led to important changes in the floristic composition, among them the enhancement in ruderal and exotic species.

EU Habitat 2230 Malcolmietalia *dune grasslands*

Major features: The habitat is characterized by associations with many small annuals species and often abundant ephemeral spring bloom. It is located in the clearings of perennial vegetation and the plant species in these open spaces could reach a high coverage.
Diagnostic species: *Malcolmia ramosissima, Filago asterisciflora.*
Most frequent species in the dataset: *Vulpia fasciculata, Lagurus ovatus, Silene colorata, Rumex bucephalophorus, Medicago littoralis.*
Phytosociological associations (in order of abundance): *Vulpio fasciculatae-Leopoldietum gussonei* Brullo & Marcenò 1974 (endemic of Sicily), *Sileno coloratae-Vulpietum membranaceae* (Pignatti 1953) Géhu & Scoppola 1984, *Sileno coloratae-Ononidetum variegatae* Géhu et al. 1986, *Glaucio flavi-Matthioletum tricuspidatae* Blasi, Fascetti, Veri, Bruno 1983 (only in Campania), *Senecioni leucanthemifolii-Matthioletum tricuspidatae* Géhu & Biondi 1994 (Sardinian-Corsican endemism), *Ambrosio coronopifoliae-Lophochloetum pubescentis* Biondi, Brugiapaglia, Allegrezza, Ballelli 1989, *Onobrychido-Cerastietum gussonei* Brullo & Grillo 1985 (endemic of Sicily), *Loto-Ononidetum serratae* Brullo & Grillo 1985 (only on Linosa island; Sicily), *Scabiosetum rutifoliae* Brullo, Di Martino, Marcenò 1974 (endemic of Sicily), *Sileno nicaeensis-Chamaemeletum mixti* Brullo, De Santis, Furnari, Longhitano, Ronsisvalle 1988 (Sicilian-Sardinian endemism), *Malcolmio ramosissimae-Linarietum sardoe* Bartolo, Brullo, De Marco, Dinelli, Signorello, Spampinato 1992 (endemic of Sardinia), *Sileno nummicae-Malcomietum ramosissimae* Biondi & Bagella 2005 (only in Sardinia), *Maresio-Walenbergietum nutabundae* Brullo & Grillo 1985 (endemic of Aeolian islands, Sicily), *Vulpio fasciculatae-Hormuzakietum aggregatae* Brullo, Guarino, Ronsisvalle 2000 (endemic of Sicily), *Vulpio fasciculatae-Silenetum coloratae* Pignatti 1953 corr. Diez-Garretas & Asensi 2003 (only in Latium), *Anthemido-Centauretum conocephalae* Brullo & Grillo 1985 (Sicilian-Calabrian endemism), *Cutandio-Parapholidetum marginatae* Bartolo, Brullo, Minissale, Spampinato 1988 (endemic of Lampedusa island, Sicily), *Anthemido secundirameae-Desmazerietum siculae* Brullo 1985 (only in Sicily), *Corrigiolo telephifoliae-Corynephoretus articulatae* (Géhu, Biondi, Géhu-Franck, Toffetani 1987) Géhu & Biondi 1994 (Sardinian-Corsican endemism), *Sileno nicaeensis-Cutandietum maritimae* Géhu & Biondi 1994.
Geographical distribution and conservation status: This habitat is widespread throughout the Italian coasts (Fig. 4). Its conservation status is inadequate for the Continental bioclimatic region and it is unknown for the Mediterranean one. Floristic composition is often modified by presence of ruderal species, particularly in trampled areas.

EU Habitat 2240 Brachypodietalia *dune grasslands with annuals*

Major features: This habitat includes dune formations of the habitat 6220 Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*. The vegetation is mostly open, rich in perennial grass species and annual psammophilous species, often in common with the habitat 2230 *Malcolmietalia* dune grasslands. The habitat is localized on the xeric side of the dunes and it develops on calcareous substrates.
Diagnostic species: *Trachynia distachya.*
Most frequent species in the dataset: *Rumex bucephalophorus, Lotus angustissimus, Coleostephus myconis, Tuberaria guttata.*
Phytosociological associations (in order of abundance): *Euphorbio terracinae-Hyparrhenietum hirtae* Brullo & Siracusa 1996, *Moenchio-Tuberarietum guttati* Lucchese & Pignatti 1987, *Psiluro-Crassuletum tillaeae* Lucchese & Pignatti 1990.
Geographical distribution and conservation status: Although relevés in the database include only the Latium region (Fig. 4), the 2240 habitat is distributed along the Italian coasts except in the northern Adriatic Sea (Biondi et al., 2009). The habitat conservation status is inadequate in the Continental bioclimatic region and it is unknown in the Mediterranean one. The habitat is preserved under conditions of moderate grazing and trampling, but changes of land use and overgrazing often led to loss of its ecological value.

EU Habitat 2250 Coastal dunes with* Juniperus *spp. [* priority Habitat]*

Major features: The habitat is characterized by shrub formations dominated by juniper (*Juniperus* spp.) localized on the fixed dunes. In the Mediterranean bioclimatic region *Juniperus oxycedrus* and *J. phoenicea* dominate on shrub vegetation; instead, in the Continental bioclimatic region rare formation with *Juniperus communis* are found.
Diagnostic species: *Juniperus oxycedrus, Juniperus phoenicea, Juniperus communis.*
Most frequent species in the dataset: *Juniperus oxycedrus, Pistacia lentiscus, Rubia peregrina, Smilax aspera, Asparagus acutifolius, Phillyrea angustifolia, Juniperus phoenicea.*
Phytosociological associations (in order of abundance): *Asparago acutifolii-Juniperetum macrocarpae* Géhu & Biondi 1994, *Pistacio lentisci-Juniperetum macrocarpae* Caneva, De Marco, Mossa 1981, *Junipero turbinatae-*

Quercetum calliprini Bartolo, Brullo, Marcenò 1982 (Sicilian-Sardinian endemism), *Phillyreo angustifoliae-Juniperetum turbinatae* Arrigoni, Nardi, Raffaelli 1985, *Ephedro fragilis-Juniperetum macrocarpae* Bartolo, Brullo, Marcenò 1982 (only in Sicily), *Junipero communis-Hyppophaetum fluviatilis* Géhu & Scoppola 1984 (only in Veneto), *Juniperetum macrocarpae-phoeniceae* Pedrotti & Cortini Pedrotti 1976, *Helianthemo sessiflori-Juniperetum macrocarpae* Brullo, Giusso del Galdo, Siracusa, Spampinato 2001 (endemic of Apulia), *Phillyreo latifoliae-Juniperetum phoeniceae* Arrigoni, Nardi, Raffaelli 1985 (endemic of Apulia), *Sparto juncei-Juniperetum macrocarpae* Vagge & Biondi 1999 (endemic of Tuscany).
Geographical distribution and conservation status: The geographical distribution of 2250* priority habitat is scattered along the Italian coasts (Fig. 4); its conservation status is bad in Continental bioclimatic region and it is inadequate in the Mediterranean one. Due to urban development in coastal areas, many fixed dunes habitats have been removed in the last 50 years. In particular, during summer these habitats have been subjected to intense recreational activities, as the trampling and the transit of off-road vehicles (Picchi, 2008).

EU Habitat 2260 Cisto-Lavanduletalia *dune sclerophyllous scrubs*

Major features: The habitat occupy the more inland and stabilized sand bars. Sclerophyllous and lauriphyllous scrubs are the dominant vegetation with high cover values. It also includes the replacement garrigues and the degraded stages of the wooded dunes. The habitat is widespread in places where the inland dunes have been well-conserved.
Diagnostic species: *Cistus laurifolius, Cistus monspeliensis, Cistus salvifolius, Erica multiflora, Halimium halimifolium, Rosmarinus officinalis, Cirsium creticum.*
Most frequent species in the dataset: *Rubia peregrina, Asparagus acutifolius, Pistacia lentiscus, Cistus salvifolius, Phillyrea latifolia, Sixalix atroporpurea, Smilax aspera.*
Phytosociological associations (in order of abundance): *Phillyreo latifoliae-Ericetum scopariae* Blasi, Stanisci, Filesi, Milanese, Perinelli, Riggio 2002 (only in Latium), *Loto-Thymetum capitati* Géhu, Biondi, Géhu-Franck, Marchiori 1984 (only in Apulia), *Erico multiflorae-Halimietum halimifolii* Taffetani & Biondi 1989, *Sparto juncei-Phillyretum angustifoliae* Vagge & Biondi 1999 (only in Tuscany), *Helianthemo jonii-Fumanetum thymifoliae* Taffetani & Biondi 1989, *Pistacio lentisci-Haliemietum halimifolii* Arrigoni 1996 (only in Sardinia), *Cisto eriocephali-Rosmarinetum officinalis* Biondi 1999, *Ephedro fragilis-Pistacietum lentisci* Biondi, Brugiapaglia, Farris, Filigheddu, Secchi 2004 (only in Sardinia), *Helichryso stoechadis-Cistetum eriocephali* Biondi 1999 (only in Tuscany).
Geographical distribution and conservation status: This habitat is mainly distributed in Mediterranean region (Fig. 4); its conservation status is bad in Continental bioclimatic region and inadequate in the Mediterranean one. It has often been replaced by artificial pine plantations.

EU Habitat 9340 Quercus ilex *and* Quercus rotundifolia *forests*

Major features: The habitat includes Meso-Mediterranean holm-oak forests where *Quercus ilex* dominates, often mixed with deciduous oaks. These forests could be found in a large variety of ecological and edaphic conditions (rocky, psammophilous or mesophilic) and they are widespread both in coastal and inland Apennine and pre-Alpine areas. The Mediterranean thermophilic oak woods are characterized by a dense tree layer and an undergrowth shrub-dominated evergreen sclerophyllous.
Diagnostic species: *Quercus ilex.*
Most frequent species in the dataset: *Smilax aspera, Quercus ilex, Pistacia lentiscus, Rubia peregrina, Asparagus acutifolius, Phillyrea angustifolia, Lonicera implexa, Clematis flammula, Arbutus unedo, Hedera helix, Myrtus communis, Phillyrea latifolia, Ruscus aculeatus.*
Phytosociological associations (in order of abundance): *Phillyreo angustifoliae-Ericetum multiflorae* Arrigoni, Nardi, Raffaelli 1985, *Asplenio-Quercetum ilicis* Rivas-Martínez 1974, *Viburno tini-Quercetum ilicis* (Br.-Bl. 1936) Rivas-Martínez 1975, *Pistacio lentisci-Rhamnetum alaterni* Bòlos 1970.
Geographical distribution and conservation status: The relevés in the dataset were performed only in Latium and Tuscany (Fig. 4). However, this habitat is widespread in many Italian regions (Biondi et al., 2009). The conservation status is favourable both in the Mediterranean and in the Continental regions. The habitat may be threatened by uncontrolled fires and by deforestation.

Discussion

Along the Italian coasts there is a wide variety of psammophilous plant communities, linked to the variability of bioclimatic and phytogeographic features. Moreover, the insular areas are characterized by high species richness and by endemic and rare associations. In addition, on the northern Adriatic coast there is a high concentration of associations with a restricted geographic distribution mainly

related to the Continental bioclimate (Brullo et al., 2001).
The dataset reasonably reflects the current knowledge of Italian coastal dunes vegetation. However, as the time span of relevés concerns more than 40 years, it is also probable that in some areas the presence of coastal habitats could have been overestimated. In fact, some communities may have disappeared due to a more recent habitat loss. In addition, it is also possible that in other areas habitats were underestimated because of the lack of published phytosociological studies.
The results of the meta-analysis showed that community patterns shift from annual beach communities to shrub-covered fixed dunes, probably associated with changes in the environmental characteristics along the sea-inland gradient. This pattern has already been observed in other coastal European sand dune ecosystems (Olff et al., 1993; Rosenzweig 1995; Sýkora et al., 2004; Isermann 2005; Forey et al. 2008; Acosta et al. 2009). In fact, moving inland, plant communities are progressively less exposed to the extreme conditions of the fore dunes and, gradually, less tolerant to salt spray, winds, and sand burial (Wiedemann & Pickart, 2004; Carboni et al., 2011). The vegetation zonation pointed out here is also coherent with previous studies on Italian sandy coasts at national scale (Géhu et al., 1984; Pignatti, 1993; Biondi, 1999; Brullo et al., 2001).
The boundaries between dune habitats are not sharp-cut as there is a gradual transition from one community to the other, so we can highlight a partial overlap of the dune habitats (Stanisci et al., 2004; Acosta et al., 2003). Nevertheless the perennial woody vegetation of fixed dunes habitats differ substantially from the upper beach, mobile dune and transition dune communities, separated in a well-defined group of relevés. We can also pinpoint a sub-group represented by the north Adriatic juniper association characterized by a particular species assemblage (Gamper et al., 2008).
We have highlighted that Italian coastal dunes and inland dunes are among the most threatened habitats at national level, mainly due to anthropic activities. As it is highly probable that human development and recreational activities along coasts will continue to be intense, an appropriate management of well-preserved dune systems, paired with the restoration of the more damaged ones, are urgently needed. The information derived from this database could be used for the monitoring and surveillance of EU habitats and species, as required by Habitats Directive (EEC, 1992), as well as for the "Natura 2000" ecological network management (Boillot et al., 1997). An adequate implementation of the Habitats Directive will help to guarantee that coastal dunes retain their major features, promoting their conservation for the future generations.

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REFERENCES

Acosta A.T.R., Stanisci A., Ercole S., Blasi C., 2003. Sandy coastal landscape of the Lazio region (Central Italy). Phytocoenologia 33, 715-726.

Acosta A.T.R., Carranza M.L., Izzi, C.F., 2009. Are there habitats that contribute best to plant species diversity in coastal dunes? Biodiversity and Conservation 18, 1087-1098.

Barbier E.B., Hacker S.D., Kennedy C., Koch E.W., Stier A.C., Silliman B.R., 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs 81(2), 169-193.

Biondi E., 1999. Diversità fitocenotica degli ambienti costieri italiani. Bollettino Museo Civico Scienze Naturali Venezia 49, 39-105. Arsenale Editore.

Biondi E., 2007. Thoughts on the ecology and syntaxonomy of some vegetation typologies of the Mediterranean coast. Fitosociologia 44(1), 3-10.

Biondi E., Blasi C., Burrascano S., Casavecchia S., Copiz R., Del Vico E., Galdenzi D., Gigante D., Lasen C., Spampinato G., Venanzoni R., Zivkovic L., 2009. Manuale Italiano di interpretazione degli habitat della Direttiva 92/43/CEE (Italian Interpretation Manual of the 92/43/EEC Directive Habitats).
Retrived from http://vnr.unipg.it/habitat/index.jsp.

Braun-Blanquet J., 1928. Pflanzensoziologie. Grundzüge der Vegetationskunde. Springer, Berlin, DE.

Braatz S., Fortuna S., Broadhead J., Leslie R., 2007. Coastal protection in the aftermath of the Indian Ocean Tsunami. What role for forests and trees? Proceedings of the Regional Technical Workshop, Khao Lak, Thailand, 28-31 August 2006. FAO, Bangkok, Thailand.

Boillot F., Vignault M.P., De Benito J.M., 1997. Process for assessing national lists of proposed Sites of Community Interest (pSCI) at biogeographical level. Natur und Landschaft 72, 474-476.

Brullo S., Giusso del Galdo G.P., Siracusa G., Spampinato G., 2001. Considerazioni fitogeografiche sulla vegetazione

psammofila dei litorali italiani. Biogeographia 22, 93-137.

Carboni M., Santoro R., Acosta A.T.R., 2011. Dealing with scarce data to understand how environmental gradients and propagule pressure shape fine-scale alien distribution patterns on coastal dunes. Journal of Vegetation Science 22, 751-765.

Cochard R., Ranamukhaarachchi S.L., Shivakoti G.P., Shipin O.V., Edwards P.J., Seeland K.T., 2008. The 2004 tsunami in Aceh and Southern Thailand: a review on coastal ecosystems, wave hazards and vulnerability. Perspectives in Plant Ecology, Evolution and Systematics 10, 3-40.

Conti F., Abbate G., Alessandrini A., Blasi C. (eds) (2005). An Annotated Checklist of the Italian Vascular Flora. Ministero dell'Ambiente e della Tutela del Territorio, Dipartimento di Biologia Vegetale, Università degli Studi di Roma "La Sapienza". Palombi Editori, Roma.

Cori B., 1999. Spatial dynamics of Mediterranean coastal regions. Journal of Coastal Conservation 5, 105-112.

Doing H., 1985. Coastal foredune zonation and succession in various parts of the world. Plant Ecology 61, 65-75.

EEC, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal L. 206, 22/07/1992.

ESRI (Environmental Systems Research Institute Inc.), 2006. ArcGIS 9.2. Redlands, CA, USA.

European Commission DG Environment, 2007. Interpretation Manual of European Union Habitats. EUR 27.

European Commission DG Environment, 2008. Article 17 Technical Report 2001-2006 (http://biodiversity.eionet.europa.eu/article17). European Topic Centre on Biological Diversity.

Feola S., Carranza M.L., Schaminée J.H.J., Janssen J.A.M., Acosta A.T.R., 2011. EU habitats of interest: an insight into Atlantic and Mediterranean beach and foredunes. Biodiversity and Conservation 20,1457-1468.

Forey E., Chapelet B., Vitasse Y., Tilquin M., Touzard B., Michalet R., 2008. The relative importance of disturbance and environmental stress at local and regional scales in French coastal sand dunes. Journal of Vegetation Science vol. 19, issue 4, 493-502.

Gamper U., Filesi L., Buffa G., Sburlino G., 2008. Diversità fitocenotica delle dune costiere nord-adriatiche. Le comunità fanerofitiche. Fitosociologia 45, issue 1: 3-21.

Géhu J.M., Costa M., Scoppola A., Biondi E., Marchiori S., Peris J.B., Franck J., Caniglia G., Veri L., 1984. Essay synsystématique et synchorologique sur les végétations littorales italiennes dans un but conservatoire. Documents Phytosociologiques 8: 393-474.

Hennekens S.M. 1996. TURBO (VEG). Software package for input, processing, and presentation of phytosociological data. User's guide. Wageningen, NL & University of Lancaster, UK.

Hennekens S.M., Schaminée J.H.J., 2001. TURBOVEG, a comprehensive database management system for vegetation data. Journal of Vegetation Science 12(4), 589-591.

Houston J., 2008. Management of Natura 2000 habitats. 2130 *Fixed coastal dunes with herbaceous vegetation ("grey dunes"). European Commission.

Isermann M., 2005. Soil pH and species diversity in coastal dunes. Plant Ecology, 178: 111-120.

Jongman R.H.G., ter Braak C.J.F., van Tongeren O. (eds.), 1987. Data analysis in community and landscape ecology. Pudoc, Wageningen.

Koch E.W., Barbier E.B., Silliman B.R., Reed D.J., Perillo G.M.E., Hacker S.D., Granek E.F., Primavera J.H., Muthiga N., Polasky S., Halpern B.S., Kennedy C.J., Kappel C.V., Wolanski E., 2009. Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. Frontiers in Ecology and the Environment 7, 29-37.

La Posta A., Duprè E., Bianchi E., 2008. Attuazione della Direttiva Habitat e stato di conservazione di habitat e specie in Italia. Ministero dell'Ambiente e della Tutela del Territorio e del Mare. Direzione per la protezione della Natura. Palombi editore, Roma.

Martínez M.L., Psuty N.P. (eds.) 2004. Coastal dunes. Ecology and conservation. Springer-Verlag, Heidelberg, Germany.

McCune, B., Mefford M.J, 2006. PC-ORD. Multivariate Analysis of Ecological Data. Version 5.10. MjM Software, Gleneden Beach, Oregon, U.S.A.

McLachlan A., Brown A.C., 2006. The Ecology of Sandy Shores. Academic Press, Burlington, MA, USA.

Miller T.E., Gornish E.S., Buckley H.L., 2010. Climate and coastal dune vegetation: disturbance, recovery, and succession. Plant Ecology 206, 97-104.

Mücher C.A., Hennekens S.M., Bunce R.G.H., Schaminée J.H.J., 2004. Mapping European Habitat to support the design and implementation of a Pan-European Network; the PEENHAB project. Wageningen, Alterra. Alterra report 952. Nederland, pp. 124.

Olff H., Huisman J., Van Tooren B.F., 1993. Species

dynamics and nutrient accumulation during early primary succession in coastal sand dunes. Journal of Ecology, vol. 81, issue 4, 693-706.

Picchi S., 2008. Management of Natura 2000 habitats. 2250 *Coastal dunes with *Juniperus spp.* European Commission.

Pignatti S., 1993. Dry coastal ecosystems of Italy. In: van der Maarel E. (ed.). Dry coastal ecosystems. Polar Regions and Europe. Ecosystems of the World 2A, pp. 379-290. Elsevier, Amsterdam, NL.

Rosenzweig M.L., 1995. Species diversity in space and time. University Press, Cambridge.

Schaminée J.H.J., Hennekens S.M., Chytrý M., Rodwell J.S., 2009. Vegetation-plot data and databases in Europe: an overview. Preslia 81, 173-185.

Stanisci A., Acosta A.T.R., Ercole S., Blasi C., 2004. Plant communities on coastal dunes in Lazio (Italy). Annali di Botanica, nuova serie IV, 115-128.

Sýkora K.V., van den Bogert J.C.J.M., Berendse F., 2004. Changes in soil and vegetation during dune slack succession. Journal of Vegetation Science 15(2), 209-218.

van der Maarel E., 2003. Some remarks on the functions of European coastal ecosystems. Phytocoenologia 33(2-3), 187-202.

van der Meulen F., Udo de Haes H.A., 1996. Nature conservation and integrated coastal zone management in Europe: present and future. Landscape and Urban Planning 34, 401-410.

Wätzold F., Schwerdtner K., 2005. Why be wasteful when preserving a valuable resource? A review article on the cost-effectiveness of European biodiversity conservation policy. Biological Conservation 123, 327-338.

Westhoff V., van der Maarel E., 1973. The Braun-Blanquet approach. In: Whittaker R. H. (ed.) Classification of plant communities. pp. 289-399, W. Junk, The Hague, NL.

Wiedemann A.M., Pickart A.J., 2004. Temperate zone coastal dunes. In: Martinez M., Psuty N. (eds). Coastal dunes: ecology and conservation. Springer, pp. 53-65.