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Sand dune vegetation along the eastern Adriatic coast

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Abstract

Questions: What is the current state of knowledge on the distribution of psammophytic vegetation along the eastern Adriatic coast? Which are the main vegetation types and how do they vary from a floristic and ecological point of view? **Study area:** The eastern Adriatic coast of Croatia, Montenegro and Albania. **Methods:** We collected all available vegetation relevés (a total of 191, published and unpublished) and historical references of sand dune vegetation from the eastern Adriatic coast. Classification and ordination were performed on the dataset and a syntaxonomical overview of the different plant communities along a seashore-inland zonation and their geographical distribution is presented. **Results:** The classification of the phytosociological data show eight floristically and ecologically well-defined clusters. The first group of embryonic foredunes comprises of the *Cakilo-Xanthietum*, *Euphorbia paralias* community and *Eryngio-Sporoboletum*, whilst the second group is found on the more stable dunes with *Euphorbio paraliae-Agropyretum junceiformis, Medicagini marinae-Ammophiletum australis* and *Scabiosa argentea-Ephedra distachya* communities. The latter is newly described and is found only along the Albanian coast. The number of plant communities is lower than in surrounding countries, particularly on fixed dunes. The presence of the EU habitat type '*Crucianellion maritimae* fixed beach dunes' (2210) is newly reported for Albania. **Conclusions:** Sand dunes are important habitats from a nature conservation point of view and they are endangered due to strong human impact. The protection of sand dune habitat types throughout the study area is urgent, since they are still in good condition in Albania, while sand dune plant communities are fragmented in Croatia and under strong human impact in Montenegro.

Keywords: Albania; *Ammophiletea*; Balkan Peninsula; *Cakiletea*; Croatia; *Crucianellion maritimae;* Montenegro; psammophytes

Nomenclature: For vascular plant taxa Euro+Med (http://ww2.bgbm.org/EuroPlusMed/, accessed 2 April 2016), except for *Calystegia soldanella*, *Cistus incanus*, *Cistus salvifolius*, *Citrullus lanatus*, *Clematis flammula*, *Cucumis melo*, *Fumana procumbens*, *Helianthemum jonium*, *Helianthemum nummularium*, *Knautia integrifolia*, *Lonicera implexa*, *Nigella arvensis*, *Oenothera biennis*, *Paliurus spina-christi*, *Polygonum maritimum*, *Radiola linoides*, *Rumex crispus*, *Rumex pulcher*, *Scabiosa argentea*, *Scabiosa atropurpurea*, *Tamarix dalmatica*, and *Viburnum tinus* according to Flora Europaea (Tutin et al. 1964–1980,1993); for higher syntaxa Mucina et al. (2016), for associations see the overview in this paper.

Abbreviations: DCA = Detrended Correspondence Analysis; PNV = potential natural vegetation.

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Introduction

Coastal dunes are complex ecosystems occupying zones of transition between terrestrial and marine ecosystems. This is a very dynamic environment, with distinct degrees of stabilisation depending on the topography, natural disturbance and distance from the sea, and it harbours a mosaic of habitats (van der Maarel 2003). Plant communities on sand dunes have specific ecological requirements determining their position along the gradient from the sea inland (Carboni et al. 2009). Various ecological factors influence the distribution of plants along this gradient: sand abrasion, salt spray, burial by sand, erosion, accretion, tide level, wave attack, wind blasting and dehydration (Maun 2009; Miller et al. 2010). Zonation is very stable and a regular sequence of plant communities along

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the gradient can be observed worldwide (Doing 1985; Attorre et al. 2013). Vegetation of beaches and mobile dunes is considered azonal (Doing 1985), while more inland, stable dunes are covered by plant communities more adapted to local conditions (Buffa et al. 2012).

Sand dune vegetation occurs all along the Mediterranean coasts and several authors have provided syntaxonomical schemes of this vegetation type. In the central and eastern part of the Mediterranean, overviews have been made for Italy (Géhu et al. 1984; Géhu & Biondi 1996; Brullo et al. 2001; Biondi 2007; Pirone 2014), Greece (Sýkora et al. 2003) and Turkey (Géhu et al. 1989), but not for the eastern Adriatic coast along the Balkan Peninsula.

The history of vegetation research along the eastern Adriatic coast varies greatly in the last century due to the division of the region into two countries with different political systems. Research on psammophytic (sand dunes) vegetation started with Beck von Mannagetta (1901) and Morton (1915), who refer to the "Formation des Dünensandes". Horvatić (1934, 1939) was the first to study and provide a deeper insight into this vegetation type according to the Braun-Blanquet method, on the islands of Pag and Rab (Croatia), and he added new data in 1963 (Horvatić 1963). Extensive studies in Croatia were carried out by Trinajstić (1974, 1989a, 1995), Trinajstić & Jasprica (1998) and Alegro et al. (2003, 2004) Trinajstić & Jasprica (1998) and in Montenegro by Trinajstić (1989b) and Mijović et al. (2006, 2012).

Vegetation research in Albania applying the Braun-Blanquet method only started in the late 1980s. One of the pioneering works was on the coastal vegetation of Albania (Mullaj 1989), while studies of halophytic and psammophytic vegetation have only recently emerged (Imeri et al. 2010; Fanelli et al. 2015). These differences in the degree of vegetation research along the eastern Adriatic coast are evident from the distribution maps of the localities of sand dunes, on which the eastern Adriatic coast must still be considered a white spot in Europe (Géhu 1989; Trinajstić 1989a).

The main aims of this paper are: (a) to present the current state of knowledge on the distribution of psammophytic vegetation along the eastern Adriatic coast, (b) to determine the main vegetation types by numerical analysis and (c) to describe these vegetation types from a floristic and ecological point of view. The paper is also a contribution to knowledge of the vegetation of Albania, which is still under-explored.

Study area

The eastern Adriatic coast, or Adriatic coast of the Balkan Peninsula, is bound by the mouth of the Soča River in the northwest and the Strait of Otranto in the southeast (Fig. 1). Sand dunes, or even sandy sea shores, are very rare along this coast, in contrast to the Adriatic coasts of Italy and the Ionian or Aegean coasts of the Balkan Peninsula. Several factors are important: (a) the tectonics of Dalmatia with its relatively steep coast that influences the production of coarse clastic material, (b) water courses are oriented towards north-northwest, and (c) the active contact zone between the External Dinarides and the small Adriatic microplate is narrow and does not allow the formation of "stable" sedimentation space, where fine, sorted sediment accumulates (Juračić et al. 2009). The north-eastern Adriatic coast therefore consists mainly of solid and steep limestone rocks; in the northern part, sandy beaches are scarce, small and with fragmented vegetation. Towards the south-east, the number of localities with sandy shores increases and well developed low sand dunes occur southwards, from the border between Montenegro and Albania extending to the Strait of Otranto (Trinajstić 1989a; Simeoni et al. 1997).

According to Köppen's climate classification, the southern and central Adriatic sea have a dry summer Mediterranean climate (Csa), whereas the northern Adriatic has a humid subtropical climate (Cfa) (Lionello et al. 2012). The predominant winter wind is the bora and sirocco (jugo) which is observed during fall and spring.

Methods

We collected all available published and unpublished relevés (191) on sand dunes that were recorded using the standard Central European method (Braun-Blanquet 1964) along the eastern Adriatic coasts (Appendix, Fig. 1). The 191 relevés were entered into the TURBOVEG (Hennekens & Schaminée 2001) database. Relevés were *a posteriori* georeferenced. Although plot areas varied in size from 4 to 200 m^2, with the majority (74%) being between 10-50 m^2 (first quartile 25, median 30 and third quartile 50 m^2) all relevés were used for the analyses.

Ecological indicator values (Pignatti 2005) were used for interpretation of the ecological gradients.

Numerical classification of vegetation plots, on the basis of their species composition, was performed with the PC-ORD 5.0 program (McCune & Grace 2002). The original Braun-Blanquet cover values (sensu van der Maarel 1979) were transformed into percentages (mean values of percentage cover classes) and then square rooted. Euclidean distance (as distance measure) and the Ward method (for group linkage) were used.

Clusters were identified by their diagnostic species, using the JUICE program (Tichý 2002). Diagnostic species were determined using the phi-coefficient as a fidelity measure (Chytrý et al. 2002). The size of all groups was standardized to equal size and Fisher's exact test ($p < 0.001$) was applied. Species with phi-coefficient values higher than 0.10 were considered to be diagnostic. After preliminary grouping of the diagnostic species as a

Fig. 1. Distribution of sand dune vegetation along the eastern Adriatic coast (circle-relevés, triangle-literature references).

result of using lower or higher threshold values, the mentioned phi value was subjectively selected. The selected phi-coefficient value threshold was chosen to be both low enough for a sufficient number of diagnostic species from an ecological and phytogeographical point of view, allowing the description of clusters, and high enough to avoid many generalist species, or species occurring in more than one cluster, from being considered diagnostic species.

The relation between clusters and environmental indicator values was visualized using DCA ordination, in which the square-rooted cover percentages of species were used, and rare species were down-weighted. The original relevés and mean unweighted ecological indicator values calculated for each relevé were used in DCA. Ordination results are presented on spider plots, in which each relevé is linked to the centroid of its cluster by a line and vectors representing indicator values were plotted on the ordination diagram. Analyses were performed by means of R (R Development Core Team 2012; http://cc.oulu.fi/~jarioksa/softhelp/vegan.html) using functions in the vegan package.

Results

The vegetation table (191 relevés) includes 190 plant species. Among the species characteristic for the class *Cakiletea maritimae* (sensu Mucina 1997) most common were *Xanthium orientale* ssp. *italicum* and *Cakile maritima*, while among the common species of the *Ammophiletea* were *Elytrigia juncea, Echinophora spinosa, Eryngium maritimum, Euphorbia paralias* and *Medicago marina*. There is an evident increase of some psammophytic species towards the south of studied area: *Glaucium flavum, Matthiola tricuspidata, Polygonum maritimum, Ammophila arenaria, Ephedra distachya, Achillea maritima* and *Sporobolus pungens*. Rare psammophytes in the studied area were *Ephedra distachya*, *Stachys maritima*, *Helichrysum italicum* and *Ononis variegata*.

Classification

The results of cluster analysis are presented in a dendrogram (Fig. 2) and a synoptic table (Table 1). Diagnostic species are ordered according to the decreasing phi value. Two main groups were distinguished in the dendrogram and the groupings of the communities reflect their syntaxonomic classification and site conditions. The first group (clusters 1–3) includes plant communities on embryonic foredunes and driftlines, while the second group comprises communities on more stable dunes (white and grey dunes) (clusters 4–8). The classification produced a dendrogram with 8 clusters that were ecologically most meaningful and also in accordance with traditional vegetation classification. The geographical distribution of the clusters is presented in Fig. 3.

Cluster 1 *Cakilo-Xanthietum strumarii*
Diagnostic species: *Cakile maritima, Xanthium orientale* ssp. *italicum, Salsola kali* aggr.

This halo-therophytic plant community is first in the zonation of vegetation from the sea towards the inland and occurs on nutrient rich sandy beaches. It occurs in Croatia, Montenegro and Albania.

Cluster 2 *Euphorbia paralias* community
Diagnostic species: *Euphorbia paralias, Tamarix dalmatica, Crepis foetida, Cistus incanus, Medicago orbicularis, Scabiosa atropurpurea, Scirpoides holoschoenus, Cistus salvifolius, Alkanna tinctoria.*

A special plant community dominated by *Euphorbia paralias* that develops on embryonic shifting dunes and was classified as a separate cluster. It occurs only in Albania and can spread over large areas, but it has not been reported from other countries in the literature.

Cluster 3 *Eryngio-Sporoboletum virginici*
Diagnostic species: *Sporobolus pungens*, *Plantago coronopus*, *Limbarda crithmoides*, *Juncus acutus*.

This community occurs in the first part of dune systems on lower sites that are regularly inundated by the sea, or unstable dunes under the influence of salt spray. It is the most halophytic plant community of the sand dune vegetation. The association is distributed along the whole Albanian coast, with one isolated location in Croatia (island of Mljet).

Clusters 4, 5 and 6 represent the broad transitional association *Agropyretum mediterraneum* (syn. of *Euphorbio paraliae-Agropyretum junceiformis*), characterised by the presence of *Ammophiletea* species (*Echinophora spinosa*, *Elytrigia juncea*, *Cyperus capitatus*), and it is distributed over the whole researched area.

Cluster 4 *Euphorbio paraliae-Agropyretum junceiformis* wet variant
Diagnostic species: *Xanthium orientale* ssp. *italicum*, *Schoenus nigricans*, *Juncus maritimus*.

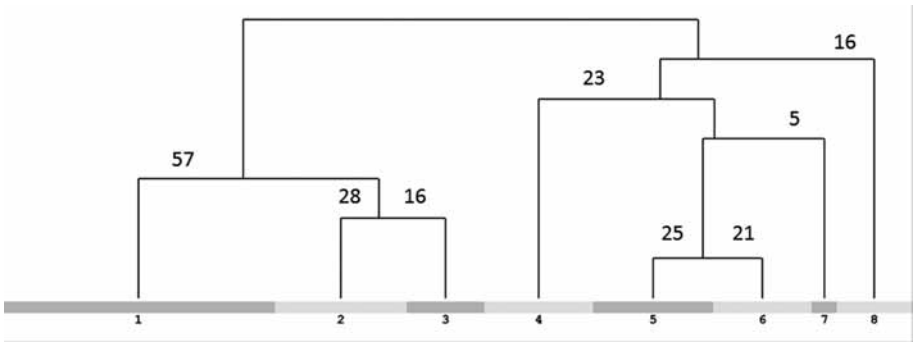

Fig. 2. Simplified dendrogram of relevés of vegetation on sand dunes along the eastern Adriatic coast. The number above the dendrogram branches indicates the number of relevés. 1 – *Cakilo-Xanthietum strumarii,* 2 – *Euphorbia paralias community*, 3 – *Eryngio-Sporoboletum virginici,* 4 – *Euphorbio paraliae-Agropyretum junceiformis* wet variant, 5 – *Euphorbio paraliae-Agropyretum junceiformis otanthetosum maritimi*, 6 – *Euphorbio paraliae-Agropyretum junceiformis typicum*, 7 – *Scabiosa argentea-Ephedra distachya* comm., 8 – *Medicagini marinae-Ammophiletum australis.*

Table 1. Synoptic table of psammophytic vegetation along the eastern Adriatic coast. The first number in the column is frequency in percentage and the second fidelity (phi value multiplied by 100). Among other species only those occurring in more than 8 relevés are presented.

Cluster	1		2		3		4		5		6		7		8	
No. of releves	**57**		**28**		**16**		**23**		**25**		**21**		**5**		**16**	
Diagnostic species																
Salsola kali aggr.	58	11.1	21		6		13		8		38		.		25	
Cakile maritima	74	16.9	46		38		9		20		38		.		.	
Xanthium orientale ssp. *italicum*	81	13.8	96	6.1	50		96	15.2	.		71		40		6	
Euphorbia paralias	35		96	27.4	31		65		12		67		.		62	
Tamarix dalmatica	5		32	19.1	.		.		.		.		.		.	
Crepis foetida	2		54	18.6	.		4		8		10		.		12	
Scirpoides holoschoenus	.		50	11.7	12		.		.		5		60		19	
Alkanna tinctoria	.		43	10.2	.		.		.		24		40		25	
Medicago orbicularis	.		29	14.8	12		.		.		.		.		.	
Cistus incanus	.		29	17.6	.		.		4		.		.		.	
Scabiosa atropurpurea	.		14	13.3	.		.		.		.		.		.	
Cistus salvifolius	.		29	10.7	.		.		28	14.3	.		.		.	
Sporobolus pungens	19		61		100	46.9	13		48		10		.		12	
Plantago coronopus	.		7		38	19.7	.		.		.		.		.	
Limbarda crithmoides	26		14		62	14.9	26		8		14		.		.	
Juncus acutus	.		.		25	11.7	.		.		.		20		.	
Juncus maritimus	2		.		25		26	11.8	.		.		.		.	
Schoenus nigricans	.		.		12		30	11.9	.		.		.		.	
Calicotome villosa	.		.		.		.		20	20.9	.		.		.	
Achillea maritima	4		.		.		.		36	20.8	.		.		.	
Matthiola tricuspidata	.		11		.		.		36	18.8	.		.		.	
Petrorhagia saxifraga	2		.		.		.		36	17.8	5		.		.	
Pinus halepensis	2		.		.		9		24	16.4	10		.		.	
Dorycnium hirsutum	.		.		.		.		20	14.8	.		.		.	
Cladanthus mixtus	.		.		.		.		16	14.1	.		.		.	
Brachypodium retusum	.		.		.		.		16	13.8	.		.		.	
Trifolium campestre	.		.		.		.		16	13.6	.		.		.	
Cyperus capitatus	18		29		38		.		72	10.8	90	14.7	100		50	
Echinophora spinosa	51		86		62		87		88		100	16.2	.		81	
Medicago minima	.		.		.		.		12		33	16.1	.		.	
Ephedra distachya	.		.		.		.		.		.		100	79.2	.	
Scabiosa argentea	.		.		.		.		.		.		100	37.1	.	
Ononis variegata	.		.		.		.		.		.		80	32.6	.	
Plantago crassifolia	.		.		.		.		.		.		60	27.4	.	
Echium plantagineum	.		.		.		.		.		.		60	27.4	.	
Silene conica	.		11		.		4		.		.		80	26.9	6	
Hordeum murinum	.		18		.		.		.		.		60	24.2	.	
Teucrium polium	.		32	6	6		.		16		.		80	21.7	.	
Pseudorlaya pumila	2		21		.		22		8		43		100	18.3	50	
Oenothera biennis	2		.		.		.		.		10		60	14.8	19	
Ammophila arenaria	.		46		6		35		36		24		20		100	57.3
Silene colorata	.		.		.		.		.		.		.		31	19.7
Anchusa undulata	.		.		.		.		.		.		.		25	17.6
Maresia nana	.		18		.		.		.		.		.		38	17.1
Matthiola sinuata	9		14		.		.		.		.		.		38	16.4
Vulpia fasciculata	.		39	4.2	6		4		.		5		60		75	16.4
Glaucium flavum	4		.		.		.		.		.		.		25	16.2
Hordeum marinum	.		.		.		.		.		.		.		19	15.3
Ambrosia maritima	.		.		.		.		.		10		.		25	14.7
Cakiletea maritimae																
Atriplex prostrata	9		4		.		13		.		.		.		.	

Table 1. cont.

Cluster	1	2	3	4	5	6	7	8
No. of releves	**57**	**28**	**16**	**23**	**25**	**21**	**5**	**16**
Euphorbia peplis	33	50	31	4	8	33	.	.
Ammophiletea								
Elytrigia juncea	53	75	44	100	100	100	100	81
Eryngium maritimum	53	71	75	65	64	86	80	88
Calystegia soldanella	7	57	.	26	48	62	.	56
Lagurus ovatus	7	21	12	35	44	33	80	31
Medicago marina	11	57	6	57	24	81	8.5 100	75
Pancratium maritimum	11	21	6	39	36	90	9.2 80	69
Polygonum maritimum	26	43	12	13	.	10	60	25
Scolymus hispanicus	.	11	.	4	12	.	.	6
Others								
Dittrichia viscosa	5	50	7.7 19	.	24	5	40	50
Cynodon dactylon	14	43	6	.	20	19	20	31
Anisantha tectorum	.	14	.	22	12	.	20	31
Crithmum maritimum	14	.	.	.	24	5	.	.
Parapholis incurva	4	11	12	17	16	.	.	.
Cuscuta sp.	14	11	6	4	4	.	.	.
Phragmites australis	12	7	12	4	4	5	.	.
Catapodium rigidum	.	.	.	4	20	5	20	25
Vulpia ciliata	.	14	.	22	.	.	.	12
Arundo donax	11	11	.	.	.	5	.	.
Reichardia picroides	2	7	6	17	.	.	.	12
Imperata cylindrica	4	.	.	.	16	14	20	.
Tribulus terrestris	2	.	.	.	.	14	20	25
Xanthium spinosum	4	.	.	.	12	.	.	25
Medicago littoralis	.	14	.	4	.	.	.	25
Aegilops neglecta	.	11	.	22	9.6 .	.	.	.
Linum strictum	.	.	.	.	16	19	.	.

Species occurring in less than 7 relevés (first figure is cluster number, second is frequency in percentage): *Aethionema saxatile* 5:8; *Agave americana* 4:9; *Amaranthus albus* 8:6; *Amaranthus blitum* 2:4; *Anagallis arvensis* 2:11, 4:4; *Anchusa azurea* 8:13; *Anisantha madritensis* 6:5; *Anisantha rigida* 4:4; *Anthemis chia* 8:13; *Anthemis cotula* 8:6; *Arenaria leptoclados* 8:6; *Asparagus acutifolius* 4:4; *Asparagus maritimus* 8:6; *Atriplex tatarica* agg. 1:4; *Avena barbata* 6:5; *Avena fatua* 2:4; *Avena sterilis* 5:8; *Bituminaria bituminosa* 4:4, 6:10; *Blackstonia perfoliata* 2:7, 4:9; *Briza maxima* 5:8; *Bromus squarrosus* 8:6; *Catapodium marinum* 1:4, 4:4; *Chondrilla juncea* 2:4, 6:19, 7:20, 8:6; *Cichorium intybus* 2:4, 7:20; *Citrullus lanatus* 6:14; *Clematis flammula* 7:20; *Colutea arborescens* 5:4; *Convolvulus* sp. 1:9, 6:5; *Corynephorus articulatus* 5:8; *Crepis setosa* 5:4; *Crepis* sp. 6:5; *Cucumis melo* 6:5; *Cynanchum acutum* 2:5, 3:4; *Dasypyrum villosum* 7:20, 8:6; *Daucus carota* ssp. *major* 5:8; *Daucus guttatus* 8:13; *Daucus* sp. 4:4; *Diplotaxis tenuifolia* 4:9; *Dorycnium pentaphyllum* ssp. *herbaceum* 1:2; *Echium italicum* 5:12; *Elytrigia atherica* 2:4, 3:13, 8:25; *Erigeron canadensis* 4:4, 5:4, 5, 8:19; *Erodium cicutarium* 2:4, 5:8; *Eryngium campestre* 2:4; *Eryngium creticum* 5:4; *Euphorbia peplus* 1:2; *Fumana procumbens* 2:14, 3:6; *Fumana* sp. 5:4; *Halimione portulacoides* 1:2; *Hedypnois rhagadioloides* 1:2, 4:4; *Helianthemum nummularium* 5:12; *Helichrysum italicum* 5:8; *Heliotropium curassavicum* 8:13; *Helminthotheca echioides* 2:11; *Hieracium* sp. 5:8; *Hordeum murinum* ssp. *leporinum* 5:12; *Hyparrhenia hirta* 5:8; *Hypochaeris radicata* 2:7, 5:8, 6:10; *Juncus bufonius* 1:2; *Juniperus oxycedrus* ssp. *macrocarpa* 2:11, 6:5; *Juniperus phoenicea* 5:8; *Knautia integrifolia* 4:4; *Lactuca viminea* 8:6; *Leontodon* sp. 4:4; *Limonium cancellatum* 1:2; *Lolium multiflorum* 1:2, 2:4; *Lonicera implexa* 5:4; *Medicago lupulina* 8:6; *Medicago* sp. 6:5; *Melilotus albus* 5:12; *Melilotus officinalis* 1:2; *Ononis reclinata* 5:4; *Ononis* sp. 4:4, 5:8; *Orobanche* sp. 5:4; *Paliurus spina-christi* 1:2; *Parapholis filiformis* 3:13; *Phillyrea angustifolia* 1:2, 5:8; *Plantago afra* 5:8; *Plantago cynops* 1:4; *Plantago lanceolata* 8:6; *Polypogon monspeliensis* 1:2; *Portulaca oleracea* aggr. 7:20; *Psilurus incurvus* 2:4; *Radiola linoides* 5:8; *Raphanus raphanistrum* 2:7, 3:6, 8:6; *Rapistrum rugosum* 1:2; *Rubus ulmifolius* 7:20; *Rumex crispus* 4:4; *Rumex pulcher* 2:4; *Salsola soda* 1:2, 5:8, 6:10; *Setaria viridis* 6:5; *Sherardia arvensis* 7:20; *Silene vulgaris* 5:4; *Sinapis alba* 2:4; *Solanum nigrum* 8:13; *Sonchus arvensis* 8:6; *Sonchus asper* 2:4; *Sonchus bulbosus* 6:5; *Spergula arvensis* 7:20; *Stachys maritima* 1:2; *Statice oleifolia* 2:7; *Suaeda maritima* agg. 2:2, 3:6; *Symphyotrichum squamatum* 2:2, 4:6, 7:40; *Taraxacum* Sect. *Taraxacum* 6:10; *Torilis arvensis* 5:8; *Tragus racemosus* 4:9, 7:20; *Trifolium angustifolium* 5:4, 7:20; *Trifolium arvense* 5:8; *Tripidium ravennae* 2:14, 5:4; *Verbascum sinuatum* 2:11, 6:5; *Viburnum tinus* 5:4; *Vicia* sp. 5:4; *Vitex agnus-castus* 1:2, 7:40.

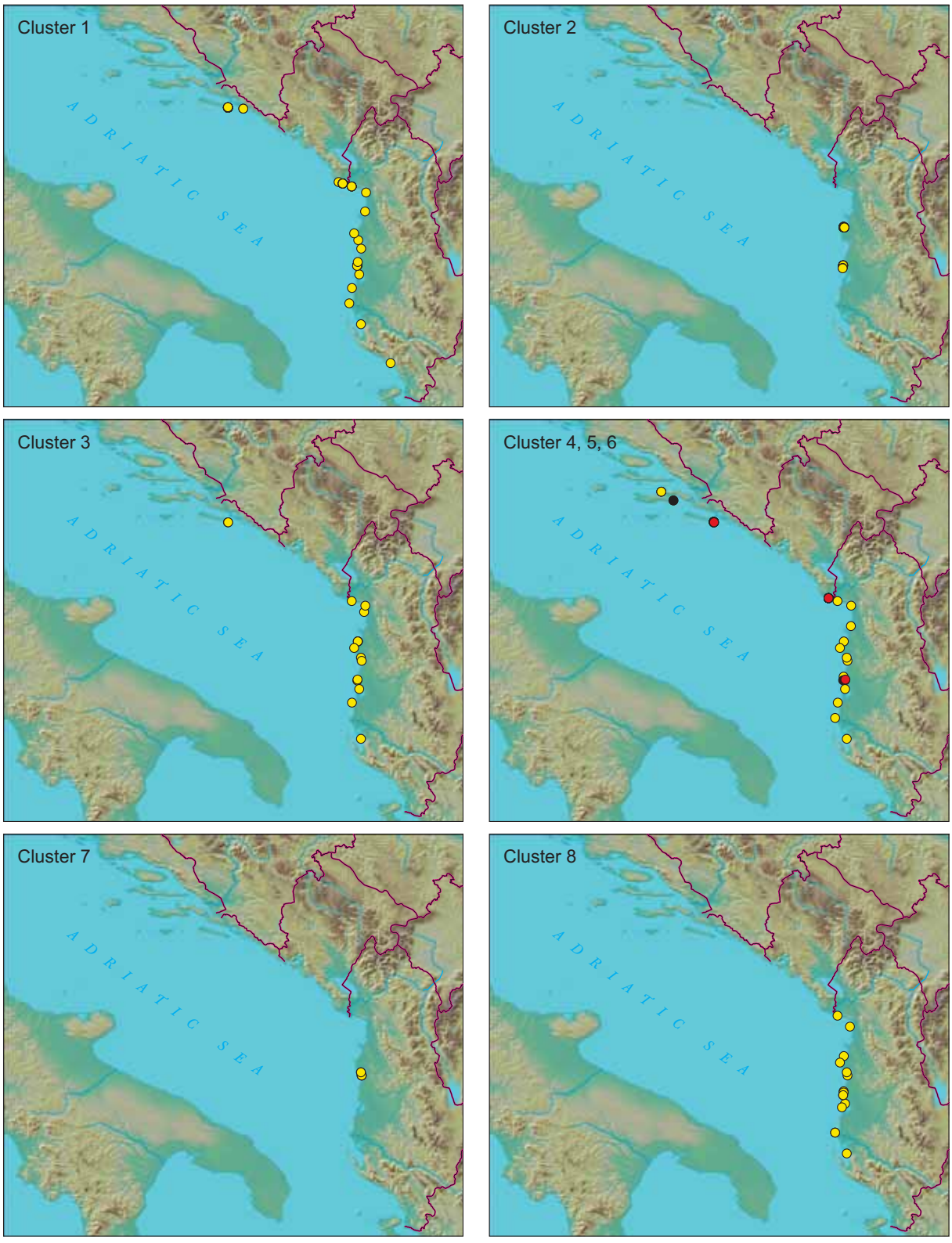

Fig. 3. Distribution maps of clusters of sand dune vegetation. Black-cluster 4, yellow-cluster 5, red-cluster 6.

A wet variant of the *Euphorbio paraliae-Agropyretum junceiformis* with dominant and constant species *Elytrigia juncea* occurs in depressions in which water is retained due to various disturbances (natural or anthropogenic) and is syndynamically related to communities from hind dunes and associations of *Juncetea maritimi* (*Juncetum maritimo-acuti*, *Eriantho-Schoenetum nigricantis*, *Holoschoenetum romani*). Differential species of this variant against the subassociations *otanthetosum* and *typicum* are *Schoenus nigricans* and *Juncus maritimus*, while *Cyperus capitatus* is absent in stands of the wet variant. Stands are found in Croatia, Montenegro and Albania.

Cluster 5 *Euphorbio paraliae-Agropyretum junceiformis otanthetosum maritimi*
Diagnostic species: *Calicotome villosa, Achillea maritima, Matthiola tricuspidata, Petrorhagia saxifraga, Pinus halepensis, Dorycnium hirsutum, Cistus salvifolius, Cladanthus mixtus, Brachypodium retusum, Trifolium campestre, Cyperus capitatus.*

The community thrives on more internal embryonic sand dunes, already stabilized and is a transition towards an *Ammophila* dominated community, with differential species *Achillea maritima*, *Mathiola tricuspidata*, and *Petrorhagia saxifraga*. The subassociation is distributed in Croatia and particularly in Albania, with many locations.

Cluster 6 *Euphorbio paraliae-Agropyretum junceiformis typicum*
Diagnostic species: *Echinophora spinosa, Medicago minima, Cyperus capitatus.*

The typical subtype is found in Croatia, Montenegro and Albania but is limited in Albania to the Gosa area. The typical subassociation is characterized by common *Ammophiletea* species.

Cluster 7 *Scabiosa argentea-Ephedra distachya* community
Diagnostic species: *Ephedra distachya, Scabiosa argentea, Ononis variegata, Plantago crassifolia, Echium plantagineum, Silene conica, Hordeum murinum, Teucrium capitatum, Pseudorlaya pumila, Oenothera biennis.*

The cluster represents a rare plant community dominated by *Ephedra distachya,* found in a limited range along the coast in Albania. It occupies small depressions behind dunes, where the sand is less permeable than in the *Medicagini marinae-Ammophiletum australis*.

The original location at Golem (Kavaja district) was destroyed by the construction of tourist facilities, but similar stands with dominant *Ephedra distachya* were recently found by Mullaj at Rana e Hedhur (Lezha district).

Cluster 8 *Medicagini marinae-Ammophiletum australis*
Diagnostic species: *Ammophila arenaria, Silene colorata, Anchusa undulata, Maresia nana, Vulpia fasciculata, Matthiola sinuata, Glaucium flavum, Hordeum marinum, Ambrosia maritima.*

The *Medicagini marinae-Ammophiletum arundinaceae* develops on higher parts of mobile dunes that have been stabilised by the rhizomatous geophyte *Ammophila arenaria*. It is the final successional stage of herbaceous sand dune vegetation and communities that are located furthest inland are very often affected by tourism or erosion. The association is well developed in Albania, and locations are known in Montenegro (without relevé material).

To underpin the description and allocation of the new plant community of *Scabiosa argentea* and *Ephedra distachya*, we made a comparison of *Crucianellion maritimae* and *Syntrichio ruraliformis-Lomelosion argenteae* associations from the southern Adriatic and Ionian seas along the coasts of Italy, Albania and Greece (Table 2). Communities belonging to these two alliances are found on fixed beach dunes. Diagnostic species of the *Ammophilion* alliance prevail in all associations. The characteristic and dominant species is *Ephedra distachya*, also the only diagnostic species of the *Crucianellion* alliance in this community, while others are lacking. On the other hand, *Scabiosa argentea* links this community to the *Syntrichio-Lomelosion* and more fixed (grey) dunes. Due to the absence of good character species and a small number of known locations so far, we decided to describe these stands as plant community without association rank and classify it within the *Crucianellion maritimae*.

Gradient analysis

Moisture, salinity and nutrients appear to be the most important ecological factors influencing the vegetation composition of sand dunes and their zonation (Fig. 4). They show a strong correlation to the main variation in the species composition of the vegetation. Soil reaction and temperature are less important. From wet, nutrient-rich, lower acidity and higher salinity to dryer, more nutrient-poor, higher acidity, the communities are ordered from left to right as follows: *Cakilo-Xanthietum italici, Eryngio-Sporoboletum virginici, Euphorbio paraliae-Agropyretum junceiformis* (*Agropyretum mediterraneum* s.lat.) and embryonic shifting dunes with *Euphorbia paralias* to *Medicagini marinae-Ammophiletum australis* and the community dominated by *Ephedra distachya.* These communities represent a zonation from the sand deposition zone (clusters 1 and 3) to embryonic foredunes to finally more stabilised dunes (clusters 7 and 8).

The first axis is positively correlated to the most important variables, while the second axis is related to temperature. On the left side of the ordination diagram are grouped vegetation types developed in the zone of deposit of sand (clusters 1 and 3), on the far left are vegeta-

Table 2. Synoptic table of fixed dune vegetation on the Adriatic and Ionian coasts. Frequency in % and range of cover values are given for each species.
1. *Scabiosa argentea-Ephedra distachya* comm.; 2. *Crucianelletum maritimae* Br.-Bl. 1933; 3. *Euphorbio-Sileneetum niceensis* Lavrentiades 1964; 4. *Artemisio variabilis-Ephedretum* Brullo, Giusso Del Galdo, Siracusa & Spampinato 2001; 5. *Ephedro distachyae-Sileneetum subconicae* Oberd. 1952; 6. *Plantagini albicantis-Scabiosetum albae* Brullo, Giusso Del Galdo, Siracusa & Spampinato 2001.

	Group No.	**1**		**2**		**3**		**4**		**5**		**6**	
	No. of releves	**5**		**6**		**21**		**11**		**97**		**7**	
	***Scabiosa argentea-Ephedra distachya* community**												
Ass. 1, 6	*Scabiosa argentea*	100	+-1	.		14	+-1	.		.		100	3-4
Ass. 1, 4, 5	*Ephedra distachya*	100	3-4	.		.		100	3-5	37	+-5	.	
	Crucianellietum maritimae												
	Crucianella maritima	.		100	2-4	.		.		.		.	
	Euphorbio-Sileneetum nicaeensis												
	Silene niceensis	.		.		81	+-1	.		.		.	
	Euphorbia terracina	.		.		95	+-3	91	+-1	.		.	
	Artemisio variabilis-Ephedretum distachyae												
	Artemisia campestris ssp. *variabilis*	.		.		.		100	1-4	.		.	
	Ephedro distachyae-Sileneetum subconicae												
	Jasione heldreichii	.		.		.		.		69	+-4	.	
	Silene congesta	.		.		.		.		62	+-2	.	
	Silene dichotoma	.		.		.		.		32	+-1	.	
	Centaurea cuneifolia	.		.		.		.		78	+-3	.	
	Silene subconica	.		.		.		.		4	+	.	
	Plantagini-Scabiosetum albae												
	Plantago albicans	.		.		.		.		.		86	+-2
	Scabiosa atropurpurea	.		.		.		64	+-1	.		100	2-3
	Ammophilion/Ammophiletalia												
	Ammophila arenaria	20	+	33	+	.		18	+	57	+-4	.	
	Echinophora spinosa	.		50	+-2	.		82	+-2	.		43	+
	Euphorbia paralias	.		.		.		.		16	+-1	.	
	Pancratium maritimum	80	+	.		.		64	+-3	15	+-4	100	+-1
	Calystegia soldanella	.		.		.		.		18	+-3	29	+-1
	Cyperus capitatus	100	+-1	100	+-1	.		45	+-2	65	+-3	29	+
	Eryngium maritimum	80	+-1	17	+	.		45	+-2	60	+-3	.	
	Medicago marina	100	+-1	50	+-1	19	+-1	27	+-1	69	+-3	.	
	Achillea maritima	.		.		.		.		36	+-3	.	
	Sporobolus pungens	.		17	+	10	+	.		16	+-2	100	+-1
	Elytrigia juncea	100	+	83	+-2	10	+	27	1-2	73	r-4	57	+-1
	Helichryso-Crucianelletalia												
	Centaurea sphaerocephala	.		.		62	+-2	.		.		.	
	Helichrysum italicum	.		.		.		82	+-2	.		.	
	Artemisio-Koelerietalia albescentis												
	Helianthemum jonium	.		.		.		.		.		86	+-1
	Phleum arenarium	.		.		.		.		2	+	.	
	Others												
	Pseudorlaya pumila	100	+-1	.		67	+-3	.		8	+	71	+
	Chondrilla juncea	20	+	.		29	+	36	+	31	+-2	.	
	Hypochaeris radicata	.		.		19	+	18	+-1	4	1	.	
	Ononis variegata	80	+-1	.		62	+-2	.		.		29	+
	Lagurus ovatus	80	+-1	.		86	+-2	.		14	+-1	.	
	Vulpia fasciculata	60	+	.		100	+-3	.		20	+-1	.	
	Scirpoides holoschoenus	60	+	33	+	.		.		20	+-4	.	
	Cynodon dactylon	20	+	.		5	+	.		27	+-3	.	

Table 2. cont.

Group No.	1			2			3			4			5			6	
No. of releves	**5**			**6**			**21**			**11**			**97**			**7**	
Dasypyrum villosum	20	+	.				14	+	.				12	+-2	.		
Teucrium polium	80	+	.				.		.				3	+	.		
Hordeum murinum	60	+-1	.				.		.				4	+-1	.		
Dittrichia viscosa	40	+-1	.				.		.				1	+	.		
Cichorium intybus	20	+	.				.		.				4	+	.		
Tribulus terrestris	20	+	.				.		.				3	+	.		
Rubus ulmifolius	20	+	.				.		.				1	+	.		
Spergula arvensis	20	+	.				.		.				2	+	.		
Polygonum maritimum	60	+	.				.		.				11	+-1	.		
Xanthium strumarium	40	+	.				.		.				24	+-1	.		
Alkanna tinctoria	40	+	.				.		.				9	+-1	.		
Anisantha tectorum	20	+	.				.		.				46	+-1	.		
Trifolium angustifolium	20	+	.				10	+-1	.				.		.		
Hedypnois cretica	.		.				100	+-4	.				12	+-1	.		
Nigella arvensis	.		.				29	+-1	.				33	+-2	.		
Trifolium scabrum	.		.				29	1-4	.				6	+-1	.		
Cutandia maritima	.		.				29	+-1	.				.		71	+-1	
Scolymus hispanicus	.		.				24	+-1	18	+	.				.		
Verbascum sinuatum	.		.				19	+-1	45	+-1	.				.		
Lotus creticus	.		.				.		100	1-3	.				43	+	
Matthiola sinuata	.		.				.		36	+	.				86	+-1	

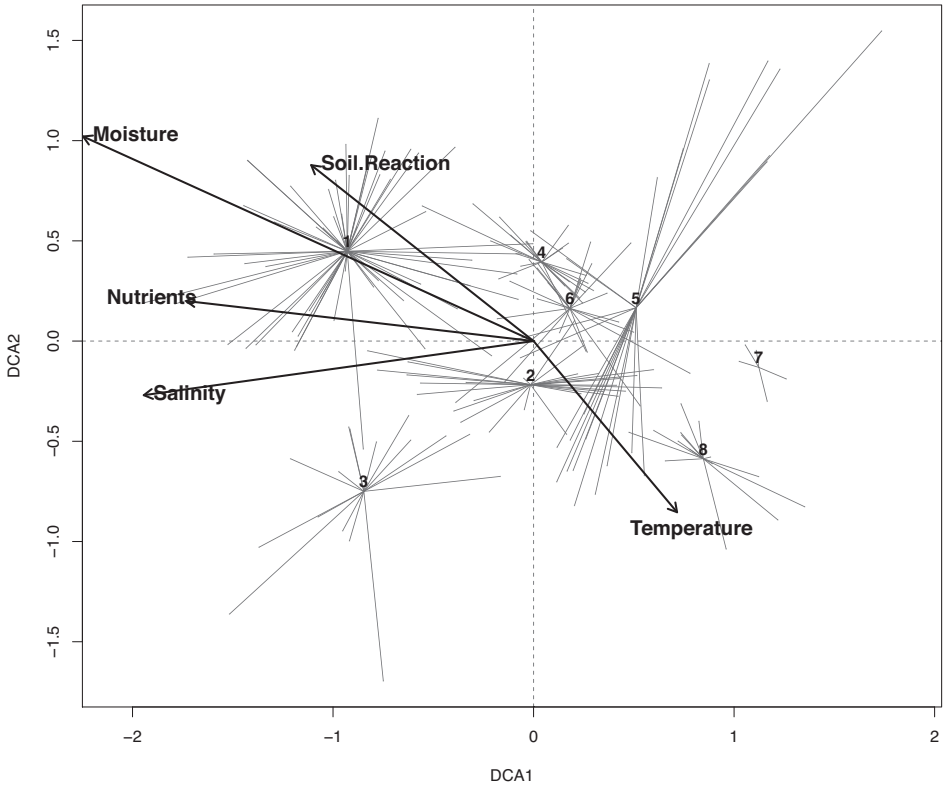

Fig. 4. DCA graph of relevés of sand dune vegetation from the eastern Adriatic littoral Environmental variables were projected onto the DCA diagram. Eigenvalues: 0.3511, 0.2440, 0.2203, 0.1776, gradient length: 3.6865, total inertia: 11.56. Numbers correspond to the centroids of the classified clusters. 1 – *Cakilo-Xanthietum strumarii*, 2 – *Euphorbia paralias community*, 3 – *Eryngio-Sporoboletum virginici,* 4 – *Euphorbio paraliae-Agropyretum junceiformis* wet variant, 5 – *Euphorbio paraliae-Agropyretum junceiformis otanthetosum maritimi*, 6 – *Euphorbio paraliae-Agropyretum junceiformis typicum*, 7 – *Scabiosa argentea-Ephedra distachy*a comm., 8 – *Medicagini marinae-Ammophiletum australis.*

Table 3. Correlation of the DCA axes with ecological factors. Significant codes: '***' 0.001, n. s.: non-significant. Squared correlation coefficient, P values based on 999 permutations.

	DCA1	DCA2	r2	Pr(>r)	Signifi-cance
Temperature	0,642	-0,766	0,078	0,001	***
Moisture	-0,910	0,414	0,381	0,001	***
Soil Reaction	-0,784	0,621	0,125	0,001	***
Nutrients	-0,993	0,115	0,190	0,001	***
Salinity	-0,990	-0,138	0,241	0,001	***
Light	0,990	0,139	0,004	0,687	

tion types on more stabilised foredunes (clusters 7 and 8), while the centre of the graph is occupied by relevés of embryonic foredunes.

Discussion

Syntaxonomy

We compiled all available vegetation relevés from the eastern Adriatic coasts that have been elaborated on, taking the study area as a whole. Previous studies have been restricted to particular beaches or countries (Mullaj 1989, Alegro et al. 2004, Mijović et al. 2012). We demonstrated that the vegetation of sandy shores belongs to six plant communities (Table 1, Fig. 2): *Cakilo-Xanthietum italici* (cluster 1), *Euphorbia paralias* community (cluster 2), *Euphorbio paraliae-Agropyretum junceiformis* (clusters 4-6), *Eryngio-Sporoboletum virginici* (cluster 3), *Medicagini marinae-Ammophiletum australis* (cluster 8) and *Scabiosa argentea-Ephedra distachya* community (cluster 7).

Syntaxonomic overview

Cakiletea maritimae Tx. et Preising ex Br.-Bl. et Tx. 1952
Thero-Atriplicetalia Pignatti 1953
Euphorbion peplidis Tx. ex Oberd. 1952
Cakilo-Xanthietum strumarii (Beg. 1941) Pignatti 1958

Ammophiletea Br.-Bl. et Tx. ex Westhoff et al. 1946
Ammophiletalia Br.-Bl. et Tüxen ex Westhoff et al. 1946
Ammophilion Br.-Bl. 1921
Euphorbio paraliae-Agropyretum junceiformis Tüxen in Br.-Bl. & Tüxen 1952 corr. Darimont, Duvigneaud & Lambinon 1962
Eryngio-Sporoboletum virginici Géhu et Uslu 1989
Euphorbia paralias community
Medicagini marinae-Ammophiletum australis Br.-Bl. 1921 corr. F. Prieto & T.E. Díaz 1991

Helichryso-Crucianelletea maritimae Géhu et al. in Sissingh 1974
Crucianellietea maritimae Sissingh 1974
Crucianellion maritimae Rivas Goday et Rivas-Mart. 1958
Scabiosa argentea-Ephedra distachya community

The typical zonation pattern consists of the following more or less distinct zones: a) zone without vegetation, b) zone of organic/sand deposition, c) embryonic dunes, d) mobile (white) dunes and e) stabilised (grey) dunes (Biondi 2007). Vegetation of cluster 1 is found in zone of deposition, embryonic dunes are colonised by vegetation classified in clusters 2 to 6. Vegetation of cluster 8 thrives on white dunes, while cluster 7 is found on grey dunes. Such complete zonation is not developed at all localities because sand dunes along the northeast Adriatic are narrower (15-20 m; Alegro et al. (2004)) than similar beaches in the southern Adriatic or in parts of Italy and Greece. The vegetation of sand dunes is better developed and richer in species in the south (Trinajstić 1989a).

The *Cakilo-Xanthietum italici* (cluster 1) had not previously been reported in Croatia (Trinajstić 2008), as relevés from the islands of Mljet (Velika and Mala Salunara) and Lopud were grouped with typical stands of this association from Montenegro and Albania in our analysis. Horvat et al. (1974) and Alegro et al. (2004) were of the opinion that the zonation of sand dunes on beaches in the central Adriatic were not typical, the transition is very gradual (orig. clinal) and conditions do not allow the development of the *Cakiletea maritimae* communities, or they are difficult to be recognised as a clearly separated belt. Nevertheless, we are of the opinion that this community is well developed in Croatia, due to the presence of the majority of characteristic species and clear aggre-

gation in cluster analysis with relevés from the southern Adriatic, where this association is typically developed.

The *Euphorbia paralias* community is developed only in Albania, but a similar stand is shown on a photograph from Lopar beach (island of Rab, Croatia) in Morton (1915), which indicates that this plant community was probably distributed along the whole eastern Adriatic coast in the past. Lavrentiades (1964) mentions a variant of the *Agropyretum mediterraneum* with the dominant species *Euphorbia paralias,* in Greece.

The *Euphorbio paraliae-Agropyretum junceiformis* is found along entire east Adriatic coast and shows high floristic diversity with three subcommunities in the researched area: *typicum,* wet variant and *otanthetosum*. In the typical subassociation *Echinophora spinosa* also occurs in stands, with high fidelity and frequency, which is a diagnostic species of the *echinophoretosum* subassociation (Sýkora et al. 2003) found on unstable dune formations adhering to rock, but Peloponnisos is the westernmost border of its distribution. The subassociation *otanthetosum maritimae* Géhu & Biondi 1984 is found on more internal embryonic dunes, which are more stable and continuous, similar to the Italian part of the Adriatic coast (Biondi 2007) and in Greece (Sýkora et al. 2003).

In the zonation (PNV) of east Adriatic sand dune systems, the *Medicagini-Ammophiletum* is usually followed by a stabilised dune occupied by woody vegetation (*Pistacio lentisci-Juniperetum macrocarpae*), while on the southern Ionian coast, the inner slopes of dunes are colonised by *Crucianellion* plant communities (Lavrentiades 1964). Only in two localities at the central Albanian coast, in depressions behind stabilised dunes, was the plant community originally classified as *Ephedretum distachyae* (we are classifying it to the rank of community), found by Mullaj (1989). The community of *Scabiosa argentea* and *Ephedra distachya* is syndynamically linked to the *Ammophilion*, although it has ecological similarities to and characteristic species (*Ephedra distachya, Vulpia membranacea*) of the *Crucianellion* alliance. Mullaj (1989) considered it vicariant to the *Crucianelletum maritimae* Br.-Bl. 1933 of the western Mediterranean and to the *Tortulo-Scabiosetum* Pignatti 1952 of the northern Adriatic (Venetian coast) and similar to the association *Ephedro distachyae-Silenetum subconicae* Oberdorfer 1952 from Greece. Although diagnostic species of the *Ammophilion* alliance prevail in all associations (Table 2) and character species of *Crucianellion* are rare, we decided to classify stands from Albania as a new plant community based also on ecology and physiognomy (Pignatti et al. 1995; Willner 2006) and classify it within the *Crucianellion*.

Our results (with new data from Albania) demonstrate that the diversity of plant communities on sand dunes of the eastern Adriatic is similar to that of the Italian Adriatic and to the Ionian coast in Greece. The diversity of communities and number of characteristic species decreases towards the north, since the coast becomes rocky in Croatia and Slovenia.

Sand dune vegetation is common and widespread along the coasts of Europe, including the whole Mediterranean. Vegetation of sand dunes consists of five to nine associations in Italy (Corbetta et al. 1989; Stanisci et al. 2004; Biondi 2007; Pirone 2014), nine in Greece (Lavrentiades 1964; Sýkora et al. 2003), five in Turkey (Géhu et al. 1989) and also five in the eastern Adriatic (Table 4). All plant communities are usually not present at the same locality due to natural and human disturbances that influence and change zonation. All five associations are not present in Croatia, where sand dunes are rare and most impacted by human activities (Korica & Lovrić 1979) but, in Albania, in the south of the researched area, they are well developed (Fig. 5), but the community of *Scabiosa* and *Ephedra distachya* occurs only locally.

Comparing plant communities and their zonation on the Italian Adriatic coast, it is obvious that some are rarer or missing on the eastern coast, e.g., communities of *Crucianellion maritimae* and *Malcolmietalia* Rivas Goday 1958. *Crucianellion maritimae* is typical vegetation on back dunes or interdunes of mobile dunes (Stanisci et al. 2004). In Greece, stands of *Crucianellion* are well developed on northern coasts and on the Peloponnisos (Sýkora et al. 2003), whereas along the Adriatic coasts in Italy, the alliance is known only in Puglia (Pirone 2014). For Albania, we found a *Crucianellion* plant community that has not previously been published and this vegetation type is not present further north along the eastern Adriatic coast. Sand dunes on the north Adriatic coast (Veneto) are specific, with various species compositions and influenced by the continental climate. Similar communities on back dunes were classified into *Syntrichio ruralis-Lomelosion argenteae* Biondi, Sburlino & Theurillat in Sburlino, Buffa, Filesi, Gamper & Ghirelli 2013 are also found in the south on the Ionian coast of Puglia, but are not present along the eastern Adriatic coast.

Vegetation of the *Malcolmietalia*, which comprises of ephemeral therophytic dune vegetation, is present only on the Italian coast (Pirone 2014) and has a western and southern Mediterranean distribution. On the other hand, other communities that are found on interdunal depressions (*Juncetum maritimo-acuti* Horvatić 1934, *Eriantho-Schoenetum nigricantis* (Pignatti 1953) Géhu in Géhu, Scoppola, Caniglia, Marchiori et Géhu-Franck 1984, *Holoschoenetum romani* Tchou 1948) are developed only in Montenegro and Albania, where sand beaches are wider, while in Croatia they are found in other habitats, e.g., salinas.

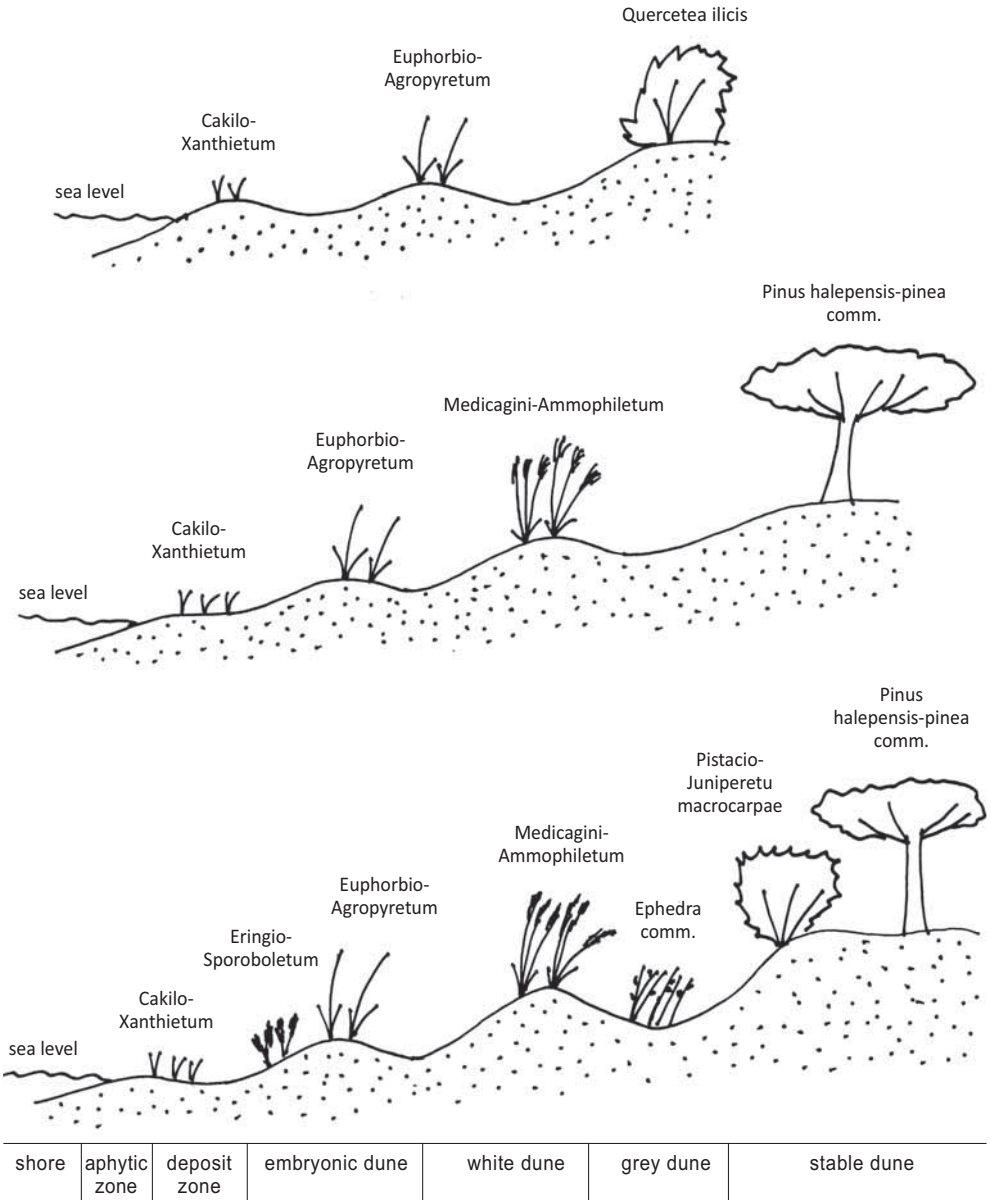

Fig. 5. Scheme of typical zonation of sand dune vegetation along east Adriatic coast from north to the south.

Conservation

Coastal areas and sandy beaches are very valuable from a nature conservation point of view, since they represent a mosaic of plant communities with high biodiversity. Many sand dune ecosystems are listed in habitats of European interest in Annex I of the Habitats Directive (Heslenfeld et al. 2004). The habitat types that appear on beach and mobile dunes in the researched area are presented in Table 4. In the future some of them should be translated into new types: 'Dunes along the Mediterranean shoreline with *Ammophila arenaria*' (new code 2280) and 'Mediterranean embryonic dunes' (new code 2290) proposed by Feola et al. (2011). Several other habitat types which also occur along Mediterranean coasts are found on more stabilized dunes in Albania and partly in Montenegro: 'Coastal dunes with *Juniperus* ssp.' (2250), and 'Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*' (2270*).

There is an urgent need for protection of these habitats on the eastern Adriatic coast. Some steps have already been taken in Croatia, where Velika and Mala Saplunara and Blace Bay (island Mljet) have been protected in the category of Protected Landscape Area since 1965 (Alegro et al. 2004) and in Montenegro, where part of Velika plaža has been protected as a Resort of Natural Landscape since 1968 (Official Gazette SRCG 30/ 68). Furthermore, the majority of the typical sandy coast species are Red listed in Croatia (Nikolić & Topić 2005). However, these categories do not provide sufficient active protection.

Table 4. Plant communities on dune systems in various countries. Association names are original as stated by authors. Italics indicate syntaxa new to country and bold indicates syntaxa present in each country and confirmed in our study.

	NATURA 2000 habitat type	CRO (Korica & Lovrić 1979, Trinajstić 2008)	MNE (Blečić & Lakušić 1976, Mijović et al. 2012)	AL (Dring et al. 2002)	GR (Sýkora et al. 2003)	I (Pirone 2014)
Zone without vegetation						
Deposition zone (drift line zone)	Annual vegetation of drift lines 1210	***Cakilo-Xanthietum strumarii***	***Cakilo-Xanthietum strumarii***	***Cakilo-Xanthietum strumarii***	*Cakilo-Xanthietum strumarii* *Salsolo kali-Cakiletum maritimae*	*Salsolo kali-Cakiletum maritimae*
Embryonic dune		***Sporoboletum***	***Echinophoro-Elymetum farcti***	***Eryngio-Sporoboletum virginici***	*Eryngio-Sporoboletum virginici*	*Sporoboletum*
	Embryonic shifting dunes 2110	***Echinophoro-Elymetum farcti***		***Euphorbio paraliae-Agropyretum junceiformis***	*Cypero mucronati-Agropyretum juncei* *Echinophoro-Elymetum farcti othanthetosum*	*Echinophoro-Elymetum farcti*
White dune (yellow dune)	Shifting dunes along the shoreline with *Ammophila arenaria* 2120	Ammophiletum australis (extinct)	*Ammophiletum australis* (no relevés)	***Medicagini marinae-Ammophiletum australis***	*Medicagini marinae-Ammophiletum*	*Echinophoro-Ammophiletum australis* *Sileno-Vulpietum*
Grey dune	*Crucianellion maritimae* fixed beach dunes 2210			***Scabiosa argentea-Ephedra distachya comm.*** (syn. *Ephedretum distachyae* Mullaj nom. inedit.)	*Euphorbio-Silenetum nicaeensis* *Ephedro distachyae-Silenetum subconicae* *Crucianellietum maritimae*	*Crucianellietum maritimae* *Artemisio variabilis-Ephedretum distachyae* *Plantagini albicantis-Scabiosetum albae*
	Fixed coastal dunes with herbaceous vegetation (grey dunes) 2130*					*Tortulo-Scabiosetum albae* (endemic N Adriatic)

There is therefore an urgent need to raise the level of protection to Special Botanical Reserve. Sandy beaches in Albania that are still in good condition but are under strong human influence, mainly by increasing tourism, are especially worth protection, particularly sand dunes in Kune-Vain, Patok and Divjakë.

Author contribution

The text was written by U.Š., who also conducted the main part of the statistical analysis. U.Š, Z.D.S, A.I., A.M., M.L. conducted field sampling of unpublished material in Albania. All authors endorsed the presentation and interpretation of the field work data and approved the final manuscript.

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Appendix

Relevé data source in database:
Alegro et al. (2004): 33 rel., Croatia; Alegro et al. (2003): 4 rel., Croatia; Fanelli et al. (2015): 4 rel., Albania;, Imeri et al. (2010): 21 rel., Albania; Mijović et al. (2006): 15 rel., Montenegro; Mijović et al. (2012): 18 rel., Montenegro; Mullaj (1989): 51 rel., Albania; Šilc et al. (unpublished): 25 rel., Albania; Trinajstić (1973): 2 rel., Croatia; Trinajstić (1989b): 7 rel., Montenegro; Trinajstić (1995): 5 rel., Croatia; Trinajstić & Jasprica (1998): 6 rel, Croatia.

Unpublished relevés (25) were made by U.Š., M.L. and Z.S.D. in June 2014 in Gosa area in Albania of following syntaxa: *Cakilo-Xanthietum strumarii, Euphorbia paralias* community, *Eryngio-Sporoboletum virginici*, *Euphorbio paraliae-Agropyretum junceiformis,* and *Medicagini marinae-Ammophiletum australis*. Plot size varies between 6 and 150 m^2, with average of 44 m^2.