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Biologia **71**/8: 865—874, 2016
Section Botany
DOI: 10.1515/biolog-2016-0111

Human impact on sandy beach vegetation along the southeastern Adriatic coast

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Abstract: We compared the zonation of vegetation and connectivity of coastal plant communities between two distinct areas, one in Montenegro and another in Albania, that differ in terms of human impact, mainly through tourism activities. Transect plots were used to gather data about plant cover and communities, their zonation and connectivity. For description of communities multivariate methods were used and for distribution zonation we used gamma connectivity and richness of boundaries. We found that the transects of vegetation zonation from Albania, with better preserved sites, were richer in the number of boundaries, with more varied combinations of boundaries and the pattern of zonation was also more diverse. On the other hand, there were two plant communities found only in Montenegro. The more impacted transects on the disturbed beaches from Montenegro were also more unidirectional from sea to hinterland but with less ideal zonation. Plant communities from Albania were distributed more straightforwardly but contacts between them were in both directions. The less disturbed beach had zonation very similar to potential vegetation, while plant communities of the touristic beach were fragmented or even substituted by replacement communities. Coastal dune systems in Albania are still well preserved, therefore monitoring and protection measures are recommended.

Key words: coastal vegetation; gamma biodiversity; sand dunes; Albania; Montenegro.

Introduction

Sand dunes are impacted by various disturbances, both natural and human. Natural disturbance has always been a normal part of dune building processes. Natural sources of disturbance include: ongoing sand abrasion, salt spray, burial by sand, erosion, accretion, tide level, wave attack, wind blasting and desiccation (Oosting & Billings 1942; Moreno-Casasola 1986; Maun 2009) and are required in these dynamic habitats to preserve its natural zonation. The most important factors for coastal vegetation zonation are wind and soil properties, the latter being more important for Mediterranean sand dunes (Tsoar 2005; Angiolini et al. 2013; Fenu et al. 2013). In populated areas, natural processes are interrupted by various human activities, such as grazing, fires, plantations and urbanization. Coastal tourism with its disturbances (bathing facilities, trampling, mechanical cleaning, swimming and surfing, and erosion) is considered to be another major conservation problem in coastal areas (Davenport & Davenport 2006; Feola et al. 2011; Attorre et al. 2013; Farris et al. 2013).

Coastal areas, and sandy beaches in particular, are among highly endangered habitats (Martínez et al. 2004; Defeo et al. 2009) with an estimated 85% of them in Europe being under threat (Heslenfeld et al. 2004). These ecosystems are very valuable for conservation, since they represent a mosaic of plant communities with high biodiversity on a very limited area, despite its wide distribution. Also they are threatened by several factors mentioned previously. Many sand dune ecosystems are therefore listed in habitats of European interest in Annex I of the Habitat Directive (Heslenfeld et al. 2004; Biondi et al. 2012). The following habitat types appear on the beach and mobile dunes and are included in the list: 'Annual vegetation of drift lines' (habitat code EC 1210), 'Embryonic shifting dunes' (habitat code EC 2110) and 'Shifting dunes along the shoreline with *Am-*

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mophila arenaria' (habitat code EC 2120) (Anonymous 1992).

Sandy beaches also provide numerous ecosystem services, such as raw materials, coastal protection, erosion control, water catchment and purification, maintenance of wildlife, carbon sequestration, tourism, recreation, education and research (van der Maarel 2003; Everard et al. 2010; Barbier et al. 2011). Then, many ecosystem services are also threatened by human use, species invasion and climate change (Lotze et al. 2006; Worm et al. 2006; Mendoza-González et al. 2013; Perrino et al. 2013). In particular, overuse, misuse and poor management of certain services (e.g., tourism) can impact on the benefits of sand dunes, so careful management, planning and conservation measures are needed.

Coastal dunes are a complex ecosystem at the border between the sea and the mainland. This is a constantly changing environment, with distinct degrees of stabilisation depending on the topography, disturbance and distance to the sea and with a mosaic of habitats (van der Maarel 2003; Moreno-Casasola 2009). Plant communities on sand dunes have specific ecological requirements that determine their position along the perpendicular gradient from sea to inland (Frederiksen et al. 2006; Carboni et al. 2009). Without erosion and human disturbance, zonation is very fixed and a regular sequence of plant communities on the gradient can be observed (Attorre et al. 2013). The vegetation of beaches and mobile dunes is considered azonal (it represents the edaphic climax), while inner, more stable dunes host plant communities that are more related to local climatic conditions (Buffa et al. 2012).

The studied beaches differ in terms of human impact and they can be distinguished as one (Velika plaža) with high and the other (Gosa) with low human pressure from tourism (visitors, built facilities, paths). Historic differences are also apparent, Montenegro but not Albania having a rich history of tourism. The aim of this study was to compare differences in the vegetation of sand dunes between these two south Adriatic coastal areas with very different histories of human impact, i.e., predominantly tourism, and its impact on zonation and the connectivity of plant communities.

Methods

Study area

Sand dunes have a global distribution and are widely distributed throughout the Mediterranean, while along the Adriatic coast they are more common on the western (Italian) coast, and less so in Croatia and Montenegro, where rocky coast prevails, and again very frequent along the northern shores of Albania (Horvat et al. 1974; Doody 2001; Šilc et al. 2016).

The study area (Fig. 1) comprised two sandy beaches along the south Adriatic coast (Velika plaža – Long Beach near Ulcinj in Montenegro and Gosa in Albania), with very distinct histories of human impact. The distance between the beaches is 100 km. Both beaches are known for their great length but also touristic attractiveness. Velika plaža in Ulcinj (Montenegro) is approximately 12 km long and 100 m wide. It is the longest beach on the Adriatic coast, which, together with its hinterland, forms a unique complex of sandy dunes. In 2007 (Official Gazette of Montenegro 2007), 500 ha of Velika plaža were recognized as a monument of nature. The area is still used as a tourist beach, with sports and recreational activities, but without the possibility of construction of access roads and infrastructure.

Due to the isolation of Albania in the last century, Gosa (near Spille, Albania) is a well preserved sandy beach, although tourism is rapidly developing. The beach is approximately 10 km long and 100 m wide. The sand dunes and estuary are listed as habitats of European conservation interest (Bego et al. 2013) and are on the edge of Karavasta National Park.

Climate and vegetation

According to the Köppen-Geiger system, the climates of both areas are classified as Csa type – Mediterranean climate with hot summers. Data are collected for period 1982–2012 (Climate-Data.org). The mean annual temperature in Ulcinj (Montenegro) is 15.5 °C, while the mean precipitation is 1258 mm. The warmest months are July and August (24.3 °C) and the coldest are January and February (6.8 °C). The climate is warm and temperate in Spille (Albania). The average annual temperature is 16 °C. About 1017 mm of precipitation falls annually. The warmest month of the year is August, with an average temperature of 24 °C. In January, the average temperature is 8.3 °C. The prevailing winds at Velika plaža are eastern (NE, E and ENE), while in Gosa they are western (NW, W, SW).

Under natural conditions, the sand dunes on both beaches are low, narrow, simple in structure, with only one ridge, and the vegetation zonation follows an ecological sea–inland gradient. The Velika plaža beach is affected by erosion, while Gosa beach in Albania was accreting in the first part of last century, but has been eroding since the 1990s.

The vegetation of Velika Plaža area is very complex. According to Caković et al. (2014), the following NATURA 2000 habitats have been recorded (numbers refer to Commission of the European Communities (2013) and an asterisk (*) indicates a priority habitat): 1210 Annual vegetation of drift lines, 1410 Mediterranean salt meadows (*Juncetalia maritimi*), 2110 Embryonic shifting dune, 2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes), 2190 Humid dune slack, 2220 Dunes with *Euphorbia terracina*, 2240 *Brachypodietalia* dune grasslands with annuals, 2270* Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*, 3170* Mediterranean temporary ponds, and 92A0 *Salix alba* and *Populus alba* galleries.

The following NATURA 2000 habitats have been recorded in the Gosa area (Mullaj & Ibraliu not published): 1210 Annual vegetation of drift lines, 1410 Mediterranean salt meadows (*Juncetalia maritimi*), 2110 Embryonic shifting dune, 2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes), 2250* Coastal dunes with *Juniperus* spp., 2270* Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*, and 92A0 *Salix alba* and *Populus alba* galleries.

Human impact

The studied beaches differ in terms of human impact: Velika plaža with high and Gosa with low human pressure.

Velika plaža makes the municipality of Ulcinj one of the most popular tourist destinations in Montenegro. According to the official statistics for the municipality of Ulcinj, around 1 million overnight stays were recorded during the 2012 and 2013 tourist seasons. Velika plaža is heavily impacted by

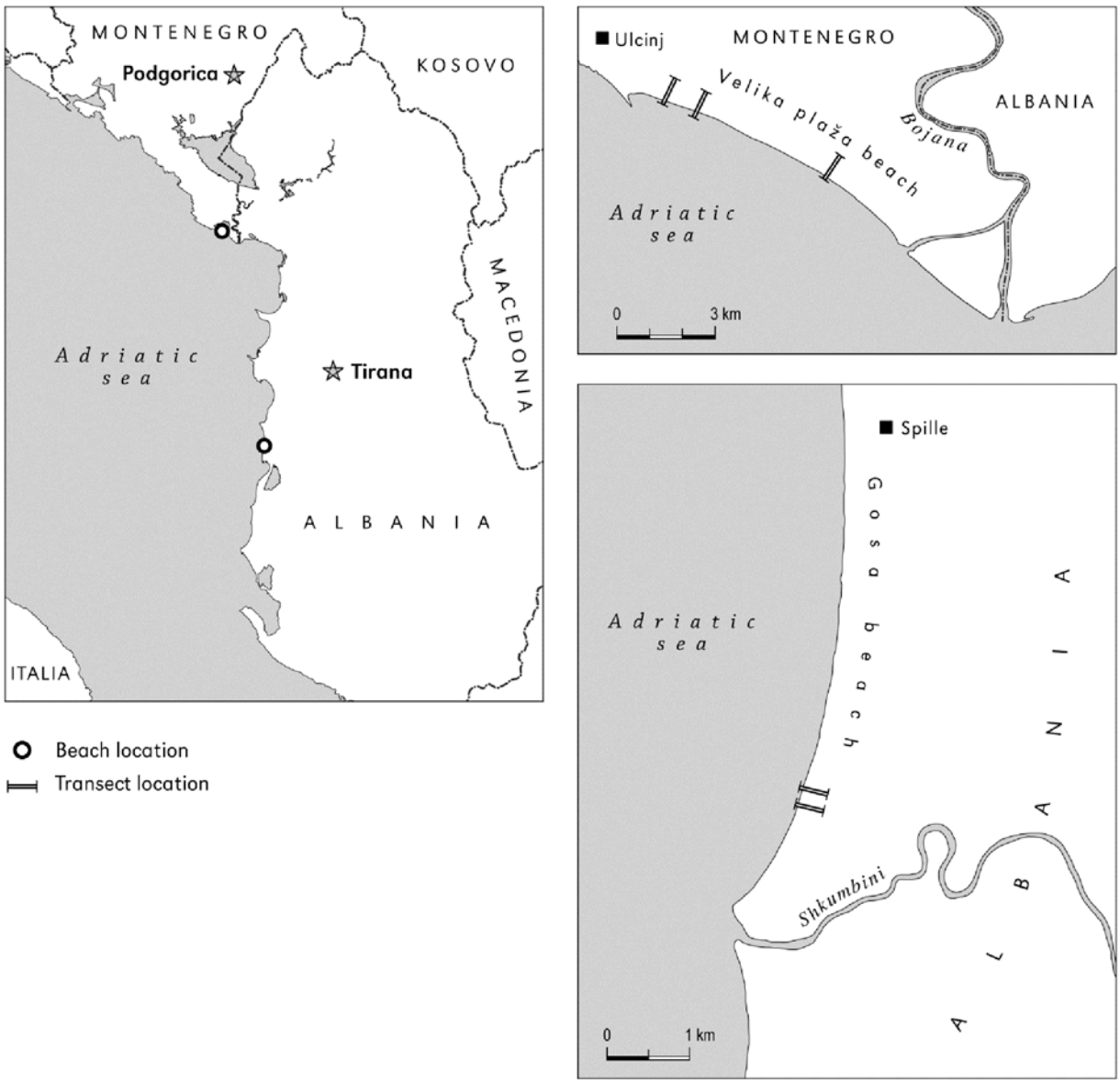

Fig. 1. Study area. The location of both sand beaches is shown by circles and, on the right hand figures, locations of transects are indicated as lines.

tourism (large number of visitors, built permanent tourist facilities such as restaurants and showers) but illegal dumping, illegal and non-planned sand exploitation, urbanization and a non-sustainable approach to touristic development are also recognized as serious problems (Petrović & Karaman 2009). In order to prevent waste accumulation during the summer season, contractors are obliged to clean their own part of the beach daily and to collect waste. The beach is cleaned manually and also mechanically by a municipal company, with special machinery with rakes.The part of the beach that is not leased is also not cleaned, except during the pre-season (Kollari pers. comm., September 2014).

The Gosa area is less impacted but tourism is developing. Albania was sealed off for decades by the communist regime, the coast having served as a military zone with limited human disturbance (Simeoni et al. 1997). The fast and unregulated economic development of Albania in the last two decades has increased human impact (Fraschetti et al. 2011) and many tourist facilities are being built on and near the beaches. This trend holds for the entire coast of Albania (Velipoje, Dhermi, Ksamil), including Gosa. Temporary tourist facilities have been built directly on the beach, while the land behind the dunes is planned for further construction. The beach is only partially manually cleaned, but machines are used to loosen the soil. There is a growing number of visitors in Albania: 3 million in 2014, compared to 500,000 in 2004 (World Travel & Tourism Council 2014). In terms of growth of contribution of tourism to GDP, Montenegro ranks first in the world, while Albania is 64th (World Travel & Tourism Council 2014).

Vegetation sampling

Vegetation was sampled in June 2013 using the transect method. A linear zonation of plant communities was assumed (Doing 1985; Acosta et al. 2000) in the sense of potential natural vegetation (PNV) when plant communities are ordered without human impact. The natural sequence of communities follows from the sea-shore to the foredune slacks. Five belt transects were set perpendicular to the

Table 1. Habitat, dominant life forms (percentage number of species in addition to prevailing therophytic life form) and proportion of alien species of the seven community types.

	Plant community	Syntaxonomy	Habitat	Natura habitat type	Life form	Proportion of alien species
1	*Sporobolus pungens-Xanthium italicum*	*Cakilo-Xanthietum strumarii*	deposition zone	1210	geophytes	10.7
2	*Polygonum maritimum-Euphorbia paralias*	*Euphorbia paralias* comm.	embryo dune	2110	chamaephytes	11.7
3	*Echinophora spinosa-Elymus juncea*	*Euphorbio paraliae-Agropyretum junceiformis sporoboletosum*	embryo dune	2110	hemicryptophytes	9.3
4	*Pancratium maritimum-Oenothera biennis*	*Euphorbio paraliae-Agropyretum junceiformis disturbed variant*	foredune	2110	hemicryptophytes	12.9
5	*Pseudorlaya pumila-Cyperus capitatus*	*Euphorbio paraliae-Agropyretum junceiformis typicum*	foredune	2110	geophytes	13.7
6	*Trifolium lappaceum-Parapholis incurva*	*Holoschoenetum romani*	dune depression	1410, 2190	hemicryptophytes	0
7	*Euphorbia terracina-Petrorhagia saxifraga*	*Medicagini marinae-Ammophiletum australis*	stabile (white) dune	2120	hemicryptophytes	6.3

shore: three in Velika plaža (Montenegro) and two in Gosa (Albania). The transects in Velika plaža were 1 km apart while in Gosa 250 m. Distances differ to obtain comparable transects with various impact. The sampling method by contiguous quadrats laid out next to each other along a transect line in the form of a belt transect was performed (Acosta et al. 2000; Kent 2012) and the size of the sampling plot (2 × 2 m) was selected as in similar studies of these vegetation types (Carboni et al. 2009; Fenu et al. 2012). The quadrats were recorded starting from the plots with the first colonizing plants towards the planted forest behind the dunes (this was the case in both studied areas) and herbaceous plant communities were sampled. Transects were between 76 and 142 m long, depending on beach width, dune morphology and also on human impact. Distances from the sea of the first plot varied from 20 to 82 m. The obtained results represent a matrix of 296 plots × 96 species of the five transects. The cover of each plant species was estimated by the Braun-Blanquet (1964) scale. Plants were determined following Pignatti (1982) and Tutin et al. (1964–80), while nomenclature is according to EURO+MED (2006). Phytosociological nomenclature is according to Biondi (2007).

Statistical analysis

Species by plot matrix from five transects was used in the statistical analyses. Braun-Blanquet cover values were transformed to percentages and square-rooted. To obtain the plant community types, we performed classification (cluster) analysis of transect plots in PC-ORD5 (McCune & Grace 2002), and the Ward method with the relative Euclidean distance measure was used. OptimClass1 analysis (Tichý et al. 2010) was performed to obtain the optimum number of clusters to represent distinct plant communities along the transect. Plant communities were described with two characteristic species: first with the highest fidelity (phi value) (Chytrý et al. 2002) and second by dominance.

Detrended correspondence analysis (DCA) was used to ordinate sample plots along two axes and to present the floristic similarity between plant communities. This approach adds a series of arrows or so called spiders, which connect each sample with the centroid of the particular groups previously defined (e.g., by means of cluster analysis). DCA was used, since the gradient was longer than 4.0 (Lepš & Šmilauer 2003). DCA was performed using the vegan package (Oksanen et al. 2008) in R (R Development Core Team 2012).

We used two indexes for evaluation of the distribution zonation pattern of plant communities: gamma connectivity (Forman & Godron 1986) and richness of boundaries (Rescia et al. 1997). The first index takes into account the position of the plot (plant community) relative to the other plots in the transect, while the second considers the number of different boundaries between plots (communities) along the transect. The boundary is the contact between two different plant communities. For further details on the analysis, see Acosta et al. (2000).

Results

Seven floristically distinct plant communities (Table 1, Fig. 2) were recognized by classification of transect plots and the Optimclass method (optimum 7 clusters). The results of cluster analysis at a higher level indicate division into two groups of communities: I – annual coenoses and embryo dunes (communities 1–3), and II – mobile and more fixed dunes (communities 4–7). The first group of communities has developed closer to the sea, while the second is found on the top of the dunes. Community 1 (*Sporobolus pungens-Xanthium italicum*) has developed in the most hostile environment, nearest to the sea, with higher influence from wind, salt spray and sand mobility. It is dominated by *Xanthium orientale* ssp. *italicum*. It is usually bounded by communities 2 and 3, dominated by *Elytrigia juncea* but distinguished by the presence of *Euphorbia paralias* and *Echinophora spinosa*. Communities 4 and 5 are dominated by *Cyperus capitatus* but the former at lower sites is differentiated by the presence of *Pancratium maritimum* and the second, in higher, more stable places, by the presence of *Pseudorlaya pumila*. Communities 5 and 6 were only found in Velika plaža, corresponding to

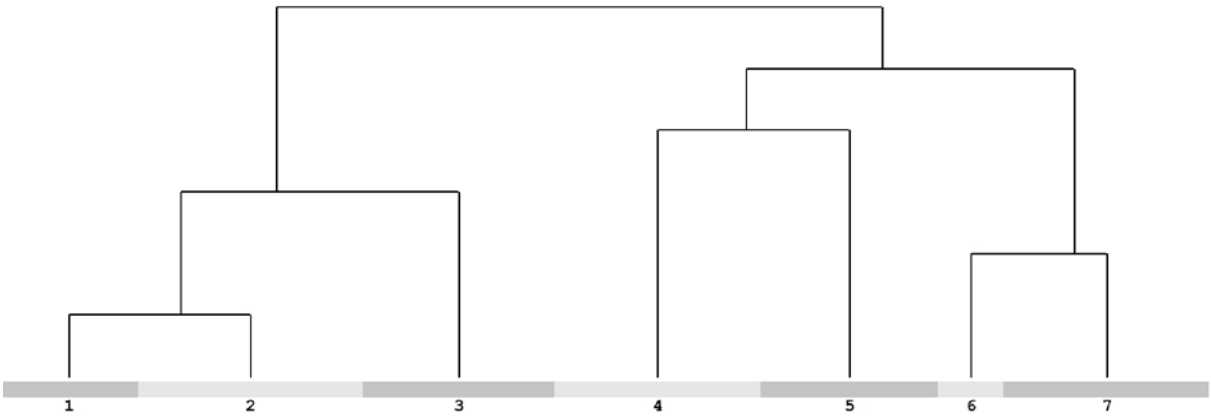

Fig. 2. Cluster analysis dendrogram. For the sake of simplicity, the bottom part is not shown. Numbers refer to plant communities. 1. *Sporobolus pungens-Xanthium italicum*, 2. *Polygonum maritimum-Euphorbia paralias*, 3. *Echinophora spinosa-Elymus juncea*, 4. *Pancratium maritimum-Oenothera biennis*, 5. *Pseudorlaya pumila-Cyperus capitatus*, 6. *Trifolium lappaceum-Parapholis incurva*, 7. *Euphorbia terracina-Petrorhagia saxifraga*.

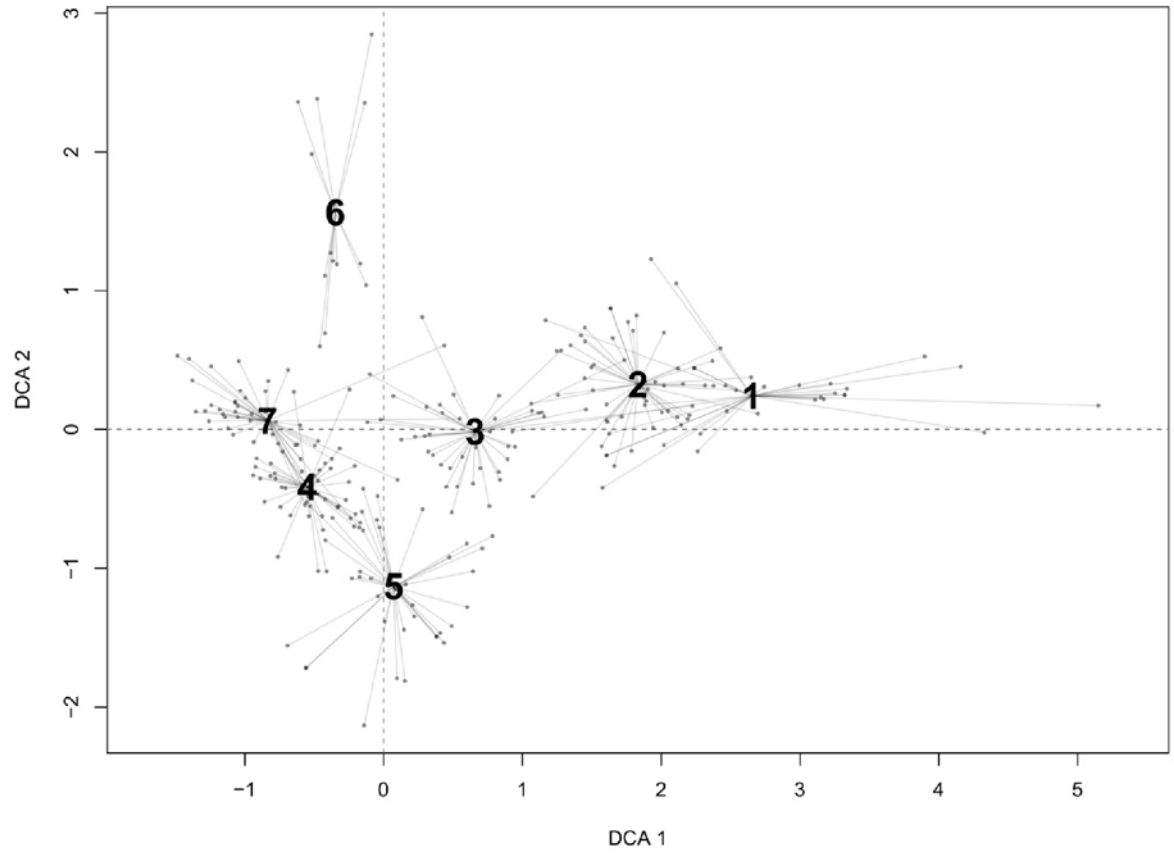

Fig. 3. DCA ordination of transect plots presented as a spiderplot. The number indicates the centroid of each class (plant community) and class members are connected to it by lines.

fore dune with the presence of *Parapholis incurva* and *Cyperus capitatus* and humid depressions dominated by *Trifolium lappaceum*. Community 7 thrives on the most stable dunes and is dominated by *Lagurus ovatus* and *Onobrychis caput-galli*.

Altogether 8 alien plant species were present on sand dune systems, representing 8.5% of plant species. The highest proportion of aliens was found on fore dunes, while neophytes were not present in wet slacks (Table 1). There was no difference between the two dune systems, in Velika plaža and Gosa, in terms of alien plant species.

DCA ordination (Fig. 3) revealed the floristic similarity of plant communities and partly also their zonation. The distribution of the various communities shows clear floristic trends that follow the vegetation zonation. Pioneer communities on beach and embryo dunes (1, 2 and 3) are in the right part of the diagram and zonation to more developed communities on most stable dunes is visible along the first axis (DCA 1). Communities from

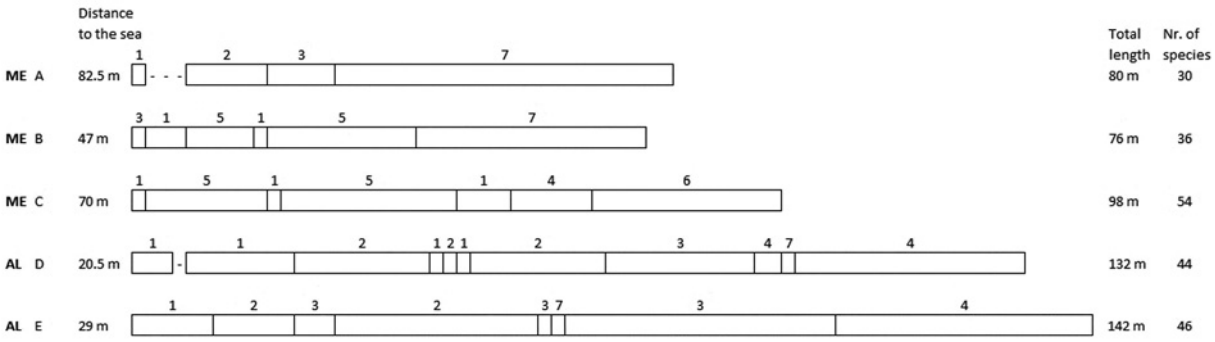

Fig. 4. Spatial pattern of plant communities along the sampled transects. The numbers indicate presence of particular community type, letters to locations and dot lines represent plots with naked sand. ME-Montenegro, AL-Albania.

Table 2. Types and number of boundaries between plant communities in the particular transects, ordered in the direction from the sea to the lagoon, and connectivity indexes in both directions, from the sea to the lagoon and vice versa.

	Types of boundaries sea-lagoon						Number of boundaries		Gamma connectivity index		Whittaker
							sea-lagoon	lagoon-sea	sea-lagoon	lagoon-sea	beta diversity
Velika plaža, Transect 1	1/2	2/3	3/7				n=3	n=3	0.5	0	1.82
Velika plaža, Transect 2	3/1	1/5	5/1	5/7			n=3	n=4	0.5	0.2	3.08
Velika plaža, Transect 3	1/5	5/1	1/4	4/6			n=3	n=4	0.3	0.3	4.56
Gosa, Transect 4	1/2	2/1	2/3	3/4	4/7	7/4	n=4	n=6	0.4	0.2	5.19
Gosa, Transect 5	1/2	2/3	3/2	3/7	7/3	3/4	n=4	n=6	0.4	0.2	4.70

Velika plaža (5 and 6) are distinguished along the second axis (DCA 2). Eigenvalues for the first four DCA axes are 0.526, 0.279, 0.249 and 0.167, respectively.

Transects from the two areas differed in the distance of the first recorded plot from the sea. In Gosa, transects started at 20 and 29 m from the sea, while in Velika plaža, the distances were 47, 70 and 82 m from the sea. Transects from Gosa have higher beta diversity indices compared to Velika plaža (Table 2) indicating larger variation in species composition. Differences in the spatial pattern between the two areas were found (Fig. 4). Transects at Velika plaža were shorter particularly at the first part, where an annual plant community (*Sporobolus pungens-Xanthium italicum*) is present.

There were 15 different boundaries between the plant communities of sand dunes. The pattern of zonation from Gosa was also more diverse (Fig. 4) due to the presence of a higher number and combination of boundaries and different beta diversity (Table 2).

An ideal zonation of plant communities comprises of 5 communities and they would follow a pattern from 1 to 7. Communities 5 and 6 are found only at Velika plaža. Their distinct floristic composition and position within the zonation is shown by DCA ordination (Fig. 3). In Gosa, a more stabilized community on foredune (5) and plant community of wet slacks (6) are not present, while community 4 occupies large portion of sand dune system.

The model of plant community distribution based on the graph theory (Fig. 5) shows pairwise relations between objects (plant community types). Transects from Velika plaža are more unidirectional (from sea to inland) but, on the other hand, also more diversified,

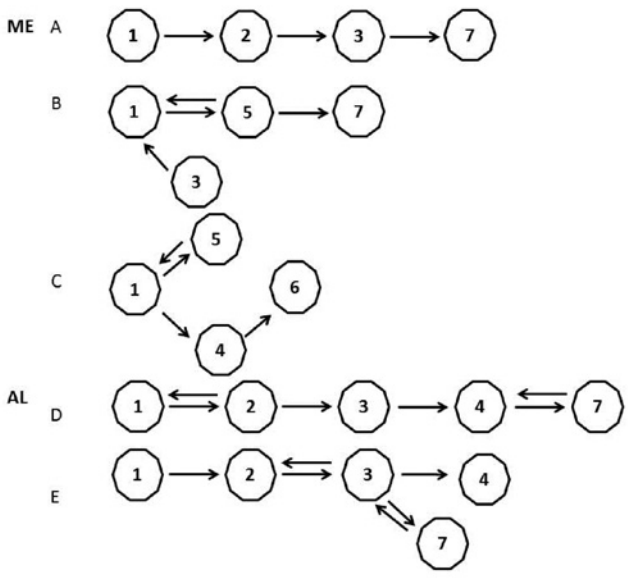

Fig. 5. Model of connectivity between plant communities present in the studied transects. Arrows indicate directions of the transect and boundaries. Nodes represent plant communities that are connected to each other and arrows indicate the direction from the sea or inland. Numbers refer to plant communities from cluster analysis. ME-Montenegro, AL-Albania.

with less ideal zonation. In contrast, plant communities from Gosa are distributed more straightforwardly but contacts between them are in both directions.

Discussion

According to Doing (1985) and Maun (2009), vegeta-

tion on sand dunes along sea coasts exhibits a zonation pattern extending from the beach to inland dunes. The zones are discrete (although sometimes boundaries may not be sharp) and occur in parallel series, with distinctly different species compositions and, in the absence of anthropogenic disturbance, such zonation is considered ideal. Concept of potential natural vegetation (PNV) refers to a plant community that would become established if all successional sequences were completed without human inference (Tüxen 1956; Acosta et al. 2006; Farris et al. 2010). Due to the still low level of human impact, zonation of plant communities in the Gosa area is very similar to the ideal PNV zonation (*Salsolo kali-Cakiletum maritimae, Echinophoro spinosae-Elymetum farcti, Echinophoro spinosae-Ammophiletum arundinaceae*), while at Velika plaža it is distinctly different from PNV, even in the transect that was set in the most preserved part of the sand system. The two remaining transects (Fig. 4, transects A and B, from Velika plaža) reflect strong anthropogenic pressure, which has caused changes in the sand micro topography and zonation of plant communities. Changes in dune morphology (elevation) alterate edaphic factors that reflect in changes of species composition (Mijović et al. 2012) and particularly zonation. A similar changes were found in Lazio (Italy), where complete zonation of plant communities was related to the distance from areas of urban development. Higher degree of alteration of the sequence of communities and more ruderal species were found in disturbed sites (Acosta et al. 2006). The two beaches differ in the number of plant communities, since two (5 and 6) are found only in Velika plaža. This could be related to the width of beach. However, the number of plant communities can be small despite a long transect if the ecological gradient changes slowly and the dune system is more homogenous. Disturbance is also very important in destabilizing a dune system (Biondi 2007) and this leads to substitution, alteration of sequence or even the disappearance of plant communities (Acosta et al. 2006). More frequent loops and backward jumps in the sequence, which indicate higher connectivity, are indicators of disturbance (Acosta et al. 2000) and similar pattern was observed in Albania.

The absence of vegetation on a wide part at the beginning of the transects (Fig. 4) in Velika plaža is mainly related to human impact (beach cleaning, trampling by vehicles) although natural erosion is also present. On Velika plaža, communities with *Cakile maritima* (community *Sporobolus pungens-Xanthium italicum*) occupy the very narrow first part of the beach. The *Cakile* zone usually forms elongated patches under natural conditions, while, with human disturbance, these long strips are fragmented into many small, regular patches (Malavasi et al. 2016) of a few square metres, with depleted species composition. Beach tourism and mechanical cleaning negatively influence the *Cakile* community (Attore et al. 2013). On Velika plaža, it can be confirmed that the first two factors (beach tourism and cleaning) have shortened the *Cakile* zone (classified into EU 1210 habitat type) compared to Gosa beach and that bathing establishments have been beneficial for *Cakile* (Aćić pers. comm.), while Attore et al. (2013) report it for *Elymus* community. Such facilities are not present at Gosa beach. Different results were obtained by Ciccarelli (2014), who found the factors (erosion, trampling and paths) most correlated with degradation and habitat loss (mostly of drift line and embryonic fore dunes) but that study was made in two protected areas. In our case, erosion is less expressed and we associate the differences in habitats with other factors. We can also confirm that the greatest differences in zonation are between high and low levels of human pressure, as has been reported for partially vegetated dunes and densely vegetated dunes (Malavasi et al. 2016).

In terms of connectivity between plant communities, a diversified graph with many forward–backward connections is an indicator of a disturbed ecosystem (Acosta et al. 2000). In ecology, high connectivity between elements (from landscapes to evolutionary processes) is considered to be positive and even worth restoring (Worboys et al. 2010). Acosta et al. (2000) have already noted that in sand dune ecosystems with linear zonation high connectivity values are not considered more ecologically 'beneficial'. High connectivity is generally related to strong disturbance and fragmentation, although fragmentation is caused by both natural processes and human activities (Forman 1995). A higher connectivity value on more disturbed dunes is related to a decrease in the structural quality and floristic composition of vegetation and zonation of communities (Carboni et al. 2009).

Sand dunes are on a severe abiotic coast-to-inland gradient but also under anthropogenic pressure. Intensive human activity in littoral areas favours the invasion of ruderal and widely distributed species, fragmentation of plant communities, alteration of sequences along the zonation of communities or their replacement, and also the disappearance of phytocoenoses (Acosta et al. 2006). In our case, there were no differences in the invasion of alien species between the two localities (5 species in each site). We must stress out that we considered *Xanthium orientale* ssp. *italicum* as a neophyte, although this status was questioned (Del Vecchio et al. 2015). We confirmed the findings of Carboni et al. (2010) of a modest number of alien species on sand dunes, which do not cause the disappearance of typical plant communities or alter their zonation on preserved or highly impacted sand dunes. Ciccarelli (2014) reported a low number of alien species present on sand dunes and together with diversity index were not very useful as indicator of disturbance. Alien plant species are especially abundant on Velika plaža on embryonic shifting dunes and shifting dunes along the shoreline with *Ammophila* (Stešević & Petrović 2010; Stešević & Caković 2013). Most invaded zones with higher cover of alien plants are associated with some specific communities, in which anthropogenic impact and natural conditions intersect (Carboni et al. 2010) and these conditions are exploited

by some alien species (e.g., *Oenothera* spp., see Table 1).

Although some parts of the sand dunes in Velika plaža are protected, the entire area is small (500 ha). For conservation purposes, the protected area should be elongated and also connected into a cross-border area with Albania, where the beaches of Velipoje are also touristically over-exploited and zonation is disappearing (Fanelli et al. 2015). The Gosa area could be included in the larger, neighbouring Karavasta National Park to protect the still well preserved dunes, since the impact of tourism is already growing. In both areas, we propose the exclusion of some areas with still well preserved dunes and zonation of plant communities. This is more difficult in the case of Velika plaža, where access is unrestricted, while in the Gosa area, advantage could be taken of some areas that are harder to access. Conserved areas should also be selected in parts without erosion, visitor access, recreation and bathing and the absence of mechanical cleaning of the sandy beach. In addition to protection of so far unaffected beaches, management and restoration efforts must be directed at already altered sand dunes (Gomez-Pina et al. 2002; Martínez & Psuty 2004) and assesment of access and establishement of protective fences that prevent trampling should be considered (Munoz-Valles & Cambrolle 2014).

The use of vegetation as a bioindicator of the conservation status of sandy coastal ecosystems has been considered in several studies (Carboni et al. 2009; Landi et al. 2012; Malavasi et al. 2016) and some monitoring schemes have also been proposed (Acosta et al. 2005; Attorre et al. 2013). The establishment of monitoring is the next step for east Adriatic sand dunes, in order to preserve their favourable conservation status for habitat type under increasing human pressure on these habitat types and to ensure timely warning of conservation problems.

We can conclude that the transects of vegetation zonation from Gosa were richer in the number of boundaries, with more varied combinations of boundaries, and the pattern of zonation was also more diverse. On the other hand, there were two plant communities found only in Velika plaža. The more impacted transects from Velika plaža were also more unidirectional from sea to hinterland but with less ideal zonation. Plant communities from Gosa were distributed more straightforwardly but contacts between them were in both directions. The results show that coastal dune systems in Gosa are still very well preserved and have high conservation value. Declaration of protection and monitoring are needed to conserve this valuables plant communities types at the eastern Mediterranean coastline.

Our results confirm that species composition and zonation are good bio-indicators of sand dune ecosystems and can provide information of their fragmentation or integrity. Therefore we recommend application of long term monitoring programs in these two countries.

Acknowledgements

We thank Alfred Mullaj, Julian Shehu, Svetlana Aćić, Thani, Bujar for help during field work and preparation of manuscript. We thank the four anonymous reviewers and the editor whose comments helped improve and clarify this manuscript. Martin Cregeen and Matjaž Kuntner kindly checked our English. The research was partly financed through the Rufford project, ARRS [P1-0236], grant Ministry of Education and Science of Serbia [31057] and FP7 Project AREA [316004].

References

Acosta A., Blasi C. & Stanisci A. 2000. Spatial connectivity and boundary patterns in coastal dune vegetation in the Circeo National Park, Central Italy. J. Veg. Sci. **11:** 149–154.

Acosta A., Carranza M.L. & Izzi C.F. 2005. Combining land cover mapping of coastal dunes with vegetation analysis. Appl. Veg. Sci. **8:** 133–138.

Acosta A., Ercole S., Stanisci A. & Blasi C. 2006. Sandy coastal ecosystems and effects of disturbance in central Italy. J. Coast. Res. **39:** 985–989.

Angiolini C., Landi M., Pieroni G., Frignani F., Finoia M. G. & Gaggi C. 2013. Soil chemical features as key predictors of plant community occurrence in a Mediterranean coastal ecosystem. Estuarine, Coastal and Shelf Sci. **119:** 91–100.

Anonymous 1992. European Communities Council, Directive 92/43/CEE on the Conservation of Natural Habitats and of Wild Fauna and Flora. European Communities, Brussels.

Attorre F., Maggini A., Di Traglia M., De Sanctis M. & Vitale M. 2013. A methodological approach for assessing the effects of disturbance factors on the conservation status of Mediterranean coastal dune systems. Appl. Veg. Sci. **16:** 333–342.

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. Ecol. Monographs **81:** 169–193.

Bego F., Mullaj A., Kashta L. & Zotaj A. 2013. The status of the habitats of European conservation interest along the Adriatic coast of Albania. Inter. J. Ecosyst. Ecol. Sci. (IJEES) **3:** 203–210.

Biondi E. 2007. Thoughts on the ecology and syntaxonomy of some vegetation typologies of the Mediterranean coast. Fitosociol. **44:** 3–10.

Biondi E., Burrascano S., Casavecchia S., Copiz R., Del Vico E., Galdenzi D., Gigante D., Lasen C., Spampinato G., Venanzoni R., Zivkovic L. & Blasi C. 2012. Diagnosis and syntaxonomic interpretation of Annex I Habitats (Dir. 92/43/EEC) in Italy at the alliance level. Plant Sociol. **49:** 5–37.

Braun-Blanquet J. 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde. Springer Verlag, Wien, 865 pp.

Buffa G., Fantinato E. & Pizzo L. 2012. Effects of Disturbance on Sandy Coastal Ecosystems of N-Adriatic Coasts (Italy), pp. 338-372. In: Lameed G.A. (ed.), Biodiversity Enrichment in a Diverse World, Intech,

Caković D., Stešević D., Vuksanović S. & Tan K. 2014. *Colchicum cupanii* subsp. *glossophyllum* (Heldr.) Rouy, *Datura innoxia* Mill. and *Eclipta prostrata* (L.) L., new floristic records in Montenegro and western Balkan. Acta Bot. Croat. **73:** 255–265.

Carboni M., Carranza M.L. & Acosta A. 2009. Assessing conservation status on coastal dunes: A multiscale approach. Landsc. Urban Plann. **91:** 17–25.

Carboni M., Santoro R. & Acosta A.T.R. 2010. Are some communities of the coastal dune zonation more susceptible to alien plant invasion? J. Plant Ecol. **3:** 139–147.

Chytrý M., Tichý L., Holt J. & Botta-Dukat Z. 2002. Determination of diagnostic species with statistical fidelity measures. J. Veg. Sci. **13:** 79–90.

Ciccarelli D. 2014. Mediterranean coastal sand dune vegetation: Influence of natural and anthropogenic factors. Environ.l Manag. **54:** 194–204.

Climate-Data.org Published on the Internet http://en.climate-data.org/. [accessed

Davenport J. & Davenport J.L. 2006. The impact of tourism and personal leisure transport on coastal environments: A review. Estuarine, Coastal and Shelf Sci. **67:** 280–292.

Defeo O., McLachlan A., Schoeman D.S., Schlacher T.A., Dugan J., Jones A., Lastra M. & Scapini F. 2009. Threats to sandy beach ecosystems: A review. Estuarine Coastal and Shelf Sci. **81:** 1–12.

Del Vecchio S., Pizzo L. & Buffa G. 2015. The response of plant community diversity to alien invasion: evidence from a sand dune time series. Biodiv. & Conserv. **24:** 371–392.

Doing H. 1985. Coastal fore-dune zonation and succession in various parts of the world. Vegetatio **61:** 65–75.

Doody J. P. 2001. Coastal Conservation and Management: an Ecological Perspective. Kluwer academic Publishers, Boston, 306 pp.

EURO+MED 2006. Euro+Med PlantBase – the information resource for Euro-Mediterranean plant diversity. Published on the Internet http://ww2.bgbm.org/EuroPlusMed. [accessed March 9, 2013].

Everard M., Jone L. & Watts B. 2010. Have we neglected the societal importance of sand dunes? An ecosystem services perspective. Aquatic Conservation: Marine and Freshwater Ecosystems **20:** 476–487.

Fanelli G., De Sanctis M., Gjeta E., Mullaj A. & Attore F. 2015. The vegetation of the Buna river protected landscape (Albania). Hacquetia **14:** 129–174.

Farris E., Filibeck G., Marignani M. & Rosati L. 2010. The power of potential natural vegetation (and of spatial-temporal scale): a response to Carrion & Fernandez (2009). J. Biogeography **37:** 2212–2213.

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

Fenu G., Cogoni D., Ferrara C., Pinna M. S. & Bacchetta G. 2012. Relationships between coastal sand dune properties and plant community distribution: The case of Is Arenas (Sardinia). Plant Biosyst. **146:** 586–602.

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

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. Biodiv. & Conserv. **20:** 1457–1468.

Forman R.T.T. & Godron M. 1986. Landscape Ecology. John Wiley & Sons, New York, 618 pp.

Forman R.T.T. 1995. Land Mosaics. The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, 632 pp.

Fraschetti S., Terlizzi A., Guarnieri G., Pizzolante F., D'Ambrosio P., Maiorano P., Beqiraj S. & Boero F. 2011. Effects of unplanned development on marine biodiversity: A lesson from Albania (Central Mediterranean Sea). J. Coast. Res. **58:** 106–115.

Frederiksen L., Kollmann J., Vestergaard P. & Bruun H.H. 2006. A multivariate approach to plant community distribution in the coastal dune zonation of NW Denmark. Phytocoenologia **36:** 321–342.

Gomez-Pina G., Munoz-Perez J.J., Ramirez J.L. & Ley C. 2002. Sand dune management problems and techniques, Spain. J. Coast. Res. **36:** 325–332.

Heslenfeld P., Jungerius P.D. & Klijn J.A. 2004. European coastal dunes: ecological values, threats, opportunities and policy development, pp. 335–351. In: Martínez M.L. & Psuty N.P. (eds), Coastal dunes. Ecology and conservation, Springer, Heidelberg.

Horvat I., Glavač V. & Ellenberg H. 1974. Vegetation Südosteuropas. Gustav Fischer Verlag, Stuttgart, 768 pp.

Kent M. 2012. Vegetation Description and Data Analysis: A Practical Approach Wiley-Blackwell, Chichester, 414 pp.

Landi M., Ricceri C. & Claudia A. 2012. Evaluation of dune rehabilitation after 95 years by comparison of vegetation in disturbed and natural sites. J. Coast. Res. **28:** 1130–1141.

Lepš J. & Šmilauer P. 2003. Multivariate Analysis of Ecological Data using CANOCO. Cambridge University Press, Cambridge, 282 pp.

Lotze H.K., Lenihan H.S., Bourque B.J., Bradbury R.H., Cooke R.G., Kay M.C., Kidwell S.M., Kirby M.X., Peterson C.H. & Jackson J.B. C. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science **312:** 1806–1809.

Malavasi M., Santoro R., Cutini M., Acosta A.T.R. & Carranza L.M. 2016. The impact of human pressure on landscape patterns and plant species richness in Mediterranean coastal dunes. Plant Biosyst. **150:** 73–82.

Martínez M.L., Psuty N.P. & Lubke R.A. 2004. A perspective on coastal dunes, pp. 3–10. In: Martínez M.L. & Psuty N.P. (eds), Coastal Dunes. Ecology and Conservation, Springer, Heidelberg.

Maun M.A. 2009. The Biology of Coastal Sand Dunes. Oxford University Press, New York, 265 pp.

McCune B. & Grace J.B. 2002. Analysis of Ecological Communities. MjM Software Design, Glenden Beach, 300 pp.

Mendoza-González G., Martínez M.L., Rojas-Soto R., Vázquez G. & Gallego-Fernández J.B 2013. Ecological niche modeling of coastal dune plants and future potential distribution in response to climate change and sea level rise. Global Change Biology **19:** 2524–2535.

Mijović A., Popović Z., Vukov T., Smiljanić M., Matić R. & Bojović S. 2012. Sand topography influences the distribution of xerohalophytic vegetation on a southern Adriatic beach in Montenegro. Plant Biosyst. **146:** 664–673.

Moreno-Casasola P. 1986. Sand movement as a factor in the distribution of plant communities in a coastal dune system. Vegetatio **65:** 67–76.

Moreno-Casasola P. 2009. Dunes, pp. 241-246. In: Jorgensen S.E. (ed.), Ecosystem Ecology, Elsevier, Amsterdam.

Munoz-Valles S. & Cambrolle J. 2014. Successes and failures in the management of coastal dunes of SW Spain: Status analysis nine years after management decisions. Ecol. Engineer. **71:** 415–425.

Official Gazette of Montenegro 2007.

Oksanen J., Kindt R., Legendre P., O'Hara B., Simpson G., Henry M., Stevens H. & Wagner H. 2008. Vegan: Community ecology package. http://cran.r-project.org/, http://vegan.r-forge.r-project.org/

Oosting H.J. & Billings W.D. 1942. Factors effecting vegetational zonation on coastal dunes. Ecology **3:** 131–142.

Perrino E. V., Tomaselli V., Costa R. & Pavone P. 2013. Conservation status of habitats (Directive 92/43 EEC) of coastal and low hill belts in a Mediterranean biodiversity hot spot (Gargano–Italy). Plant Biosyst. **147:** 1006–1028.

Petrović D. & Karaman M. 2009. Important plant areas in Montenegro – IPA Programme. NVO Zelena Gora, Podgorica, 79 pp.

Pignatti S. 1982. Flora d'Italia. Edagricole, Bologna.

R Development Core Team 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing.

Rescia A.J., Schmitz M.F., deAgar P.M., dePablo C.L. & Pineda F.D. 1997. A fragmented landscape in northern Spain analyzed at different spatial scales: Implications for management. J. Veg. Sci. **8:** 343–352.

Simeoni U., Pano N. & Ciavola P. 1997. The coastline of Albania: morphology, evolution and coastal management issues. Bulletin de l'Institut oceanographique n° special **18:** 151–168.

Stešević D. & Petrović D. 2010. Preliminary list of plant invaders in Montenegro. Biologica Nyssana **1:** 35–42.

Stešević D. & Caković D. 2013. Contribution to the alien flora of Montenegro and Supplementum to the Preliminary list of plant invaders. Biologica Nyssana **4:** 1–7.

Šilc U., Mullaj A., Alegro A., Ibraliu A., Dajić Stevanović Z., Luković M. & Stešević D. 2016. Sand dune vegetation along the eastern Adriatic coast. Phytocoenologia, DOI: 10.1127/phyto/2016/0079

Tichý L., Chytrý M., Hájek M., Talbot S. S. & Botta-Dukát Z. 2010. OptimClass: Using species-to-cluster fidelity to determine the optimal partition in classification of ecological communities. J. Veg. Sci. **21:** 287–299.

Tsoar H. 2005. Sand dunes mobility and stability in relation to climate. Physica A: Statistical Mechanics and its Applications **357:** 50–56.

Tutin T.G., Heynard V.H., Burges N.A., Valentin D.H., Walters S.M. & Webb D.A. e. 1964-80. Flora Europaea. Cambridge University Press, Cambridge, 464, 455, 370, 505 & 452 pp.

Tüxen R. 1956. Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung. Angew. Pflanzensoziol. (Stolzenau) **13:** 5–42.

van der Maarel E. 2003. Some remarks on the functions of European coastal ecosystems. Phytocoenologia **33:** 187–202.

Worboys G., Francis W.L. & Lockwood M. 2010. Connectivity Conservation Management: A Global Guide (with Particular Reference to Mountain Connectivity Conservation). Earthscan, 382 pp.

World Travel & Tourism Council 2014. Travel & Tourism Economic impact 2014 – Albania. World Travel & Tourism Council, 24 pp.

Worm B., Barbier E.B., Beaumont N., Duffy J.E., Folke C., Halpern B.S., Jackson J.B.C., Lotze H.K., Micheli F., Palumbi S.R., Sala E., Selkoe K.A., Stachowicz J.J. & Watson R. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science **314:** 787–790.

Received April 18, 2016
Accepted July 8, 2016