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Sand topography influences the distribution of xerohalophytic vegetation on a southern Adriatic beach in Montenegro

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Abstract

Totally, 26 xerohalophytic species belonging to the associations *Cakilo-Xanthietum italici* and *Echinophoro-Elymetum farcti* were registered at the Velika plaža beach (Montenegro); they were distributed following the spatial succession common in this type of habitat. Three transects of different terrain morphology (positioned perpendicularly to the shoreline) were surveyed to establish if there were any differences in the floristic composition and species distribution due to the configuration discrepancy. Moreover, each transect was divided into zones: The first zone from 0 to 30 m inland, the second zone from 30 m to 60 m inland, and the third zone from 60 m to the end of beach (75–115 m, depending on transect length). The floristic composition was relatively uniform in the different transects. However, the number of individuals per species differed significantly among these transects. An analysis of the qualitative composition of transects/zones showed high differences between zones within transects I and II, whereas species composition of zones within transect III was mostly similar. When analyzing the quantitative composition of species, a positive correlation between the distance from the shoreline and the number of individuals per species in transects I and II was registered for most analyzed species (Spearman correlation, $p < 0.001$). This indicates that terrain configuration affected the ability of present species to become established and propagate.

Keywords: Cakilo-Xanthietum italici, Echinophoro-Elymetum farcti, *psammophytic vegetation, sand micro-topography, species distribution, xerohalophytic vegetation*

Introduction

Xerohalophytic vegetation of the sand dunes along the Adriatic coast is predominantly distributed on the western Italian forecast, where sandy shores are a frequent type of habitat (Pignatti 1959; Caniglia 1982), but to a much lesser extent in Croatia and Montenegro where rocky and steep shorelines make up more than 80% of coastal reliefs (Horvatić 1974; Janković & Stevanović 1983). This vegetation type is endangered by tourism, which is the reason for special attention being given to these species and their habitats in biodiversity protection programs both in Montenegro and adjacent countries. On eastern Adriatic sandy coasts, the characteristic plant species constituting sand pioneer and dune xerohalophytic vegetation are included into plant associations from two classes: Cakiletaea maritimae Tx. et Prsg. 1950 and Ammophiletea Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946 (Mijović & Stevanović 1988; Pulević 1973, 1982).

Plants at foreland habitats are exposed to specific stresses, such as salt spray, episodic over-wash, highly unstable substrate, low field capacity, high air and soil temperatures, drought, and strong wind (Barbour et al. 1985; Rozema et al. 1985; Clark 1986; Hesp 1991; Kumler 1997; Randall & Scott 1997). In accordance with their basic ecological features, such as persistence and ability to overcome water shortage, xerohalophytic species show more or less regular zonal distribution perpendicular to the shoreline (Maun 1994). Thus, the draft zone is mostly occupied by the "pioneers of dunes", i.e. annuals with extensive root systems (Salisbury 1952). The zone which follows is mostly inhabited by the same but more frequent species and partly by perennials. The perennial species associated with

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lower sand salinity inhabit the third zone, which meets with another type of vegetation – a typical garrigue (Salisbury 1952; Ranwell 1972). However, in the investigated area, instead of garrigue, stands of the class Thero-Brachypodietea Br.-Bl. 1947 are present (Mijović & Stevanović 1988). Specific depositional topography alters the physico-chemical properties of the sand base and, consequently, can affect the distribution and number of species (Costa et al. 1996). Therefore, the aim of our study was to demonstrate the distribution of xerohalophytic vegetation in relation to terrain geo-morphology.

Materials and methods

Study area

Field data were collected from the Velika plaža beach near Ulcinj (location given in Figure 1) during the growth season of 2002. This is the most southern point of the Montenegrinian coast, and the largest beach in this part of southern Adria (approximately 11.5 km in length); it extends into the Albanian foreland south of the delta of the Bojana River. The study area is characterized both by high patchiness and fragmentation, with various landscape elements such as mobile sand dunes and semi-fixed dunes. Meteorological data for the Ulcinj area over a 30-year period (1969–1999), obtained from the Hydro-meteorological Service of the Republic, are given in Table I.

Figure 1. Geographical position of Velika plaža.

Vegetation survey

The survey was made by total plant census along the three strip transects (each 3-m wide) of unequal length perpendicular to the shoreline and randomly selected quadratic plots. The starting point of all three transects is the shoreline (0 m from the sea). Each transect survey was conducted along different shore configurations to establish if there were differences in the floristic composition due to configuration discrepancy. The first transect was made across rising terrain (from sea level going inland), the second one was made along the dune where the terrain first rose and then descended going inland, and the third one was made along the depression (i.e. the terrain descended and then rose going inland) (Figure 2). The length of transects depended on the floristic composition (transect census was made as long as the species of the associations *Cakilo-Xanthietum italici* and *Echinophoro-Elymetum farcti* were present). When the floristic composition changed, i.e. species from another type of vegetation predominated, the survey was stopped. Each transect was divided into three zones: The first zone from 0 to *ca*. 30 m inland; the second zone from *ca*. 30 to 60 m inland; and the third zone from *ca*. 60 m to 114, 99 and 75 m inland in the first, second, and third transect, respectively.

Eighteen plots were selected randomly (size of plot 25 m^2) at different distances from the sea (from 30 to 120 m). Total census of individuals present in the each square was carried out during the survey. The standard keys for determination of plants were used (Tutin et al. 1964a, 1964b, 1972, 1976, 1980; Domac 1984). A combined scale was used for evaluation of species' abundance and cover, as proposed by Westhoff and van der Maarel (1973).

Substrate analyses

Along each transect, surface soil samples were taken, from each zone, three times during the growth season (April, June, and September; Mijović 1997). Soil samples (0–20 cm depth) from each transect/zone square were taken at three different points and mixed into a composite sample for a specific transect/zone combination. The sand samples were immediately placed into 30-ml containers and taken back to the laboratory, weighed, dried at 105°C and weighed again to calculate the water content. The air-dried subsamples were passed through a 2-mm sieve. The electrical conductivity (EC) was measured in a 1:5 soil:water extract (Rhoades et al. 1999). Nitrogen (N) determination was done by semi micro-Klejdahl analysis according to Markham (1942). Samples for analysis were digested with sulfuric acid at 350°C for 4 h. Results of substrate analyses are given in Table II.

Table I. Meteorological data for Ulcinj area for 30-year period (1969–1999).

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yearly	VI–X
T	6.9	10.4	10.4	13.7	18	21.6	24.4	24.2	21.1	16.9	12.3	8.5	15.5	20.5
P	157.7	138.8	116	113.6	62.2	52.1	29.8	50	85.5	142	173	157.4	1278.1	393
I	116.1	119.2	164.8	194.3	253.6	289.1	337.7	312.2	247.8	191.8	120.7	106.4	204.5	275.7

Months from January (I) to December (XII); T, temperature (°C); P, precipitation (%); and I, duration of sunshine (hours).

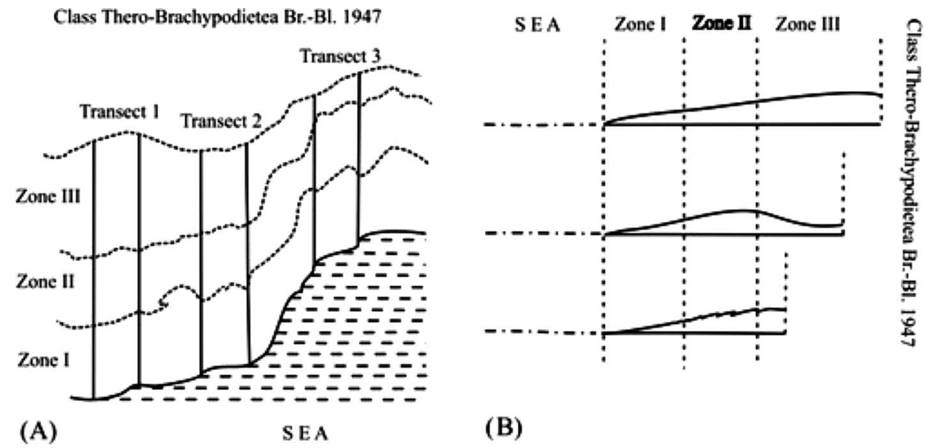

Figure 2. Surveyed transects: (A) horizontal profile and (B) vertical profile.

Table II. Characteristic of soil probes taken from surveyed transects/zones (mean values ± SD).

Probe	Water content (%)	Total N content (ppm)	pH	Electrical conductivity (mmol/L)
T1Z1	2.7 ± 0.02	68 ± 0.4	7.30 ± 0.06	0.71 ± 0.005
T1Z2	4.5 ± 0.03	74 ± 0.5	7.88 ± 0.06	0.84 ± 0.006
T1Z3	5.1 ± 0.03	88 ± 0.6	8.79 ± 0.07	0.46 ± 0.004
T2Z1	2.8 ± 0.02	116 ± 0.9	7.35 ± 0.06	0.73 ± 0.006
T2Z2	3.8 ± 0.02	72 ± 0.6	7.65 ± 0.06	0.32 ± 0.003
T2Z3	5.7 ± 0.03	91 ± 0.07	7.90 ± 0.07	0.91 ± 0.007
T3Z1	3.1 ± 0.02	81 ± 0.07	7.81 ± 0.07	0.66 ± 0.004
T3Z2	4.1 ± 0.02	98 ± 0.09	8.05 ± 0.06	0.23 ± 0.001
T3Z3	5.9 ± 0.03	153 ± 1.1	8.20 ± 0.07	0.19 ± 0.001

Data analysis

Correspondence analysis was performed to evaluate differences in the qualitative composition of transects and of the zones within them (for a total of nine samples: Three transects*three zones in each transect). The output of the analysis was coordinates of rows (transect*zone) and columns (species) on correspondence axes superimposed on the scatter diagram. Spearman's rank test was used to test relations between the distance from the sea and number of individuals per species. Statistical relevance of differences between transect pairs was verified with a test for the difference between two proportions. Bray–Curtis cluster analysis based on root-root transformed quantitative data for transect*zone samples was performed to establish levels of similarity between samples. Statistical analysis was performed using the statistical packages Statistica 5 for Windows and BioDiversity Pro (McAlecee et al. 1997). Canonical correlation analysis (CCA) was performed to explore linear relationships between two sets of variables (species abundance and substrate characteristics). The results of the CCA were plotted as a two-dimensional graph with species as points and substrate variables as arrows originating from the center of the graph. Canonical correlation analysis (CCA) was performed using the SAS 9.1 package (SAS, SAS Institute, Gary, NC).

Results

Plots

A total of 26 species from the associations *Cakilo-Xanthietum italici* and *Echinophoro-Elymetum farcti* were recorded in eight plots. It is evident that the abundance of species of the association *Cakilo-Xanthietum italici* decreases with increasing distance from the sea, while the abundance of species of the association *Echinophoro-Elymetum farcti* increases with increasing distance from the sea (Table III).

Transects

Qualitative composition of transects. A total of 10 species of the associations *Cakilo-Xanthietum italici* and *Echinophoro-Elymetum farcti* were analyzed for their distribution along the transects (other recorded species were too few to participate in further analyses). Four of these species were members of *Cakilo-Xanthietum italici* ass.: *Xanthium italicum* Mor., *Cakile maritima* Scop., *Salsola kali* L., and *Euphorbia peplis* L. and six were members of *Echinophoro-Elymetum farcti* ass.: *Euphorbia paralias* L., *Eryngium maritimum* L., *Elymus farctus* (Viv.) Runemark ex Melderis, *Echinophora spinosa* L., *Ammophila arenaria* (L.) Link, and *Pancratium maritimum* L.

Ten, nine, and six species were recorded in the first, second, and third transect, respectively. Differences in the qualitative composition of transects and of the zones within them are illustrated in Figure 3. Two groups of samples can be distinguished along the second correspondence axis. The first group contains all three zones of the third transect e (III-1, III-2, III-3) and the second transect-second zone sample (II-2). The second group contains the first and second zone of the first transect (I-1, I-2) and the first zone of the second transect (II-1).

The number of species increases with increasing distance from the sea in transects I and II (four species in zone 1, five species in zone 2 for both transects I and II, 10 species in zone 3 of transect I, and nine species in zone 3 of transect II). Transect III is specific because there is no increase in number of species along zones (five species in zones 1 and 2 and three species in zone 3).

Quantitative composition of transects. Spearman's rank test showed a statistically significant positive correlation between the distance from the sea and the number of individuals per species for most analyzed species in transects I and II (Table IV).Statistically relevant differences in the quantitative composition of transects are presented in Table V. In transect I, the largest number of individuals have *E. farctus* (38.45%) and *X. italicum* (31.00%), in transect II *X. italicum* (68.80%) and *E. farctus* (22.77%), and in transect III *X. italicum* (55.06%) and *E. peplis* (29.96%). Better insight into the quantitative composition was obtained when the transects were subdivided into zones (Table VI). *X. italicum* outnumbered all species in seven samples (zones), *E. farctus* had the largest number of individuals in zone 3 of transect I (40.35%) and *E. peplis* in zone 1 of transect III (61.36%).

Similarities and dissimilarities between samples (transect*zone) obtained by cluster analysis of the quantitative data set (Figure 4) are compatible with the results of the correspondence analysis based on the qualitative data set (see above).

Relationship of species' abundance and substrate characteristics

The first canonical correlation axis was the only significant axis and accounted for 80% of the species' abundance/substrate characteristics relationship. The strongest correlations were between the first axis and pH (Figure 5). Other substrate characteristics (electrical conductivity EC, N content, water content) showed weaker correlations along the graph axes.

Discussion

Plots

Spatial succession of the two analyzed plant communities occurred, with an overlapping zone where species of both communities were established. Characteristic species of the association *Cakilo-Xanthietum italici* became less abundant, whereas the species of the association *Echinophoro-Elymetum farcti* became more frequent with increasing distance from the sea. Generally, there are two difficulties for vegetation development on mobile sand dunes (Li et al. 1997): (1) the extremely barren soil limiting plant growth and (2) the unstable substrate (wind erosion) which prevents the propagules of most plants from becoming established. Thus, only specific ecophysiological adaptations (e.g. salt and drought tolerance) and reproductive features (e.g. mode of seed dispersal) enable the establishment of particular species on these sites. Annual species with an extensive root system, which are more tolerant to sea spray and seawater inundations (ass. *Cakilo-Xanthietum italici*), are common in the zone nearest the sea (Barbour & DeJong 1977; Maun 1994). The dispersion of these species in deeper landward zones is attributable to wind action (van der Valk 1974) or specific seed features aiding animal dispersal (e.g. *X. italicum* which is present far inland). A gradual transition to the other association (i.e. from *Cakilo-Xanthietum italici* to *Echinophoro-Elymetum farcti*) is noticeable by the increasing number of *Elymus farcti* (already at 50 m). The tussocks of this grass species are the main agents of dune evolution since these "immobilize" sand movements, and become a

Table III. Species abundance in eight plots.

	Plot code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Distance from sea (m)	30	50	50	60	70	70	80	80	80	80	90	90	100	100	120	120	120	120
	Size of relevé (m^2)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	Coverage (%)	15	40	40	30	45	45	40	35	40	40	60	60	65	65	60	60	60	60
Characteristic species of ass.	*Xanthium italicum* Mor.	5	5	5	7	7	7	5	5	5	5	3	3	5	5	3	3	3	3
Cakilo-Xanthietum italici	*Cakile maritima* Scop.	2	2	2	1														
Characteristic species of class Cakiletea	*Salsola kali* L.	1		1															
	Euphorbia peplis L.			1															
	Polygonum maritimum L.				2	2	2	1		1									
	Artiplex hastata L.						1						1						
Characteristic species of ass.	*Elymus farctus* (Viv.) Runemark.		4	5	3	4	5	7	7	7	7	8	8	8	8	8	8	8	8
Echinophoro-Elymetum farcti	*Echinophora spinosa* L.				1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Characteristic species of	*Eryngium maritimum* L.	1	2	2			1	3	3	2	3	2	2	1	1				
class Ammophiletea	*Euphorbia paralias* L.				1				1		1			1	1		1	1	
	Medicago marina L.						1	1	2	2	2	2	2			1	1		
	Ammophila arenaria (L.) Link.													5	5	5	4	5	5
	Pancratium maritimum L.									1	1		1						
	Calystegia soldanella (L.) R. Br.												1	1					
	Pseudorlaya pumila (L.) Grande									1					1				
Others	*Aegilops ovata* L.								1		1				1				
	Blackstonia perfoliata (L.) Huds.																	1	
	Bromus tectorum L.									1	1		1						
	Cuscuta sp. L.		3	3		3	3												
	Inula crithmoides L.										1	1							
	Juncus maritimus Lam.															3	3	2	3
	Parapholis incurva (L.) C. E. Hubb.										1		1						
	Reichardia picroides (L.) Roth.											1							
	Schoenus nigricans L.								1		1		1		1				
	Vulpia ciliata Dumort.									1	1		1						
	Lagurus ovatus L.				1					1			1		1				

nucleus for further accretion and eventual dune formation (Harris & Davy 1986). Finally, the full establishment of *Ammophilla arenaria* (after 100 m) indicates a significant decrease of sand salinity. This species has a significant role in the development and stabilization of sand dune systems on European coasts (Salisbury 1952; Ranwell 1972; Deshmukh 1977), but it is usually present only on broader beaches (Alegro et al. 2004).

Qualitative composition of transects. When the most numerous species from the total census were analyzed separately for their presence in particular transects/zones, certain effects due to length of transects were observed. Thus, specimens of *E. farctus* and *A. arenaria* were present only in I-3 and II-3 samples, whereas *P. maritimum* was registered only in I-3. In the grouping of samples along the second correspondence axis, it could be noted that in transect III, zonation of species was almost absent. Moreover, the species present in transect III were similar to those of sample II-2. On the other hand, samples I-1, I-2, and II-1 were grouped. The segregation of these samples was due to the presence or absence of *C. maritima*. Apparently, this species is more invasive landwards along the continuously rising terrain of transect I. Quantitatively, the most frequent species were *X. italicum* and *E. maritimum* (present in nine and seven samples, respectively, and not affected by transect length or topography).

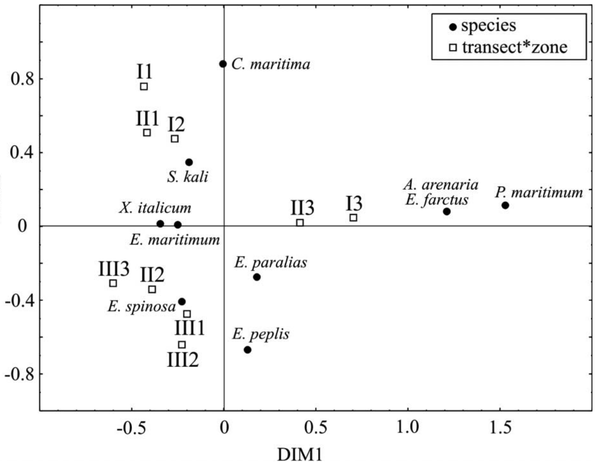

Figure 3. CA ordination graph of transects (I, II, III, the first, second, and third transect, respectively) and zones within (1, 2, 3, the first, second, and third zone, respectively).

Transects I and II are characterized by the gradual shift from species belonging to one association to species from the other association: In zone 1 species of the ass. *Cakilo-Xanthietum italici* prevail, while zone 2 has a similar number of species of both associations; in zone 3 species of the ass. *Echinophoro-Elymetum farcti* prevail. Transect III is once again distinct from the others because there is no such obvious shift in species composition.

Quantitative composition of transects. In general, the number of species increased with increasing distance from the sea in transects I and II, but not in transect III. Also, the number of individuals per species increased according to the same pattern (in transects I and II, but not in III). There were several exceptions to this rule (*S. kali* in transects I and II; *C. maritima* and *E. peplis* in transect II). The pattern of increasing number of individuals with increasing distance from the sea is applicable for the cumulative number of individuals of both associations for transects I and II as well. In transect III, the rule fits for ass. *Echinophoro-Elymetum farcti*, but not for ass. *Cakilo-Xanthietum italici*. The better soil properties landwards, especially in zone 3, favored an enhanced establishment of most species, which resulted in an increase of their number. This regularity is confirmed by the positive correlation between the distance from the sea and the number of individuals for each species.

Table IV. Spearman correlation between distance from the sea and number if individuals per species.

	Transect I		Transect II		Transect III	
Species	Spearman R	*P*	Spearman R	*P*	Spearman R	*P*
X. italicum	0.85	***	0.76	***	0.71	***
C. maritima	0.65	**	0.23	ns	/	/
S. kali	−0.13	ns	−0.09	ns	−0.30	ns
E. peplis	0.12	ns	0.03	ns	0.09	ns
E. paralias	0.40	*	0.54	**	0.05	ns
E. maritimum	0.68	***	0.61	***	0.59	**
E. farctus	0.78	***	0.62	***	/	/
E. spinosa	0.78	***	0.48	**	0.72	***
A. arenaria	0.13	ns	0.39	*	/	/
P. maritimum	0.40	*	/	/	/	/

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; ns – non-significant.

Table V. Quantitative composition of transects with statistical relevance of difference between transect pairs.

	Transect I		Transect II		Transect III		I/II	I/III	II/III
Species	A. N.	%	A. N.	%	A. N.	%	*P*	*P*	*P*
X. italicum	954	31.00	955	68.80	147	55.06	***	***	***
C. maritima	419	13.62	5	0.36	0	0.00	***	***	ns
S. kali	8	0.26	6	0.43	3	1.12	ns	*	ns
E. peplis	3	0.10	4	0.29	80	29.96	ns	***	***
E. paralias	91	2.96	20	1.44	5	1.87	**	ns	ns
E. maritimum	206	6.69	16	1.15	8	3.00	***	*	*
E. farctus	1183	38.45	316	22.77	0	0.00	***	***	***
E. spinosa	191	6.21	54	3.89	24	8.99	**	ns	***
A. arenaria	8	0.26	12	0.86	0	0.00	**	ns	ns
P. maritimum	14	0.45	0	0.00	0	0.00	*	ns	ns

A.N. – absolute number of specimens; $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; ns – non-significant.

Table VI. Quantitative composition of zones within transects.

Species	A.n.	Z1 (%)	A.n.	Z2 (%)	A.n.	Z3 (%)
Transect I						
X. italicum	14	51.85	52	44.07	888	30.29
C. maritima	10	37.04	29	24.58	380	12.96
S. kali	2	7.41	3	2.54	3	0.10
E. peplis	0	0.00	0	0.00	3	0.10
E. paralias	0	0.00	2	1.69	89	3.04
E. maritimum	1	3.70	32	27.12	173	5.90
E. farctus.	0	0.00	0	0.00	1183	40.35
E. spinosa	0	0.00	0	0.00	191	6.51
A. arenaria	0	0.00	0	0.00	8	0.27
P. maritimum	0	0.00	0	0.00	14	0.48
Transect II						
X. italicum	8	53.33	89	82.41	858	67.83
C. maritima	2	13.33	0	0.00	3	0.24
S. kali	2	13.33	3	2.78	1	0.08
E. peplis	0	0.00	2	1.85	2	0.16
E. paralias	0	0.00	0	0.00	20	1.58
E. maritimum	0	0.00	1	0.93	15	1.19
E. farctus	0	0.00	0	0.00	316	24.98
E. spinosa	3	20.00	13	12.04	38	3.00
A. arenaria	0	0.00	0	0.00	12	0.95
P. maritimum	0	0.00	0	0.00	0	0.00
Transect III						
X. italicum	12	27.27	113	62.43	22	52.38
C. maritima	0	0.00	0	0.00	0	0.00
S. kali	3	6.82	0	0.00	0	0.00
E. peplis	27	61.36	53	29.28	0	0.00
E. paralias	1	2.27	4	2.21	0	0.00
E. maritimum	0	0.00	1	0.55	7	16.67
E. farctus	0	0.00	0	0.00	0	0.00
E. spinosa	1	2.27	10	5.52	13	30.95
A. arenaria	0	0.00	0	0.00	0	0.00
P. maritimum	0	0.00	0	0.00	0	0.00

A.n. – absolute number of specimens. Z1 – zone 1; Z2 – zone 2; Z3 – zone 3.

The transects were significantly different considering the number of individuals of analyzed species. Thus, the largest differences in quantitative composition were between the transects I and II, somewhat smaller, but still large differences were between the transects I and III. When transects were divided into zones, more subtle differences were observed. *X. italicum* was very numerous in all nine samples (zones) but outnumber all species in seven samples (zones). *E. farctus* had the largest number of individuals in I-3 sample and *E. peplis* in III-1 sample. When the cluster analysis based on quantitative data set was applied, we confirmed the previously presented results of the correspondence analysis based on quantitative data set.

The morphology of the terrain at the sand beaches and the physico-chemical conditions of substrate are the most important factors determining the presence, distribution, number and abundance of plant species (Álvarez-Rogel et al. 2000, 2007; Jafari et al. 2004; Lortie & Cushman 2007; Bornman et al. 2008). Soil characteristics estimated in this study were used for establishing the relationship between these variables and species abundance in CCA analysis. These characteristics only partially reflect the conditions at certain microsites, but still we can deduce some conclusions comparable with previous findings. Species' abundances were mostly affected with pH values, the number of specimens increased with increasing pH (third transect is excluded from this conclusion, because of lack of correlation between the abundances and pH values). Soil water regime and EC affected the abundance of few species (*A. arenaria* and *X. italicum*), whereas soil nitrogen content had the least impact to the plants' abundance. High heterogeneity of estimated soil characteristics, as a consequence of constant human activity and disturbance, has resulted in a poor correlation between the soil variables and species' abundances.

Overall, our results show that two factors affect the plant distribution and species abundance along the shoreline. One is the distance from the sea, and we confirmed the gradual distribution of species, and the more or less regular shift of plant communities with increasing distance from the sea, as previously shown in earlier studies (Pakeman & Lee 1991; Acosta et al. 2007; He et al. 2007). Another is the set of soil characteristics, which was highly heterogeneous and, in relation to the distance from the sea, particularly irregular. Similar results were obtained from the studies on plant distribution along coastal dunes (Álvarez-Rogel et al. 2006, 2007, Dasti et al. 2010), where it has been shown that the soil type and vegetation positioning were connected with terrain

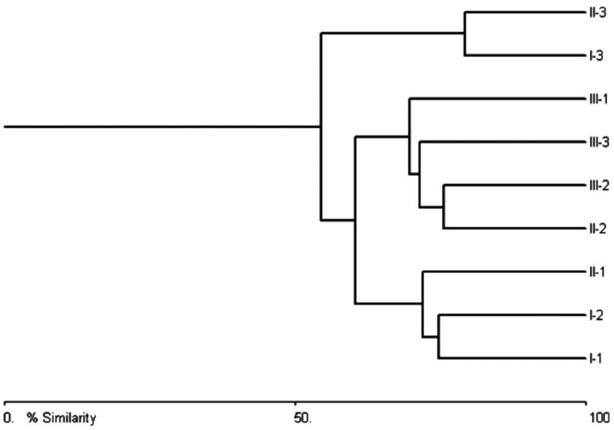

Figure 4. Bray–Curtis dendrogram of transect*zone samples (I, II, III, the first, the second, and the third transect, respectively; 1, 2, 3, the first, the second, and the third zone, respectively).

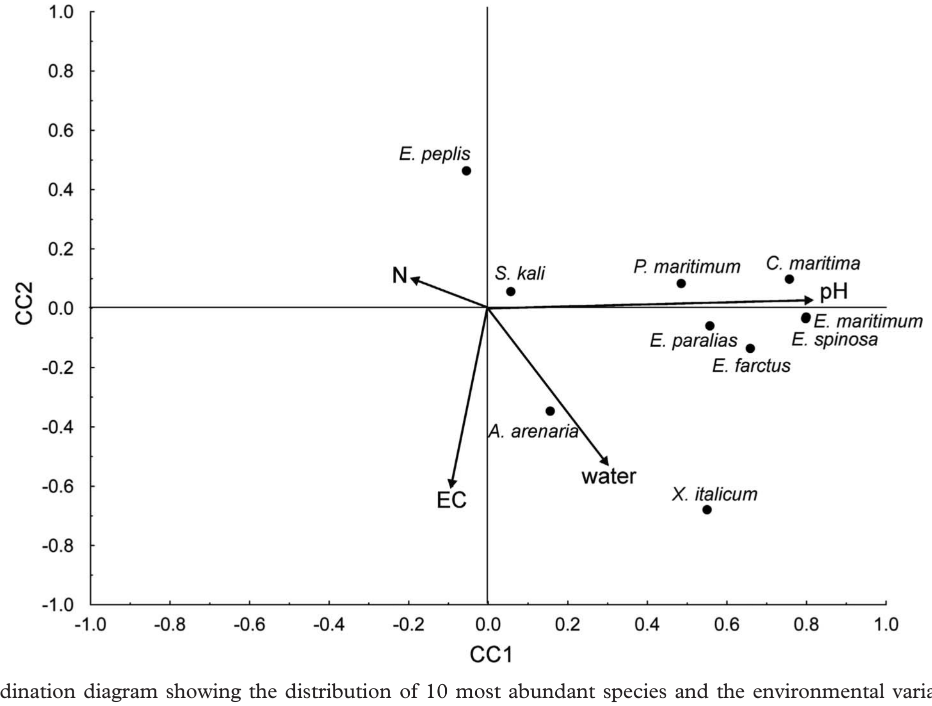

Figure 5. CCA ordination diagram showing the distribution of 10 most abundant species and the environmental variables. N – nitrogen content, EC – electrical conductivity.

configuration, regardless of the distance to the shoreline. Lortie and Cushman (2007) also showed that wind is an important factor affecting abiotic factors (soil moisture, N content) along the sand dune shoreline.

The fluctuating environment of coastal foredunes, characterized by a variety of geomorphological features, soil properties, and environmental factors (Seelinger 1992), causes specific vegetation composition. Generally, foredune vegetation is dominated by few species, which are limited to beaches and coastal foredunes, and which show a wide geographical distribution, with a number of many subordinate species with a more limited distribution (van der Maarel & van der Maarel-Versluys 1996). Foredune morphology may play a key role for certain species by offering temporary refuges where more stable populations survive, becoming the source for future propagules (Davy & Figueroa 1993). Variable topography implies differences in edaphic factors, and consequently affects the presence, number and relative abundance of species (Jafari et al. 2004, Álvarez-Rogel et al. 2006), and relatively small differences in elevation may produce large differences in species composition (Barrett 2006). The alternations in dune morphology are particularly important in rare or heavily disturbed communities, where these may cause changes in coastal vegetation, even the disappearance of some species/communities (Acosta et al. 2007; Cutini et al. 2010).

Adaptations to a broad array of micro-environmental factors are demonstrated in a number of structural and functional plant characteristics, making them recognizable as specific functional types (García-Mora et al. 1999). Low competitive pressure at sand shorelines, accompanied by eutrophication and human pressure, allows the colonization of alien species of suitable functional types, which may, consequently, alter community composition (Stanisci et al. 2010).

In summary, the xerohalophytic species belonging to the associations *Cakilo-Xanthietum italici* and *Echinophoro-Elymetum farcti* were more or less regularly zonated at the Velika plaža beach, following the spatial succession of species common for this type of habitat. With regard to the different microtopography along the investigated transects, significant differences in number of individuals of plant species among these transects were observed. However, the floristic composition was relatively uniform between transects. This indicates that terrain configuration significantly affects the ability of present species to establish and propagate. *X. italicum*, which is a representative of the plant association typically distributed in draft zones, showed the widest distribution along the investigated beach, indicating the great ecological amplitude and dispersal advantages of this species. Strong anthropogenic pressure on touristically attractive beaches of the southern Adriatic foreland contributes to changing sand micro-topography, thereby disturbing the vegetation communities occurring on them. For the purposes of conservation, sand sieving and gardening of gradually arising dunes may improve the establishment of plants over the entire beach width.

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