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Habitat quality assessment through a multifaceted approach: the case of the habitat 2130* in Italy

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Abstract
Sand dune perennial grasslands are valuable coastal habitats, considered among those with major conservation concerns. The priority EU habitat 2130* has an almost continuous distribution area along the coasts of Northern Europe and the Black Sea. In the Mediterranean basin it is found only along the North Adriatic coast, isolated from the rest of the distribution area, thereby representing a unique aspect of the habitat variability. The first aim of this study was to evaluate the conservation status of the EU habitat 2130* by using the concept of 'diagnostic species pool' and a 'reference state' approach by comparing extant plant community attributes to the expected condition in the absence of major environmental and anthropogenic disturbances. The second aim was to investigate the effects of natural and anthropogenic factors on EU habitat 2130* conservation status. Our study allowed to evidence an overall bad conservation status of the habitat, with a generalized decrease in the average species richness and modifications of the habitat structure. The concepts of 'diagnostic species pool' and 'reference state' turned out as the most straightforward tools to assess the conservation status. While geomorphological features, in particular dune width, and human disturbance revealed significant correlation with the conservation status, sedimentological data were not useful to detect community's quality changes. To preserve the EU 2130* priority habitat, representing a peculiar element of the North Adriatic coast, the entire dune system integrity should be pursued, avoiding direct foredune destruction and other actions preventing dune development. In addition to this, the access to the dune system should be managed in order to protect the sensitive dune vegetation from trampling impacts.

Key words: coastal dunes, conservation status, diagnostic species, North Adriatic, reference state, vegetation structure.

Introduction

Coastal dunes belong to one of the most vulnerable and threatened ecosystems in Europe (Bakker *et al*., 2016; Janssen *et al*., 2016). They are valuable environments, which host many rare plant and animal species, often restricted to coastal habitats (van der Maarel, 2003; Acosta *et al*., 2009). Currently, they are suffering a consistent loss of biodiversity, as well as a decline in their extent (Janssen *et al*., 2016). Due to their degradation and disappearing, coastal environments are of great conservation concern (EEA, 2008; Keith *et al*., 2013; Janssen *et al*., 2016).

Among coastal habitats, perennial dune grasslands are the most threatened (Janssen *et al*., 2016). Major threats are represented by both human impact and natural hazards (Ciccarelli, 2014; Malavasi *et al*., 2014). The disproportionate touristic exploitation has destroyed large areas that were formerly rich in plants, causing a loss of dune systems of about 80% in the Mediterranean (EEA, 1999). Human trampling, in particular, is considered as an important damaging factor for dune grasslands (Kerbiriou *et al*., 2008; Santoro *et al*., 2012; Farris *et al*., 2013), leading to the fragmentation of plant communities, through the formation of several paths, and increasing the percentage of bare soil areas. Non-vegetated areas can be colonized by opportunistic and alien species, whose interaction with native species can further alter plant communities (Del Vecchio *et al*., 2015; Del Vecchio *et al*., 2016). Human trampling also affects pedogenetic processes, by varying the accumulation and erosion dynamics of the sand and the amount of the deposited organic matter (Bini, 2002). Natural hazards such as coastal erosion, and changes in the wind intensity and direction, can as well influence the sand transport and accumulation, and alter some geomorphologic parameters of the dune system, such as the height and the width of the foredune (Bakker *et al*., 2016). The modification of the dune morphology impairs important functions provided by healthy dune systems, such as the protection of inlands habitats from the limiting abiotic factors, like intense salty wind and sand burial (Buffa *et al*., 2007; Fenu *et al*., 2013, Del Vecchio 2013a). By establishing on the semi-fixed dunes, in a sheltered position, dune grasslands are expected to be particularly dependent on healthy dune systems and the protection service they provide (Doing, 1985; Houston, 2008).

According to Annex I of the Habitat Directive (92/43/EEC), coastal dune grasslands are split into two main categories on the basis of their distribution area: "Sea dunes of the Atlantic, North Sea and Baltic coasts" (distinguished by the code 21) and "Sea dunes of the Mediterranean coast" (code 22).

Despite being included in the Mediterranean region, the North Adriatic coastal stretch has long been de-

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scribed as peculiar. The landscape is characterised by a remarkable phytocoenotic originality, evidenced in past and recent studies (Béguinot, 1913, 1941; Marcello, 1960; Buffa *et al*., 2007; Sburlino *et al*., 2008; Sburlino *et al*., 2013), that is the result of the interplay of physical and biogeographical factors. From the bioclimatic point of view, the N-Adriatic seacoast can be included in the Eurosiberian region, Appennine-Balcanic province and Po-Valley subprovince, thereby representing the only coastal sector of the Mediterranean basin to be included in the temperate region (Sburlino *et al*., 2013). Moreover, the area has been interested by an extensive migration of species during the III and the 1st millennium BC, which enriched the regional species pool in Mediterranean, alpine and eastern species (Lorenzoni, 1983; Buffa *et al*., 2007). At levels higher than that of species, the region also hosts plant communities that cannot be found elsewhere (Buffa *et al*., 2007; Gamper *et al*., 2008). Within coastal grasslands, the area hosts an endemic plant community, the *Tortulo-Scabiosetum* Pignatti 1952, which pertains to the EU habitat 2130* "Fixed coastal dunes with herbaceous vegetation - grey dunes" (Habitat Directive 92/43/CEE), a priority habitat of coastal systems (Buffa *et al*., 2005; Buffa *et al*., 2007; Biondi *et al*., 2009; Sburlino *et al*., 2013). The habitat is almost continuous along the coasts of Northern Europe, from the Baltic Sea to the Atlantic coasts of Portugal (Houston, 2008), and along the coasts of the Black Sea (Tzonev *et al*., 2005; Agir *et al*., 2014), while in the Mediterranean basin it is present only along the coasts of the North Adriatic Sea (Géhu *et al*., 1984; Biondi 1999; Buffa *et al*., 2005; Buffa *et al*., 2007; Sburlino *et al*., 2013). Being isolated from the rest of the distribution area of the habitat, the North Adriatic community represents a unique aspect of the variability of the habitat EU 2130* across its distribution area, raising conservation concerns.

Indeed, preserving the variability may contribute to allow resilience to changing climate and environmental conditions and counteract the effects of biodiversity loss (Smith *et al*., 2001; Gigante *et al*., 2016a; Janssen *et al*., 2016). Focusing on the conservation of areas which represent peculiar and unique aspects of habitats and species characterized by a wider distribution, has been suggested as a valid contribution to the preservation of the variability (Gargano *et al*., 2007; Del Vecchio *et al*., 2012). In this context, the conservation of the only Mediterranean site of the EU habitat 2130* may represent an important contribution for the conservation of this valuable habitat as a whole.

Understanding the main factors which guarantee a good conservation status represents a mandatory step in conservation planning (Buffa & Del Vecchio, 2016; Fantinato *et al*., 2016; Gigante *et al*., 2016b). Many methods for the assessment of the conservation status of coastal habitats have been proposed (Ciccarelli, 2014). Several studies provided evidence that the analysis of such plant community attributes as species composition and vegetation structure (e.g. plant life cycle, life forms, species cover and richness) are effective descriptors of the plant community quality (Isermann, 2008; Poldini *et al*., 2011; Buffa & Villani, 2012; Keith *et al*., 2013; Del Vecchio *et al*., 2015; Del Vecchio *et al*., 2016; Gigante *et al*., 2016a; Slaviero *et al*., 2016).

Given the conservation concerns arisen around coastal grasslands, and given the peculiarity of the Northern Adriatic coast, the first aim of this study was to evaluate the conservation status of the EU habitat 2130* by using the concept of 'diagnostic species pool' and a 'reference state' approach by comparing extant plant community attributes to the expected condition in the absence of major environmental and anthropogenic disturbances. The second aim was to investigate the effects of natural and anthropogenic factors on conservation status. Since coastal habitats are highly sensitive to human as well as environmental stressors (e.g. soil humidity, grain size, organic matter content, pH) which affect their structure and functioning (Provoost *et al*., 2004; Carboni *et al*., 2010; Prisco *et al*., 2016; Riksen *et al*., 2016), we integrated plant community attributes with sedimentological data, geomorphological features, and human disturbance, measured as the intensity of trampling.

Methods

Study area

The study area corresponds to the Venetian portion of the North Adriatic coast (north-eastern Italy), and focused on five sites, which host the most representative dune systems of the area: Laguna del Mort, Penisola del Cavallino, Ca' Roman, Isola Verde, Porto Caleri (Buffa *et al*., 2012).

Sites consist of narrow, recent dunes (Holocene), bordered by river mouths and tidal inlets (Del Vecchio *et al*., 2015); sediments are sandy carbonate deposits that come from rivers that flow into the Adriatic Sea, determining a variability of sediment composition from North to South: the northern area is made of dolomitic sediments that come from Piave and Tagliamento rivers, while the southern area is made of siliciclastic sediments from Brenta, Adige and Po rivers (Zunica, 1971; Audisio & Muscio, 2002).

The climate of the study area is a connotative factor, since the North Adriatic coast is the only coastal zone in the Mediterranean basin that doesn't belong to the Mediterranean climatic region (Rivas-Martìnez & Penas, 1999; Rivas-Martínez *et al*., 2004), but it presents an oceanic temperate bioclimate (Buffa *et al*., 2007).

This climate derives from the combination of different factors, which act at multiple scales. At global-scale, the area is influenced by the Atlantic Ocean airstream from the west, and by the Mediterranean subtropical anticyclone from the south (Barbi *et al*., 2012). At regional scale, the presence of the Adriatic Sea mitigates the temperature, maintains high levels of moisture and gives origin to marine winds (breeze; Barbi *et al*., 2012). As a result, rainfalls are rather uniform during the year with a total annual amount between 800 and 1,000 mm, and the area lacks the summer drought, typical of the Mediterranean climate. The mean annual temperature is about 13°/14° C (Buffa *et al*., 2007; Barbi *et al*., 2012).

Soils of semi-fixed dunes are classified as Typic Haploxerept and Arenic Eutrudept (Inceptisols) (Bini, 2002; Bini *et al*., 2002a; Bini *et al*., 2002b). Inceptisols gradually develop from Entisols, at increasing distance from the sea. They are more stable, deeper, with lower values of salinity and higher values of organic matter and moisture compared with the embryo and mobile dune soil (Bini, 2002; Acosta & Ercole, 2015).

The semi-fixed dune system of the study area is occupied by the EU habitats 2230 (*Malcolmietalia* dune grasslands) and 2130* (Buffa *et al*., 2005; Del Vecchio *et al*., 2015; Del Vecchio *et al*., 2016), which have different structure and species composition. The first one, which in the study area corresponds to the *Sileno conicae-Avellinietum michelii* Sburlino *et al*. 2013, is mainly made of herbaceous annual species, which define a very dynamic community. The cryptogamic cover is reduced or absent (Biondi *et al*., 2009; Sburlino *et al*., 2013; Acosta & Ercole, 2015). The community develops as a result of the destructuration of *Tortulo-Scabiosetum* caused by wind erosion or, more frequently, by trampling (Sburlino *et al*., 2013). On the contrary, the latter is a perennial dry short-grassland whose structure is mainly determined by a high percentage cover of herbaceous perennial species and dwarf shrubs, and a thick carpet of bryochamaephytes (*Syntrichia ruralis* var. *ruraliformis* p. max p.) and, sometimes, of lichens.

Field sampling and data collection

A total of 34 plots of standard size (2x2 m^2) were selected using a stratified random sampling design within the semi-fixed dune sector of the studied area. We used the habitat map of the Veneto region (available at www.regione.veneto.it) to identify the patches of the EU habitat 2130* in the field. For each plot, we georeferenced the position and recorded all the vascular plants together with their percentage cover using the Braun–Blanquet's scale (Braun-Blanquet, 1932; Dengler *et al*., 2008). Furthermore, we recorded total vegetation cover (%), the cover of the moss layer (%) and the relative distance from the sea (calculated as percentage of the total width of the dune system from the coastline, in m). Geomorphological data, such as the height and the width of the active dune in correspondence of each plot, were measured as well.

For each plot, we collected a soil sample, at 30-40 cm depth. Soil pH and moisture were measured according to the "Official methods of soil chemical analysis" (D.M. of 13/09/1999 of the Agricultural, Alimentary and Forestry politics' ministry). Moisture content was measured by the Gravimetric method (Method II.2 of the protocol). Organic matter content was measured by the "Loss On Ignition" (LOI) procedure (Schulte e Hopkins, 1996). Soil samples were dried at 105° C for 12 hours, afterward 5 g of soil were incubated at 375° C for 16 hours (in porcelain crucibles, previously sterilised at 950° C for 2 hour) and the temperature was reached gradually, through intermediate steps. After the combustion, the crucibles with soil were weighted again. Granulometric characteristics were measured by sieving; samples of 50 g of dried sediments were sieved in a nested column of six sieves with decreasing openings: 1 mm, 500 μm, 300 μm, 150 μm, 106 μm, 63 μm (ASTM category), and the pan collected grains smaller than 63 μm, which corresponded to the last sieving class (silt and clay). Complete sieving was obtained by using a mechanical sieve shaker for 15 minutes. Afterwards, the content of each sieve and pan was weighted, and the percentage weight on the initial total weight was calculated. Granulometric curves were analyzed by the software GRADISTAT 8.0, and the average size of the particles and the sorting were determined by the method of moments (Krumbein, 1938; Friedman *et al*., 1982).

As a proxy for human disturbance, for each plot we measured the trampling intensity as the total lengh of tracks within a buffer centred to each plot. The georeferenced plots were overlaid to the most recent available aerial photographs (year 2015) in GIS environment (QGIS 2.6). Visible tracks were marked through photo-interpretation, and their quantity in meters was calculated in a circular buffer of 20 m diameter. According to the features of the study area and to photo-interpretation, the buffer size of 20 m diameter was the most adequate to measure the trampling intensity since trampling was underestimated in smaller size buffers, while bigger size included areas that were not related to human trampling around the plot, such as settlements, roads, or the sea.

Data analyses

We built the 'reference state' (Tab. 1) starting from the phytosociological table of the *Tortulo-Scabiosetum* community provided in Sburlino *et al*. (2013), which represents the 'community type' of the habitat in Italy. The 'reference state' included the 'diagnostic species pool' (i.e., characteristic and differential species of *Tortulo-Scabiosetum*, *Syntrichio ruraliformis-Lomelosion* *argenteae* Biondi, Sburlino & Theurillat in Sburlino, Buffa, Filesi, Gamper & Ghirelli 2013, *Artemisio-Koelerietalia albescentis* Sissingh 1974 and *Koelerio-Corynephoretea* Klika in Klika & Novák 1941, and the differential species of *Tortulo-Scabiosetum fumanetosum* Pignatti 1952), and the main structural characteristics (e.g. total vegetation cover, cryptogamic cover, species richness, etc.). Diagnostic species were also grouped in three main categories on the basis of their life cycle: a) Annual species (Therophytes), with a short life cycle, well adapted to disturbed sites. They complete their life cycle within one year (often in few months), and normally die after seed production; b) Herbaceous perennial species (Hemicryptophytes and Geophytes), plants whose aerial shoots can either die periodically or not, but the plant survives thanks to persistent belowground shoots or storage organs; c) Dwarf shrubs (Chamaephytes), perennial plants with woody stems, up to 0.5 m tall (Cornelissen *et al*., 2003; Perez-Harguindeguy *et al*., 2013). To figured out the mean cover of the three categories, phytosociological codes were transformed according to Hennekens & Schaminée (2001). The ratio among the percentage cover of herbaceous annual species, herbaceous perennials and dwarf shrubs was used as an indicator of ecological processes, and its variation as an indicator of habitat transformation (Del Vecchio *et al*., 2013b; Del Vecchio *et al*., 2015; Del Vecchio *et al*., 2016). Species nomenclature follows Conti *et al*. (2005; 2007).

The matrix of 34 relevés x 60 species was analyzed by cluster analysis (PC-ORD 5.1 software). For each group of relevés emerged by the clustering, we calculated the mean values of: (i) species richness; (ii) vascular species cover (%); (iii) moss cover (%); (iv) the percentage cover of herbaceous annual species, herbaceous perennial species, and dwarf shrubs; (vi) Evenness index J (as H'/lnS, where H' is the Shannon diversity index and S the number of species); (vii) relative distance from the sea; (viii) soil pH, moisture, organic matter content, size and sorting of sand grains; (ix) foredune height and width; (x) trampling intensity. These parameters were compared among the groups through a PERMANOVA test (Permutational Multivariate Analysis of Variance; 9999 randomizations; Past Software), using the group of the cluster analysis as independent variable. Significant differences were tested by "LSD" post hoc test. Furthermore, the parameters of each group were compared with those of the reference state through Mann-Whitney U test (9999 randomizations; Past Software), except for the sedimentological and geomorphological data, and human trampling, which were not available for the reference state.

Results

The cluster analysis (Fig. 1) highlighted three main groups of relevés. All the relevés shared some common characters (Tab. 1) such as the presence of a dense carpet of bryochamaephytes, and the presence of diagnostic species like *Fumana procumbens*, *Lomelosia argentea*, *Carex liparocarpos*, *Centaurea tommasinii*, *Phleum arenarium*, and *Cerastium semidecandrum*.

However, the comparison with the reference state (Tab. 1) evidenced significant differences in many structural features of the three groups. In particular, extant vegetation had lower percent cover of vascular species, lower species richness and higher cover of annual species.

PERMANOVA test evidenced significant differences among the three groups ($F=6.144$; $p=0.0001$). Overall, neither the total percentage cover of vascular species, nor the mean species richness per plot significantly changed among the three groups. However, the comparison of the cover of the three main groups of species based on life cycle and the comparison with the diagnostic species pool allowed to evidence some notable differences.

Group 1 showed the highest, although changeable, percentage cover of herbaceous annual species (56.55

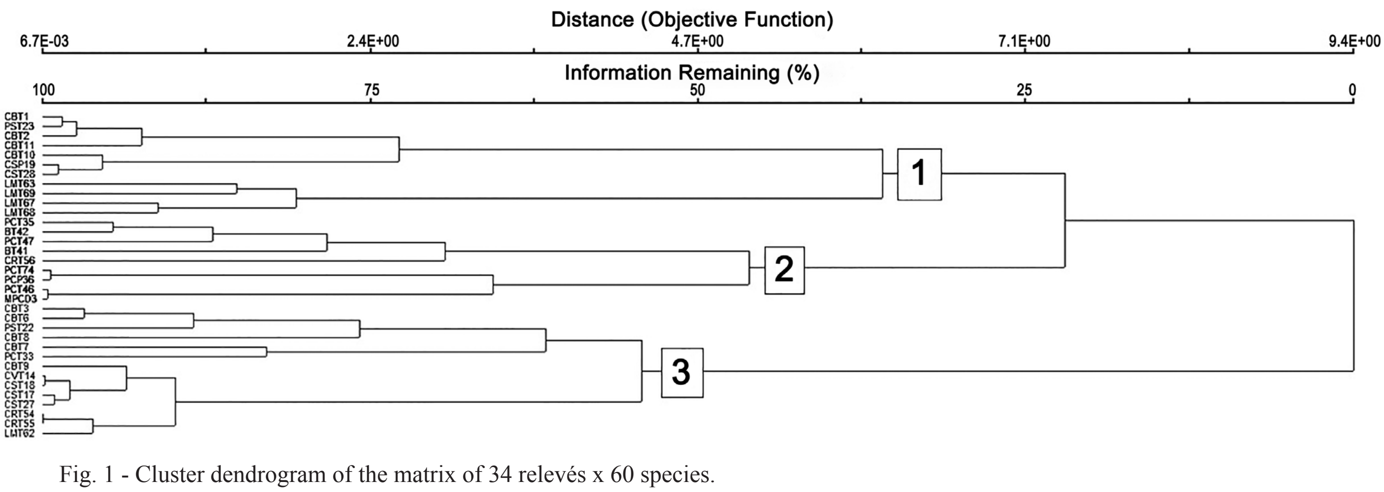

Fig. 1 - Cluster dendrogram of the matrix of 34 relevés x 60 species.

± 43.47), which was more than 9 times higher compared to that of the reference state. The increase in annual species cover was mostly due to the increase in cover of species of the diagnostic species pool such as *Cerastium semidecandrum*, *Phleum arenarium*, *Silene conica* and *Medicago minima*, as well as of other species like *Vulpia fasciculata*, *Silene canescens* or *Catapodium rigidum*. Although remaining higher than in the reference state, annual species cover decreased by half in the relevés of group 2, which were dominated by herbaceous perennial species such as *Lomelosia argentea*, *Hypochoeris radicata*, *Silene vulgaris* ssp. *angustifolia*, *Centaurea tommasinii*, *Carex liparocarpos*, *Cyperus capitatus* and *Petrorhagia saxifraga*. Finally, relevés of group 3 evidenced the highest percentage cover of dwarf shrubs (70.21 ± 26.75), which was two times higher than in the reference state. The increase in the dwarf shrubs cover was due to *Fumana procumbens*, which on average doubled its cover. Evenness index value was the lowest among the three groups and resulted not significantly different from that of the reference state.

The three groups also differed for some sedimentological and geomorphological characteristics. The most significant variables resulted to be the relative distance from the sea (increasing from group 1 to group 3), and dune width. The organic matter content and pH, although significantly different among groups, did not evidence a linear trend of variation. Trampling intensity significantly decreased from group 1 to group 3.

Discussion

Our study allowed to evidence an overall bad conservation status of the habitat. In particular, the comparison with the reference state drew the attention to a generalized decrease in the average species richness as well as to a certain degree of modification of the habitat structure.

The study allowed to distinguish three different aspects which can be interpreted as different degrees of conservation. Both the analysis of species composition and structure, evaluated as the ratio among herbaceous annual species, herbaceous perennials and dwarf shrubs turned out as the most straightforward tools to assess the conservation status of the habitat 2130*. Although each group evidenced differences in at least some of the variables when compared with the reference state, group 3 better corresponded to the reference state and to EU 2130* habitat type. Relevés of this group were mostly composed of diagnostic species and the structure was characterized by the dominance of dwarf shrubs such as *Fumana procumbens*, *Teucrium polium*, *Helianthemum nummularium* ssp. *obscurum*, and herbaceous perennial species. The relevés of this group could be easily referred to the *Tortulo-Scabiosetum fumanetosum* included in the *Artemisio-Koeleretalia albescentis* order and in the endemic alliance *Syntrichio ruraliformis-Lomelosion argentae* (Sburlino *et al*., 2013; Biondi *et al*., 2014). The annual component was negligible compared to that of the other groups, although significantly higher than that of the reference state. The coherence in terms of species composition and structure decreased from Group 3 to Group 1, which was dominated by annual species. Nevertheless, the presence of perennial species such as *Carex liparocarpos*, *Poa bulbosa*, *Sanguisorba minor* ssp. *muricata* testifies the relationship with the *Tortulo-Scabiosetum* and allows to make reference to the *Sileno conicae-Avellinietum michelii* (*Malcomietalia* Rivas Goday 1958 order, alliance *Laguro ovati-Vulpion membranaceae* Géhu & Biondi 1994), described as a degraded aspect of the *Tortulo-Scabiosetum* due to wind erosion or trampling and corresponding to the habitat 2230 (Biondi *et al*., 2009; Sburlino *et al*., 2013; Biondi *et al*., 2014). Relevés of group 2, dominated by herbaceous perennial species and an intermediate cover of annuals and dwarf shrubs represent the typical subassociation of the *Tortulo-Scabiosetum* (Sburlino *et al*., 2013).

Changes in structure were also evidenced by the Evenness index. Several studies provided evidence that the variation in the balance of species distribution (Evenness Index) reflects a modification of the habitat, and can indicate an alteration (Isermann, 2008, 2011; Del Vecchio *et al*., 2015; Agir *et al*., 2016; Del Vecchio *et al*., 2016). In line with these findings, according to our results a higher species equitability is associated to the degradation of the habitat. In particular, increasing equitability is coupled with the disappearing of dwarf shrubs.

The need to use both the analysis of the structure and of species identity (diagnostic species pool) for the assessment of the conservation status was particularly evident when dealing with annual species. A high percentage cover of annual species is often an indicator of habitat deterioration, since annual species do not form steady communities over time and are more adapted to dynamic and disturbed contexts (Buffa *et al*., 2007; Del Vecchio *et al*., 2013b; Del Vecchio *et al*., 2015). On the other hand, annual species are part of the diagnostic species pool of the reference state (Sburlino *et al*., 2013). However, the analysis of the species identity revealed that many annuals mostly found in the first two groups (e.g. *Vulpia membranacea*, *Catapodium rigidum*, *Lagurus ovatus*, *Silene colorata*, etc.) clearly indicate a process of transformation toward the *Sileno conicae-Avellinietum michelii* (Biondi *et al*., 2009; 2014; Sburlino *et al*., 2013; Acosta & Ercole, 2015).

Although useful in the comparison with the reference state, other plant community attributes, such as species richness, and total percentage cover of both the

Tab. 1 - Species list and variables analyzed in each group and in the Reference State (mean ± sd). Diagnostic species pool and plant community attributes for the Reference State were based on Sburlino *et al*. (2013). Variables which were significantly different to LSD test and to Mann-Whitney U test are highlighted in bold. Within the category "other species", those with a percentage cover lower than 0.5 % in the three groups are not shown. DS= Dwarf shrub; HA= Herbaceous annual; HP= Herbaceous perennial.

			Gr. 1		Gr. 2		Gr. 3		Reference State (RS)	Gr1 vs RS	Gr2 vs RS	Gr3 vs RS
		Number of relevés	11		9		14		39			
		Vascular species cover (%)	76 ± 16	a	87 ± 17	a	81 ± 18	a	**90.64 ± 7.17**	*	*	*
		Moss cover (%)	64 ± 24	a	68 ± 34	a	68± 20	a	69.62 ± 18.01	ns	ns	ns
		Herbaceous annual (% cover)	**56.55 ± 43.47**	**a**	**28 ± 21.47**	**b**	**23.21 ± 18.35**	**b**	**6.33 ± 5.21**	*	*	*
		Herbaceous perennial (% cover)	**29.55 ± 20.10**	**a**	**75.56 ± 42.85**	**b**	**19.57 ± 23.27**	**a**	**22.97 ± 19.70**	ns	*	ns
		Dwarf shrubs (% cover)	**4.09 ± 6.47**	**a**	**16.22 ± 17.85**	**a**	**70.21 ± 26.75**	**b**	**38.64 ± 41.59**	*	ns	*
		Species richness	10.73 ± 2.53	a	11.44 ± 4.28	a	10.79 ± 2.52	a	**19.26 ± 4.01**	*	*	*
		Evenness index	**0.78 ± 0.10**	**a**	**0.76 ± 0.09**	**a**	**0.64 ± 0.12**	**b**	**0.62 ± 0.08**	*	*	ns
		pH	**8.48 ± 0.10**	**a**	**8.11 ± 0.19**	**b**	**8.39 ± 0.16**	**a**				
		Moisture (g/kg)	31 ± 15	a	24 ± 15	a	47 ± 43	a				
		Organic matter (%)	**0.55 ± 0.23**	**a**	**0.97 ± 0.29**	**b**	**0.70 ± 0.24**	**a**				
		Size of sand grains (µm)	256 ± 45	a	258 ± 49	a	240 ± 23	a				
		Sorting of sand grains (µm)	187 ± 132	a	177 ± 39	a	189 ± 69	a				
		Relative distance from the sea (m)	**84 ± 12**	**a**	**85 ± 13**	**a**	**95 ± 11**	**b**				
		Dune width (m)	**15 ± 11**	**a**	**55 ± 26**	**b**	**20 ± 13**	**a**				
		Dune height (m)	1.3 ± 0.96	a	1.5 ± 0.97	a	1.1 ± 1.1	a				
		Trampling intensity (%)	**11 ± 9.0**	**a**	**5.1 ± 2.0**	**a**	**4.5 ± 3.7**	**b**				
					Mean cover per group (%)							
Diagnostic species pool	DS	*Fumana procumbens*	1.73 ± 3.93		0.33 ± 1.00		51.21 ± 25.16		28.72 ± 33.79			
	DS	*Helianthemum nummularium* ssp. *obscurum*	-		0.33 ± 1.00		6.57 ± 13.76		2.92 ± 6.73			
	DS	*Teucrium capitatum*	2.36 ± 5.26		-		6.93 ± 18.19		7.00 ± 17.74			
	HP	*Carex liparocarpos*	0.18 ± 0.60		1.78 ± 4.32		0.21 ± 0.80		4.87 ± 8.99			
	HP	*Equisetum ramosissimum*	1.18 ± 3.87		-		0.21 ± 0.80		0.87 ± 2.20			
	HP	*Centaurea tommasinii*	-		2.89 ± 5.73		-		0.72 ± 2.19			
	HP	*Poa bulbosa*	-		0.22 ± 0.67		0.21 ±0.80		6.92 ± 10.38			
	HP	*Plantago lanceolata* var.	0.18 ± 0.60		-		0.5 ± 1.01		0.23 ± 0.58			
	HP	*Lomelosia argentea*	-		23.11 ± 23.68		0.29 ± 0.73		7.56 ± 11.47			
	HP	*Stachys recta ssp. subcrenata*	-		-		-		1.03 ± 2.17			
	HP	*Petrorhagia saxifraga*	-		-		-		0.77 ± 0.90			
	HA	*Cerastium semidecandrum*	4.36 ± 4.30		1.67 ± 1.00		2.07 ± 1.21		2.15 ± 3.37			
	HA	*Phleum arenarium*	2.64 ± 0.55		5.67 ± 5.57		1.64 ± 1.15		1.33 ± 2.18			
	HA	*Silene conica*	3.00 ± 5.06		0.22 ± 0.67		0.57 ± 0.94		0.67 ± 0.74			
	HA	*Medicago minima*	7.73 ± 11.47		0.33 ± 1.00		3.21 ± 4.35		0.90 ± 2.16			
	HA	*Vicia pseudocracca*	-		10.33 ± 16.22		0.14 ± 0.54		0.38 ± 0.63			
	HA	*Arenaria serpyllifolia*	0.45 ± 1.04		-		0.21 ± 0.80		0.36 ± 0.66			
	HA	*Alyssum alyssoides*	-		-		-		0.05 ± 0.22			
	HA	*Erophila verna*	-		-		-		0.03 ± 0.16			
	HA	*Myosotis ramosissima*	-		-		-		0.03 ± 0.16			
	HA	*Plantago arenaria*	-		-		-		0.08 ± 0.27			
	HA	*Thlaspi perfoliatum* ssp. *perfoliatum*	-		-		-		0.03 ± 0.16			
	HA	*Trifolium campestre*	-		-		-		0.33 ± 2.08			
Other species	HA	*Vulpia fasciculata*	32.09 ± 31.89		2.44 ± 1.01		11 ± 17.17		2.46 ± 6.50			
	HA	*Catapodium rigidum*	1.55 ± 1.04		1.11 ± 1.05		1.36 ± 1.28		0.21 ± 0.57			
	HP	*Sanguisorba minor* ssp. *muricata*	12.00 ± 10.26		0.33 ± 1.00		8.29 ± 13.32		2.31 ± 2.85			
	HA	*Medicago litoralis*	2.45 ± 3.78		3.00 ± 4.00		0.57 ± 1.16		-			
	HA	*Silene canescens*	1.64 ± 3.91		0.78 ± 1.20		0.29 ± 0.73		0.13 ± 0.34			
	HP	*Cyperus capitatus*	1.91 ± 3.89		13.33 ± 21.51		2.21 ± 4.66		0.31 ± 0.73			
	HP	*Hypochoeris radicata*	3.45 ± 4.93		7.67 ± 12.58		0.93 ± 1.33		0.41 ± 0.75			
	HP	*Silene vulgaris*	1.27 ± 1.49		4.11 ± 5.21		0.79 ± 1.12		0.87 ± 0.95			
	HP	*Silene otites*	2.64 ± 5.20		-		0.86 ± 1.23		0.08 ± 0.27			
	HA	*Avellinia michelii*	0.18 ± 0.60		-		0.64 ± 1.08		0.03 ± 0.16			
	HA	*Clypeola jonthlaspi*	0.27 ± 0.90		-		0.79 ± 1.12		0.08 ± 0.27			
	HP	*Elymus farctus*	0.55 ± 1.21		-		0.21 ± 0.80		-			
	HP	*Scabiosa columbaria*	1.91 ± 3.88		-		0.29 ± 0.73		-			
	HA	*Lagurus ovatus*	-		2.44 ± 4.13		0.57 ± 0.94		3.13 ± 6.63			
	DS	*Helichrysum italicum*	-		15.56 ± 17.65		-		0.03 ± 0.16			
	HP	*Calamagrostis epigejos*	-		0.56 ± 0.90		-		0.08 ± 0.27			
	HP	*Calystegia soldanella*	0.18 ± 0.60		1.44 ± 1.42		-		-			
	DS	*Thymus pulegioides*	-		-		5.5 ± 10.84		-			
	HP	*Chrysopogon gryllus*	-		-		2.71 ± 10.16		-			
	HP	*Eryngium maritimum*	-		-		2.71 ± 1.00		-			

vascular species and the moss layer did not evidence any difference across groups. Species loss under increasing land-use intensity has already been reported for different species groups (Verhulst *et al*., 2004; Hoffmann & Zeller, 2005; Kleijn *et al*., 2009; Msuha *et al*., 2012), and the trend was confirmed by our study. However, species richness did not substantially change across groups with increasing bad conservation status, evidencing its scarce usefulness in detecting more subtle community's quality changes. Moreover, by disregarding the identity of species, species richness fails in evidencing species turnover and changes in species composition or abundance. Our results demonstrated that even when richness or total cover are not significantly different, some replacement of species can take place, leading to significant changes in the community.

Our study thus confirms the central importance of the definition for each habitat type of the 'diagnostic species pool', together with information on total vegetation cover, the structural layers cover, the presence/cover of dominant/typical/relevant species, or of species indicating disturbance (e.g. in our case, annual species). All these data can be used to build a 'reference state' (Reynoldson & Wright, 2000), useful to detect details about the conservation status of a habitat (Gigante *et al*., 2016a) and to predict which kinds of species may assemble in response to changes in climate and land use (Vandewalle *et al*., 2010; Pierce *et al*., 2017).

The analysis of the influence of natural and anthropogenic factors evidenced that the best conserved aspects of the habitat were the least disturbed by human trampling. The high vulnerability to human trampling has been already recognized (Buffa *et al*., 2012; Santoro *et al*., 2012; Del Vecchio *et al*., 2016) and is due to the presence of several slow-growing species, such as dwarf shrubs, and mosses and lichens, which once damaged, have a scarce recovery capacity. With particular regard to vascular species, excessive visitor pressure and consequent trampling has been proved to lead to the degradation of vegetation, though the impact varies in severity according to such species' morphological characteristics (Cole, 1995), as height, erectness, and growth form. The most tolerant plants are annuals, caespitose graminoids, rosette hemicryptophytes, and geophytes, whereas the least tolerant form is that of the chamaephytes. This framework can be used to explain the relationship between trampling intensity and the gradual increase in dominance of perennial and annual herbaceous species, and the corresponding decrease of dwarf shrubs.

However, our results also indicated significant relationships with some morphological features of the foredune system. While other studies evidenced that dune height plays a major protective role against natural disturbance (Fenu *et al*., 2013; Ciccarelli *et al*., 2017), in our case the most significant variables resulted to be the width of the foredune and the distance from the sea. In fact, the aspects with the lowest conservation status were found close to the sea, in correspondence of a narrow foredune system. Interestingly, aspects of intermediate conservation status were also found close to the sea, on the landward side of the foredune, but in correspondence of a wider dune system. Our result thus suggests that when the dune systems are low, as it is the case in the study area, dune width can act as an efficient barrier against limiting factors, such as wind and sand burial.

Although considered among the major drivers controlling the environmental variation along coastal dunes (Forey *et al*., 2008; Maun, 2009), sediment properties were almost even among the groups, and small differences were found only for the organic matter content and the pH value, always within the range of the value 8, typical of dune environments (Bini, 2002). According to Forey *et al*. (2008), environmental factors better explain regional differences, while at the local scale community composition is primarily driven by disturbance. Moreover, most studies evidencing significant differences in sediment properties were carried out taking into consideration the entire coastal zonation, thereby capturing the strong environmental gradient typical of dune environments. In our study, which considered only a particular coastal sector along the zonation, sediment characteristics mostly reflect the relevés position along the sea-inland gradient, but seem not to be useful to distinguish more subtle habitat characteristics. Sediment features seem to be primarily a consequence of the composition of the plant communities, and particularly of the life cycle of dominant species. Annual species are often small, have a thin root systems, and lack of woody parts. They produce a low amount of litter which is easily and rapidly degradable (Mazzoleni *et al*., 2007; Jones *et al*., 2008), or dispersed by wind. Herbaceous perennial species are often bigger than annual species, and have a more developed root system (taproot), or below-ground storage organs, which contribute to produce a higher quantity of organic matter, harder to be decomposed (Berg *et al*., 1998; Provoost *et al*., 2004; Incerti *et al*., 2017). Finally, being slow-growing species, often evergreen, with partially lignified stems, dwarf shrubs produce a small quantity of organic matter (Berg *et al*., 1998; Provoost *et al*., 2004).

Conclusion

Our study focused on the only Mediterranean site of the EU habitat 2130*, characterized by an endemic plant community, and representing a unique aspect of the variability of the habitat within its distribution area.

The results obtained in this study could contribute several important considerations regarding the management of coastal dune systems, which, to be efficient, need as much information as possible on habitats dynamics. In order to conserve the EU 2130* priority habitat, representing a peculiar element of the North Adriatic coast, the entire dune system integrity should be pursued, avoiding direct foredune destruction and other actions preventing dune development (e.g. beach mechanical ranking). In addition to this, the access to the dune system should be managed in order to protect the sensitive dune vegetation from trampling impacts. These actions need to be conceived within an integrated management strategy, combining economic, social and ecological interests, supported by stakeholders' awareness of dune ecosystems' value. The integrated approach offers the opportunity to reach a win-win situation creating sustainable coastal communities, as ecosystem functionality maintenance would ensure social and economic advantages.

References

Acosta A., Carranza M.L. & Izzi C.F., 2009. Are there habitats that contribute best to plant species diversity in coastal dunes. Biodiversity and Conservation 18 (4): 1087-1098.

Acosta A. & Ercole S., 2015. Gli habitat delle coste sabbiose italiane: ecologia e problematiche di conservazione. ISPRA, Serie Rapporti, 215/2015.

Agir S.U., Kutbay H.G., Karaer F. & Surmen B., 2014. The classification of coastal dune vegetation in Central Black Sea Region of Turkey by numerical methods and EU habitat types. Rendiconti Lincei-Scienze Fisiche E Naturali 25: 453-460.

Agir S.U., Kutbay H.G. & Surmen B.,2016. Plant diversity along coastal dunes of the Black Sea (North of Turkey). Rendiconti Lincei-Scienze Fisiche E Naturali 27: 443-453.

Audisio P. & Muscio G., 2002. Aspetti geologici e geomorfologici. Dune e spiagge sabbiose - Ambienti fra terra e mare. Ministero dell'Ambiente e della Tutela del Territorio, Museo Friulano di Storia Naturale, Udine.

Bakker J.P., Baas A.C.W., Bartholdy J., Jones L., Ruessink G., Temmerma S. & van de Po M., 2016. Environmental Impacts-Coastal Ecosystems. In: Quante M., Colijn F. (Eds.), North Sea Region Climate Change Assessment: 275-314. Springer International Publishing, Cham.

Barbi A., Cola G. & Mariani L., 2012. Inquadramento climatico del Veneto. Available at: http://www.arpa.veneto.it/temi-ambientali/agrometeo/file-e-allegati/atlante/inquadramento%20climatico%20del%20Veneto.pdf/view (accessed 2017).

Béguinot A., 1913. La vita delle piante superiori della Laguna di Venezia e nei territori ad essa circostanti. UIL Idr.d. R. Magistr. alle Acque 54, Venezia.

Béguinot A., 1941. La vita delle piante vascolari. La laguna di Venezia. Ferrari, Venezia.

Berg M.P., Kniese J.P., Zoomer R. & Verhoef H.A., 1998. Long-term decomposition of successive organic strata in a nitrogen saturated Scots pine forest soil. Forest Ecology and Management 107: 159-172.

Bini C., 2002. Suoli e paesaggi della fascia perilagunare dell'alto Adriatico. Suoli, ambiente, uomo: 53-64. Edifir - Edizioni Firenze, Firenze.

Bini C., Buffa G., Gamper U., Sburlino G. & Zilocchi L., 2002a. Soils and vegetation of coastal and wetland areas in Northern Adriatic (NE Italy). Options Méditerranéennes, Ser A 50: 31-36.

Bini C., Buffa G., Gamper U., Sburlino G. & Zuccarello V., 2002b. Alcune considerazioni sui rapporti fra Fitosociologia e Pedologia. Fitosociologia 39: 71-80.

Biondi E., 1999. Diversità fitocenotica degli ambienti costieri italiani. In: Aspetti ecologici e naturalistici dei sistemi lagunari e costieri. Atti XIII Convegno del Gruppo per l'Ecologia di Base "G. Gadio", Venezia, 25-27 maggio 1996. Suppl. Boll. Museo civico Storia Naturale di Venezia 49 (1998): 39-105.

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. Italian interpretation manual of the 92/43/EEC directive habitats. Società Botanica Italiana. Ministero dell'Ambiente e della tutela del territorio e del mare, D.P.N., Available at http://vnr.unipg.it/habitat/.

Biondi E., Blasi C., Allegrezza M., Anzellotti I., Azzella M. M., Carli E., Casavecchia S., Copiz R., Del Vico E., Facioni L., Galdenzi D., Gasparri R., Lasen C., Pesaresi S., Poldini L., Sburlino G., Taffetani F., Vagge I., Zitti S. & Zivkovic L., 2014. Plant communities of Italy: The Vegetation Prodrome. Plant Biosystems 148(4): 728-814.

Braun-Blanquet J., 1932. Plant sociology. Mc Graw-Hill Book Comp. New York and London.

Buffa G. & Del Vecchio S., 2016. 2130 *Dune costiere fisse a vegetazione erbacea (dune grigie). In: Angelini P., Casella L., Grignetti A., Genovesi P. (Eds.), Manuali per il monitoraggio di specie e habitat di interesse comunitario (Direttiva 92/43/CEE) in Italia: habitat. ISPRA.

Buffa G., Fantinato E. & Pizzo L., 2012. Effects of disturbance on sandy coastal ecosystems of N-Adriatic coasts (Italy). In Lameed G.A. (Ed.), Biodiversity Enrichment in a Diverse World: 339-372. InTech, DOI: 10.5772/48473. (available online at: http://www.intechopen.com/books/biodiversity-enrichment-in-a-diverse-world/effects-of-disturbance-on-sandy-coastal-ecosystems-of-n-adriatic-coasts-italy-).

Buffa G., Filesi L., Gamper U. & Sburlino G., 2007. Qualità e grado di conservazione del paesaggio vegetale del litorale sabbioso del Veneto (Italia settentrionale). Fitosociologia 44: 49-58.

Buffa G., Mion D., Gamper U., Ghirelli L. & Sburlino G., 2005. Valutazione della qualità e dello stato di conservazione delgi ambienti litoranei: l'esempio del SIC "Penisola del Cavallino: biotopi litoranei" (Venezia, NE-Italia). Fitosociologia 42: 3-13.

Buffa G. & Villani M., 2012. Are the ancient forests of the Eastern Po Plain large enough for a long term conservation of herbaceous nemoral species? Plant Biosystems 146(4): 970-984.

Carboni M., Thuiller W., Izzi F. & Acosta A., 2010. Disentangling the relative effects of environmental versus human factors on the abundance of native and alien plant species in Mediterranean sandy shores. Diversity and Distributions 16: 537-546.

Ciccarelli D., 2014. Mediterranean coastal sand dune vegetation: influence of natural and anthropogenic factors. Environmental Management 54(2): 194-204.

Ciccarelli D., Pinna M.S., Alquini F., Cogoni D., Ruocco M., Bacchetta G., Sarti G. & Fenu G., 2017. Development of a coastal dune vulnerability index for Mediterranean ecosystems: A useful tool for coastal managers? Estuarine Coastal and Shelf Science 187: 84-95.

Cole D.N., 1995. Experimental trampling of vegetation. 2. Predictors of resistance and resilience. Journal of Applied Ecology 32: 215-224 .

Conti F., Abbate G., Alessandrini A. & Blasi C., 2005. An annotated checklist of the Italian vascular flora. Palombi Editori, Roma.

Conti F., Alessandrini A., Bacchetta G., Banfi E., Barberis G., Bartolucci F., Bernardo L., Bonacquisti S., Bouvet D., Bovio M., Brusa G., Del Guacchio E., Foggi B., Frattini S., Galasso G., Gallo L., Gangale C., Gottschlich G., Grünanger P., Gubellini L., Iiriti G., Lucarini L., Marchetti D., Moraldo B., Peruzzi L., Poldini L., Prosser F., Raffaelli M., Santangelo A., Scassellati E., Scortegagna S., Selvi F., Soldano A., Tinti D., Ubaldi D., Uzunov D. & Vidali M., 2007. Integrazione della checklist della flora vascolare italiana. Natura Vicentina 10: 5-74. Vicenza.

Cornelissen J.H.C., Lavorel S., Garnier E., Diaz S., Buchmann N., Gurvich D.E., Reich P.B., Ter Steege H., Morgan H.D., Van Der Heijden M.G.A., Pausas J.G. & Poorter H., 2003. A hand book of protocols for standardised and easy measurement of plant functional traits worldwide. Australian Journal of Botany 51: 335-380.

Del Vecchio S., Giovi E., Izzi C.F., Abbate G. & Acosta A.T.R., 2012. Malcolmia littorea: The isolated Italian population in the European context. Journal for Nature Conservation 20: 357-363.

Del Vecchio S., Marba N., Acosts A., Vignolo C. & Traveset A., 2013a. Effects of *Posidonia oceanica* Beach-Cast on Germination, Growth and Nutrient Uptake of Coastal Dune Plants. Plos One 8(7): e70607.

Del Vecchio S., Acosta A. & Stanisci A., 2013b. The impact of *Acacia saligna* invasion on Italian coastal dune EC habitats. Comptes Rendus Biologies 336: 364-369.

Del Vecchio S., Pizzo L. & Buffa G., 2015. The response of plant community diversity to alien invasion: evidence from a sand dune time series. Biodiversity and Conservation 24: 371-392.

Del Vecchio S., Slaviero A., Fantinato E. & Buffa G., 2016. The use of plant community attributes to detect habitat quality in coastal environments. AoB PLANTS 8: plw040.

Dengler J., Chytrý M. & Ewald J., 2008. Phytosociology. In: Jørgensen S.E., Fath B.D. (Eds.), Encyclopedia of ecology: 2767-2779. Elsevier, Oxford, UK.

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

EEA, 1999. State and pressures of the marine and coastal Mediterranean environment. In: Izzo G., Moretti S., (Eds.), Environmental Assessment Series No. 5. Copenhagen.

EEA, 2008. Article 17 Technical Report 2001-2006. Brussels, Belgium: European Environment Agency.

Fantinato E., Del Vecchio S., Slaviero A., Conti L., Acosta A.T.R. & Buffa G., 2016. Does flowering synchrony contribute to the sustainment of dry grassland biodiversity? Flora 222: 96-103.

Farris E., Pisanu S., Ceccherelli G. & Filigheddu R., 2013. Human trampling effects on Mediterranean coastal dune plants. Plant Biosystems 147: 1043-1051.

Fenu G., Carboni M., Acosta A. & Bacchetta G., 2013. Environmental factors influencing coastal vegetation pattern: new insights from the Mediterranean basin. Folia Geobot. 48:493-508.

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. J. Veg. Sci. 19(4): 493-502.

Friedman G.M. & Johnson K., 1982. Exercises in Sedimentology. Wiley, New York.

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

Gargano D., Fenu G., Medagli P., Sciandrello S. & Bernardo L., 2007. The status of *Sarcopoterium spinosum* (*Rosaceae*) at the western periphery of its range: Ecological constraints lead to conservation concerns. Israel Journal of Plant Sciences 55: 1-13.

Géhu J-M., Scoppola A., Caniglia G., Marchiori S. & Géhu-Franck J., 1984. Les systèmes végétaux de la côte nord-adriatique italienne, leur originalité à l'échelle européenne. Doc. Phytosoc. 8: 485-558.

Gigante D., Attorre F., Venanzoni R., Acosta A., Agrillo E., Aleffi M., *et al*., 2016a. A methodological protocol for Annex I Habitats monitoring: the contribution of Vegetation science. Plant Sociology 53: 77-78.

Gigante D., Foggi B., Venanzoni R., Viciani D. & Buffa G., 2016b. Habitats on the grid: The spatial dimension does matter for red-listing. Journal for Nature Conservation 32: 1-9.

Hennekens S.M. & Schaminée J.H.J., 2001. TURBOVEG, a comprehensive data base management system for vegetation data. J. Veg. Sci 12: 589-591.

Hoffmann A. & Zeller U., 2005. Influence of variations in land use intensity on species diversity and abundance of small mammals in the Nama Karoo, Namibia. Belgian Journal of Zoology 135: 91-96.

Houston J., 2008. Management of Natura 2000 habitats. 2130* Fixed coastal dunes with herbaceous vegetation ('grey dunes') European Commission. Technical Report 2008 04/24.

Incerti G., Bonanomi G., Giannino F., Carteni F., Spaccini R., Mazzei P., Piccolo A. & Mazzoleni S., 2017. OMDY: a new model of organic matter decomposition based on biomolecular content as assessed by C-13-CPMAS-NMR. Plant and Soil 411: 377-394.

Isermann M., 2008. Expansion of Rosa rugosa and Hippophae rhamnoides in coastal grey dunes: Effects at different spatial scales. Flora 203: 273-280.

Isermann M., 2011. Patterns in Species Diversity during Succession of Coastal Dunes. Journal of Coastal Research 27: 661-671.

Janssen J., Rodwell J., Garcia Criado M., Gubbay S., Haynes T., Nieto A., *et al*., 2016. European Red List of Habitats. 1.

Terrestrial & freshwater habitats. European Commission, Brussels.
Jones M.L.M., Sowerby A., Williams D.L. & Jones R.E., 2008. Factors controlling soil development in sand dunes: evidence from a coastal dune soil chronosequence. Plant and Soil 307: 219-234.
Keith D.A., Rodriguez J.P., Rodriguez-Clark K.M., Nicholson E., Aapala K., Alonso A. *et al*., 2013. Scientific Foundations for an IUCN Red List of Ecosystems. PLoS ONE 8: 1-25.
Kerbiriou C., Leviol I., Jiguet F. & Julliard R., 2008. The impact of human frequentation on coastal vegetation in a biosphere reserve. J. Environ. Manag. 88: 715-728.
Kleijn D., Kohler F., Baldi A., Batary P., Concepcion E.D., Clough Y., Díaz M., Gabriel D., Holzschuh A., Knop E., Kovács A., Marshall E.J., Tscharntke T. & Verhulst J., 2009. On the relationship between farmland biodiversity and land-use intensity in Europe. Proceedings of the Royal Society B-Biological Sciences 276: 903-909 .
Krumbein W.C., 1938. Size frequency distribution of sediments and the normal phi curve. Journal of Sedimentary Petrology 8: 65-77.
Lorenzoni G., 1983. Il paesaggio vegetale nord Adriatico. Atti Mus. civ. St. nat. Trieste 35: 1-34.
Malavasi M., Carboni M., Cutini M., Carranza M.L. & Acosta A.T.R., 2014. Landscape fragmentation, land-use legacy and propagule pressure promote plant invasion on coastal dunes: a patch-based approach. Landscape Ecology 29 (9): 1541-1550.
Marcello A., 1960. Lacuna floristica del Veneziano e sue condizioni bioclimatiche. Mem. Biogeogr. Adr 5: 51-118.
Maun M.A., 2009. The Biology of Coastal Sand Dunes. Oxford University Press.
Mazzoleni S., Bonanomi G., Giannino F., Rietkerk M., Dekker S.C. & Zucconi F., 2007. Is plant biodiversity driven by decomposition processes? An emerging new theory on plant diversity. Community Ecology 8: 103-113.
Msuha M.J., Carbone C., Pettorelli N. & Durant S.M., 2012. Conserving biodiversity in a changing world: land use change and species richness in northern Tanzania. Biodiversity and Conservation 21: 2747- 2759.
Pérez-Harguindeguy N., Díaz S., Garnier E., Lavorel S., Poorter H., Jaureguiberry P., Bret-Harte M.S., Cornwell W.K., Craine J.M. *et al*., 2013. New handbook for standardised measurement of plant functional traits worldwide. Australian Journal of Botany 61: 167-234.
Pierce S., Negreiros D., Cerabolini B.E.L., Kattge J., Díaz S., Kleyer M., Shipley B., Wright S.J., Soudzilovskaia N.A. *et al*., 2017. A global method for calculating plant CSR ecological strategies applied across biomes worldwide. Functional Ecology 31 (2): 444-457.
Poldini L., Sburlino G., Buffa G., & Vidali M., 2011. Correlations among biodiversity, biomass and other plant community parameters using the phytosociological approach: A case study from the south-eastern Alps. Plant Biosystems 145 (1): 131-140.
Prisco I., Stanisci A. & Acosta A.T.R., 2016. Mediterranean dunes on the go: Evidence from a short term study on coastal herbaceous vegetation. Estuarine Coastal and Shelf Science 182: 40-46.
Reynoldson T.B. & Wright J.F., 2000. The Reference Condition: Problems and Solutions. In: Wright J.F., Sutcliffe D.W., Furse M.T. (Eds.), Assessing the Biological Quality of Fresh Waters. Freshwater Biological Association: 293-303. RIVPACS and Other Techniques. Ambleside, UK.
Provoost S., Ampe C., Bonte D., Cosyns E. & Hoffmann M., 2004. Ecology, management and monitoring of grey dunes in Flanders. Journal of Coastal Conservation 10: 33-42.
Riksen M., Goossens D., Huiskes H.P.J., Krol J. & Slim P.A., 2016. Constructing notches in foredunes: Effect on sediment dynamics in the dune hinterland. Geomorphology 253: 340-352.
Rivas-Martínez S. & Peñas A., 1999. Bioclimatology of the Iberian Peninsula. Itinera Geobotanica 13: 41-47.
Rivas-Martínez S, Rivas-Sáenz S., Peñas A. & Díaz T.E., 2004. Bioclimatic Map of Europe. Cartographic Service, University of León, León, Spain.
Santoro R., Jucker T., Prisco I., Carboni M., Battisti C. & Acosta A.T.R., 2012. Effects of trampling limitation on coastal dune plant communities. Environ Manag 49: 534-542.
Sburlino G., Buffa G., Filesi L. & Gamper U., 2008. Phytocoenotic originality of the N-Adriatic coastal sand dunes (Northern Italy) in the European context: The *Stipa veneta*-rich communities. Plant Biosystems 142: 533-539.
Sburlino G., Buffa G., Filesi L., Gamper U. & Ghirelli L., 2013. Phytocoenotic diversity of the N-Adriatic coastal sand dunes - The herbaceous communities of the fixed dunes and the vegetation of the interdunal wetlands. Plant Sociology 50: 57-77.
Schulte E.E. & Hopkins B.G., 1996. Estimation of organic matter by weight loss-on-ignition. In: Magdoff F.R., Tabatabai M.A., Hanlon E.A. (Eds.), Soil Organic Matter: Analysis and Interpretation: 21-31. SSSA Spec. Pub. No. 46. SSSA, Madison.
Slaviero A., Del Vecchio S., Pierce S., Fantinato E. & Buffa G., 2016. Plant community attributes affect dry grassland orchid establishment. Plant Ecology 217: 1533-1543.
Smith T.B., Kark S., Schneider C.J., Wayne R.K. & Moritz C., 2001. Biodiversity hotspots and beyond: the need for preserving environmental transitions. Trends in Ecology & Evolution 16: 431-431.
Tzonev R., Dimitrov M. & Roussakova V., 2005. Dune vegetation of the Bulgarian Balk sea coast. Hacquatia 4: 7-32.
van der Maarel E., 2003. Some remarks on the functions of European coastal ecosystems. Phytocoenologia 33: 187-202.
Vandewalle M., de Bello F., Berg M.P., Bolger T., Doledec S., Dubs F., Feld C.K., Harrington R., Harrison P.A. *et al*., 2010. Functional traits as indicators of biodiversity response to land use changes across ecosystems and organisms. Biodiversity and Conservation 19: 2921-2947.
Verhulst J., Baldi A. & Kleijn D., 2004. Relationship between land-use intensity and species richness and abundance of birds in Hungary. Agriculture Ecosystems Environment 104: 465-473 .
Zunica M., 1971. Evoluzione dei litorali dal Tagliamento all'Adige con particolare riguardo ai lidi della Laguna di Venezia (Relazione definitiva). Min. Lav. Pubbl. Com. St. Provv. Venezia, Padova.