Biologia, Bratislava, **59**/4: 435—445, 2004

Psammo-halophytic vegetation on the largest sand area on the Croatian coast: the island of Mljet, southern Adriatic

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Alegro, A., Biljaković, M., Bogdanović, S. & Boršić, I., Psammo-halophytic vegetation on the largest sand area on Croatian coast: The island of Mljet, southern Adriatic. Biologia, Bratislava, **59:** 435—445, 2004; ISSN 0006-3088.

Results of syntaxonomical research of coastal psammo-halophytic vegetation, rare and endangered on Croatian coast, have been studied. The plant formations are developed on the deposits of silicate sand on the south-east part of the island of Mljet. They belong to the class *Ammophiletea* Br.-Bl. et Tx. ex Westhoff, Dijk et Passchier 1946 and are the most intact in the whole Croatian part of the Adriatic.
The phytosociological relevés were analysed using the standard central-European phytosociological and statistical (cluster analysis and PCA) methods. Phytosociological analysis has shown that the studied vegetation can be classified into the association *Echinophoro spinosi-Elymetum farcti* Géhu 1988. However, detailed analysis has shown the existence of four subgroups within the studied vegetation depending on the distance from the sea: vegetation with prevalence of *Cakiletea maritimae* species, fragmentarily developed ass. *Echinophoro-Elymetum farcti*, typically developed ass. *Echinophoro-Elymetum farcti,* and vegetation transitive to garrigues. In this plant community there are many rare and endangered species of Croatian flora included in the Red Data Book.

Key words: *Ammophiletea*, coastal vegetation, halophyte, psammophyte, Croatia.

Introduction

In the Adriatic region the psammo-halophytic vegetation of the class *Ammophiletea* is predominantly restricted to the western Italian coast, which is low and sandy with shallow littoral sea (Trinajstić et. al., 1998). Croatian part of the Adriatic coast is predominantly rocky and steep with 84% of shorelines included in the coastal karst (Lovrić, 1993). Because of the geological structure of the Croatian coast the sandy shores are a very rare type of habitat moreover, endangered by tourism. Hence, psammophytic vegetation is developed fragmentarily in a few small isolated patches: Lumbarda on the island of Korčula (Trinajstić, 1973), Nin near Zadar (Trinajstić, 1989), Lopar on the island of Rab (Horvatić, 1939), Prž ina on the Pelješac peninsula,

Šunj Cove on the island of Lopud (Trinajstić et al., 1998) and Saplunara on the island of Mljet (Trinajstić, 1995; Trinajstić et al., 1998). The largest area covered with the most complete psammophytic vegetation is developed on the island of Mljet: in Blace, Velika Saplunara and Mala Saplunara bays.

According to the protection strategy and action plans of the Republic of Croatia (Martinić ed., 2000), sandy coasts are among the critically threatened coastal habitats. Protection of Saplunara and Blace bays is one of the priorities for the action plans for protection of coast and islands.

Area of investigation

The south Dalmatian island of Mljet has the area of 100 km^2. In their geological structure limestone and dolomites from the cretaceous period are predominant and form mainly low and rocky coast. Steep cliffs are developed mostly along the south coast, but on the easternmost part of the island diluvial sands are also present. They form sandy beaches, very rare type of habitat on the coast of Croatia.

The island has true Mediterranean climate with the lowest average temperature of 8.1 °C in January and the highest average temperature of 24.8 °C in July. Average annual amount of precipitation is 973 mm and there are 2 500 sunny hours per year (Bralić, 1995).

Mljet is covered mainly with eu-mediterranean vegetation (evergreen area of the *Quercion ilicis* woods and macchias) but its southwest and southeast parts belong to the thermo-Mediterranean subzone of *Ceratonio-Quercion* macchias, including *Pinus halepensis* woods (Bertović & Lovrić, 1992). The area of 31 km^2 in the west part of the island was proclaimed for the national park in 1960. The flora of Mljet is well researched (cf. Regula-Bevilacqua & Jurković-Bevilacqua, 1980; Regula-Bevilacqua et al., 1981; Ilijanić & Regula-Bevilacqua, 1982; Ilijanić et al., 1983; Regula-Bevilacqua & Ilijanić, 1984; Trinajstić, 1985; Pavletić, 1995) and until now 716 vascular plant taxa have been recorded.

The research included three sandy beaches positioned in two bays on the easternmost part of the island:

i) Blace is a small bay almost completely closed and separated from the open sea, with 500 m long (averagely 50 m wide) sickle-like sandy beach in the middle. Connection with the sea is restricted to one narrow passage. This situation provides very still water and unobstructed sedimentation of sand; ii) Velika (Big) Saplunara is 150 m long, (19 m wide); and iii) Mala (Small) Saplunara 50 m long (17 m wide) sandy beach, both positioned on the bottom of a bay which is more exposed to the open sea than of bay Blace. All three beaches are more or less exposed to the south and the influence of tides, currents and waves is very weak in these bays.

The Nature Protection Act of the Republic of Croatia provides special protection of this area in the category of Protected Landscape Area.

Material and methods

33 vegetation relevés with plot size 3 × 10 m were made at different distances from the sea during June and October of 2001. Elongated form of plots, parallel with the coastline, was chosen in order to avoid the intersection of ecological clines. The relevés were made using the Zürich-Montpellier School for data sampling i.e. 7-degree Braun Blanquet's scale (Braun-Blanquet, 1964; Dierschke, 1994). Before the processing abundance-cover indices of species were transformed into the ordinal scale (Van den Maarel, 1979). In addition, the values were adjusted to mean (Pfadenhauer, 1997) for the PCA. The results are presented in the graph with the first and the second PC axes (Fig. 3).

Bray & Curtis distance measured as percent dissimilarity, was used as distance measure and unweighed pair group method as clustering method (Jongman et al., 1995).

Older relevés from Croatia (Horvatić, 1939; Trinajstić, 1973, 1989, 1995, 1998) are not included in this analysis. In all cited papers the distance of relevés from the sea is not quoted. Furthermore, the plot surfaces are unequal, they differ from 10–500 m^2. Therefore, they cannot be satisfactorily compared with our relevés.

Our relevé B15 from Tab. 1 is also not included in the statistical analysis. This relevé comprises only two species. One of them, *Sporobolus pungens*, is present only in this relevé and statistical comparison with other relevés is excessive. This relevé is important because of *Sporobolus pungens*, the rare and critically endangered species in the flora of Croatia.

PcOrd 4.0 for Windows was used for statistical analysis.

The standard keys for determination of plants were used (Horvatić, 1954; Tutin et al., 1968–1980, 1993; Pignatti, 1982). The nomenclature of plant taxa was in accord with Nikolić ed. (1994, 1997, 2000). The system of characteristic species and nomenclature of higher syntaxa was accepted from Horvat et al. (1974).

Results

According to the floristic composition (Tabs 1, 2) studied vegetation can be generally classified to the association *Echinophoro spinosi-Elymetum farcti* Géhu 1988 (alliance *Ammophilion australis* Br.-Bl. (1931) 1933 em. J. M. et J. Géhu 1988, order *Ammophiletalia australis* Br.-Bl. (1931) 1943 em. J. M. et J. Géhu 1988, class *Ammophiletea* Br.-Bl. et Tx. ex Westhoff, Dijk et Passchier 1946). Eu-mediterranean species

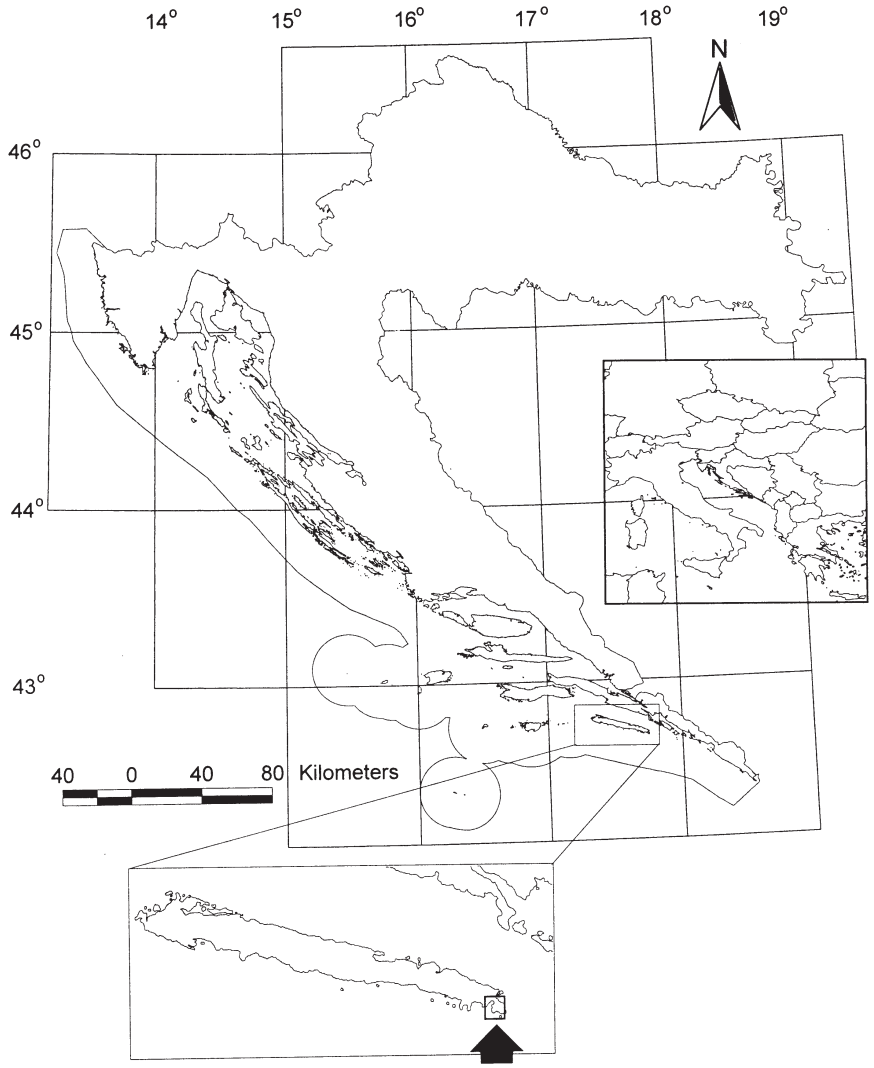

Fig. 1. The location of the investigated area on the island of Mljet.

Echinophora spinosa is designated as characteristic species and it is abundantly present in the studied area. Together with other Mediterranean species, e. g. *Pancratium maritimum*, *Pseudorlaya pumila*, *Lagurus ovatus*, *Cyperus capitatus*, *Medicago marina*, it makes this azonal plant community floristically different from the similar Atlantic coastal vegetation on sand dunes.

The studied vegetation forms a belt along the seashore with average width of 15–20 m. The soil substrate is composed of Pleistocene quartz sand with small portion of carbonate particles originating from crushed mollusk shells. The sand is brown to deep brown colored, fine-grained and without clay particles. The sand deposits are deep from 30 cm to few meters. Below the thin sand strata on the edges of the Blace bay the terra rossa sediments can be found. Generally, the soil is almost completely without organic material, except the zone where the sea deposits the remnants of *Posidonia oceanica* (L.) Delile and different species of algae (predominantly *Cystoseira* spp.). The area has no water springs or flows and it is completely dependent on rain and sea water supply. There are no significant influence of domesticated or wild animals on the vegetation and soil, while the human

Table 1. Floristic composition and syntaxonomy of psammo-halophytic vegetation on the island of Mljet. (VS – Velika Saplunara; MS – Mala Saplunara; B – Blace)

subgroup symbol	+	+	+	+	+	+	+	◇	◇	◇	◇	◇	◇	◇	◇	◇	x	x	x	x	x	x	x	x	x	x	○	○	○	○	○	○
subgroup				1.1								1.2										2							3			
releve No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
releve mark	VS4	VS5	VS3	VSs	MS2	VS2	MS4	B9	B13	B16	B12	B8	B19	B11	B3	B4	B2	MS1	VS7	MS3	B7	B5	B6	B21	B22	B1	B15	B10	B14	B17	VS6	B20	B18
distance from the sea/m	14	15	18	16	17	19	12	20	27	34	21	18	21	18	12	14	8	13	11	9	15	5	8	7	11	4	3	25	35	44	18	26	50
***Echinophpro-Elymetum farcti* GEHU 1988**																																	
Echinophora spinosa L.	2	2	1	1	r	+	+	2	2	2	1	+	1	r	r	+	r	.	.	.	+	+	.	+	+	.	.	1	1	r	+	+	.
Ammophiletea Br.-Bl. et Tx. **ex Westhoff, Dijk et Passchier 1946**																																	
Elymus farctus (Viv.) Runemark ex Melderis	2	2	2	2	1	3	1	2	2	2	1	1	+	+	r	2	.	r	+	r	.	.	.	.	.	.	.	1	1	1	r	+	+
Eryngium maritimum L.	.	+	r	+	r	1	r	r	.	r	1	1	1	.	2	.	2	1	+	1	2	.	.	.	+	.	.	+	.	.	.	+	.
Cyperus capitatus Vandelli	r	1	.	1	r	.	r	+	2	1	3	+	r	1	1	r	r/1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.
Pancratium maritimum L.	r	r	+	+	1	r	3	+	.	r	+	+	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	r	.	+	r	.	.
Euphorbia paralias L.	r	.	1	+	+	+	.	+	.	+	.	+	.	+	.	.	+	.	+	.	.	+	1	.	.	.	.	.	.	.	.	.	.
Medicago marina L.	1	2	1	1	r	1	r	.	1	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	r	.	.	r	.	.
Calystegia soldanella (L.) R. Br.	1	r	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudorlaya pumila (L.) Grande	1	r	r	+	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	+
Lagurus ovatus L.	+	r	.	+	.	r	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	+	+	.	.
***Cakiletea maritimae* Tx et Prsg 1950**																																	
Xantium strumarium L.	.	+	.	.	+	.	.	r	.	r	.	r	r	r	.	.	+	1	+	+	.	r	r	+	r	+	+	.	.	.	.	.	.
Cakile maritima Scop.	1	+	r	.	r	+	.	.	.	.	+	+	r	r	.	.	.	2	1	1	+	r	1	+	.	.	.	.	.	+	.	.	.
Salsola kali L.	.	.	.	+	.	+	.	.	.	.	+	+	.	+	.	.	.	r	.	r	+	r	1	.	+	.	.	.	.	.	.	.	.
Euphorbia peplis L.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	.	.	r	.	+	1	.	.	.	.	.	.	.	.	.
Atriplex prostrata Bouch. ex DC.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 1. (continued))

subgroup symbol	+	+	+	+	+	+	+	◇	◇	◇	◇	◇	◇	◇	◇	◇	x	x	x	x	x	x	x	x	x	x	x	○	○	○	○	○	○
***Quercetea ilicis* BR.-BL. 1947.,**																																	
***Thero-Brachypodietea* BR.-BL. 1947.**																																	
Cistus salviifolius L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1	r	1	1
Calycotome infesta (C. Presl) Guss.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	2	2	1
Petrorhagia saxifraga (L.) Link	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r	r	+	r	.
Brachypodium retusum (Pers.) P. Beauv.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	r	.	r
Dorycnium hirsutum (L.) Ser. in DC.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	r
Teucrium capitatum L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	r	.	.
Helianthemum nummularium (L.) Mill.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	+
Phyllirea angustifolia L.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Pinus halepensis Miller	.	+	.	+	r	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	.	.	1	+
Companions																																	
Convolvulus sp.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	r	+	1	.	.	+	.	.	.	.	.	.	.
Crithmum maritimum L.	.	.	.	.	r	.	.	.	.	.	.	r	.	.	+	+	.	.	.	r	.	.	.	+	r	.	.	+	.	.	.	.	.
Inula crithmoides L.	.	.	1	.	r	1	.	+	.	.	.	2	.	.	1	1	+	+	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Phragmites australis (Cav.) Trin. ex Steud.	.	.	.	.	r	r	+	.	.	.	.	.	.	.	+	.	1	+	.	.	.	r	.	.	.	1	.	.	.	.	.	.	.
Imperata cylindrica (L.) Raeuschel	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	1	+
Linum strictum L.	r	r	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r	.	.	.
Ononis sp.	.	.	.	.	.	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Helichrysum italicum (Roth) G. Don f.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	1
Bituminaria bituminosa (L.) Stirton	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium sp.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.

4: + *Avena barbata* Pott ex Link, + *Bromus madritensis* L., + *Medicago* sp.; 5: + *Reichardia picroides* (L.) Roth; 6: + *Dorycnium herbaceum* Vill.; 7: 1 *Colutea arborescens* L., + *Viburnum tinus* L., + *Saccharum ravennae* (L.) Murray, r *Trifolium angustifolium* L., r *Trifolium campestre* Schreber in Sturm; 13: + *Vitex agnus-castus* L.; 18: + *Limonium anfractum* (Salmon) Salmon; 22: + *Xantium spinosum* L.; 26: + *Cynodon dactylon* (L.) Pers.; 27: 4 *Sporobolus pungens* (Schreb.) Kunth; 28: 1 *Cistus incanus* L., + *Cuscuta* sp., r *Lonicera implexa* Aiton; 29: r *Juniperus phoenicea* L.; 32: + *Silene vulgaris* (Moench) Garcke; 33: + *Orobanche* sp.

Table 2. Synthetic table for Echinophoro-Elymetum farcti Gehu 1988 (columns 1.1, 1.2, 2 and 3 represent relevés from the researched area; columns 4, 5 and 6 releves from Corsica; and columns 7 and 8 relevés from Sicily).

subgroup symbol	+	◇	x	◯					
subgroup	1.1	1.2	2	3	4	5	6	7	8
number of rel.	7	10	10	6	29	21	15	9	18
***Echinophoro-Elymetum farcti* Gehu 1988**									
Echinophora spinosa L.	V	V	II	V	IV	V	IV	II	V
Elymus farctus (Viv.) Runemark ex Melderis	V	V	II	V	V	V	V	V	V
Anthemis maritima L.	.	.	.	.	II	IV	IV	.	.
Ammophiletea Br.-Bl. et Tx. ex **Westhoff, Dijk et Passchier 1946**									
Eryngium maritimum L.	V	IV	III	II	V	V	IV	I	V
Cyperus capitatus Vandelli	IV	V	.	I	I	II	III	.	II
Pancratium maritimum L.	V	II	I	II	II	I	I	II	V
Euphorbia paralias L.	IV	III	II	.	III	III	I	IV	II
Medicago marina L.	V	I	I	I	I	I	V	I	II
Calystegia soldanella (L.) R. Br.	IV	.	I	.	IV	II	II	.	I
Pseudorlaya pumila (L.) Grande	IV	.	.	I	.	.	.	.	I
Lagurus ovatus L.	IV	.	.	II	.	.	.	.	.
Sporobolus pungens (Schreber) Kunth	.	.	.	.	IV	IV	IV	III	III
Polygonum maritimum L.	.	.	.	.	II	I	II	.	.
Ammophila arenaria (L.) Link	.	.	.	.	I	II	II	III	I
Otanthus maritimus (L.) Hoffmanns. Et Link	.	.	.	.	II	V	II	IV	IV
Stachys maritima Gouan	.	.	.	.	.	I	II	.	.
Crucianella maritima L.	.	.	.	.	.	.	II	I	II
Cutandia maritima (L.) W. Barbey	.	.	.	.	II	II	IV	.	III
Matthiola sinuata (L.) Br.	.	.	.	.	I	I	II	.	.
Silene nicaeensis All.	.	.	.	.	I	I	I	.	I
Scolymus hispanicus L.	.	.	.	.	.	.	.	.	III
Launaea resedifolia O. Ktze.	.	.	.	.	.	.	.	II	II
Ononis variegata L.	.	.	.	.	.	.	.	II	II
***Cakiletea maritimae* Tx et Prsg 1950**									
Xantium strumarium L.	II	III	V	.	II	II	II	.	.
Cakile maritima Scop.	IV	II	IV	I	II	II	II	IV	II
Salsola kali L.	II	II	III	.	II	I	I	IV	III
Euphorbia peplis L.	.	II	II	.	II	.	I	III	.
Atriplex prostrata Bouch. ex DC.	.	.	I	.	.	.	.	.	.
Glaucium flavum Crantz.	.	.	.	.	I	.	II	.	I
***Quercetea ilicis* Br.-Bl. 1947., *Thero-Brachypodietea* Br.-Bl. 1947.**									
Cistus salviifolius L.	.	.	.	V	.	.	.	.	.
Calycotome infesta (C. Presl) Guss.	.	.	.	V	.	.	.	.	.
Petrorhagia saxifraga (L.) Link	II	.	.	V	.	.	.	.	.
Brachypodium retusum (Pers.) P. Beauv.	.	.	.	IV	.	.	.	.	.
Dorycnium hirsutum (L.) Ser. in DC.	.	.	.	IV	.	.	.	.	.
Teucrium capitatum L.	.	.	.	III	.	.	.	.	.
Helianthemum nummularium (L.) Mill.	.	.	.	II	.	.	.	.	.
Phyllirea angustifolia L.	I	.	.	II	.	.	.	.	.
Pinus halepensis Miller	IV	.	.	IV	.	.	.	.	.
Lonicera implexa Aiton	.	.	.	I	.	.	.	.	.
Cistus incanus L.	I	.	.	I	.	.	.	.	.
Convolvulus sp.	.	I	II	.	.	.	.	.	.
Crithmum maritimum L.	I	II	II	I	.	.	.	.	.
Inula crithmoides L.	III	III	II	.	.	I	I	.	.
Phragmites australis (Cav.) Trin. ex Steud.	III	I	II	.	.	.	.	.	.
Imperata cylindrica (L.) Raeuschel	.	.	I	II	.	.	.	.	.
Linum strictum L.	III	.	.	II	.	.	.	.	.
Juniperus phoenicea L.	.	.	.	I	.	.	.	.	.
Ononis sp.	II	.	.	I	.	.	.	.	.
Helichrysum italicum (Roth) G. Don f.	.	.	.	II	.	I	I	.	.
Bituminaria bituminosa (L.) Stirton	II	.	.	.	.	.	.	.	.
Hieracium sp.	I	.	.	I	.	.	.	.	.

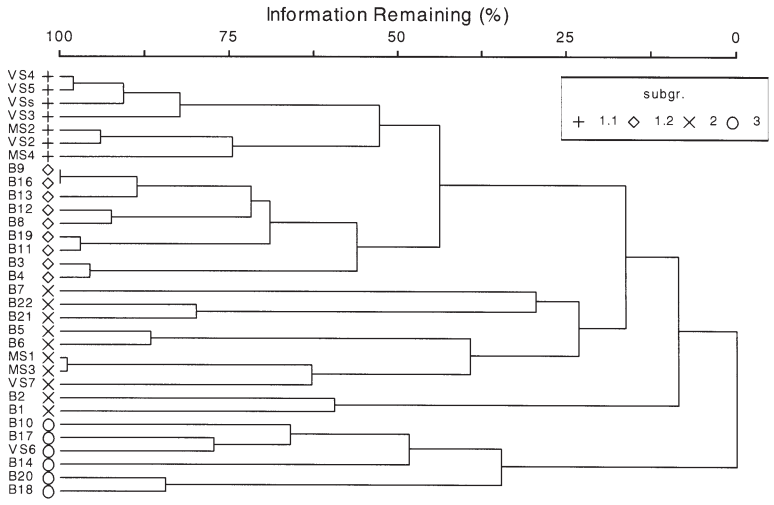

Fig. 2. Dendrogram (percent dissimilarity, UPGMA) of phytosociological relevés: 1.1. Typically developed ass. *Echinophoro-Elymetum farcti*, 1.2. Fragmentarily developed ass. *Echinophoro-Elymetum farcti*, 2. Vegetation with prevalence of *Cakiletea* species, 3. Vegetation transitive to garrigues. (VS – Velika Saplunara; MS – Mala Saplunara; B – Blace)

impact in the last decade is increasing because the island of Mljet has become attractive for tourism.

In spite of the fact that the studied vegetation had developed on a very small area, detailed research of floristic composition showed the existence of subunits and the presence of species characteristic of other syntaxonomic units. Classification of phytosociological relevés is presented in Fig. 2. Four major vegetation groups are designated. Distance from the sea i. e. decreasing influence of the sea water is the major reason for the vegetation zonation. The following zones are distinguishable: the zone with typically developed ass. *Echinophoro-Elymetum farcti*; the zone with fragmentarily developed ass. *Echinophoro-Elymetum farcti*, with the presence of species characteristic of the class *Cakiletea maritimae*; the zone with predominance of *Cakiletea maritimae* species; and the zone with fragmentarily developed ass. *Echinophoro-Elymetum farcti*, with plant species characteristic of garrigues, which is the least influenced by the sea. The differences in frequencies of plant species between the described groups are perceptible from synthetic table (Tab. 2).

1. Ass. *Echinophoro-Elymetum farcti*

The largest homogenous group of relevés (1.1 and 1.2 in Figs 2, 3 and Tab. 1) presents ass. *Echinophoro-Elymetum farcti*. It is the vegetation developed in the open, superficially mobile and dry, with relatively deep sand deposits without humus. Furthermore, this group is divided in two additional subgroups differentiated as a consequence of unequal sea influence. The first subgroup (1.1) comprises the relevés of typically developed association from Velika and Mala Saplunara and the second subgroup (1.2) comprises the relevés of more or less fragmentarily developed association from Blace bay.

1.1. Typically developed ass. *Echinophoro-Elymetum farcti*

The vegetation of ass. *Echinophoro-Elymetum farcti* in Velika Saplunara (1.1 in Figs 2, 3 and Tab. 1) grows along a low primary sand dune 12–19 m distant from the sea. This elevated position hinders direct influence of salt and organic material from the sea water. Therefore, the association is more completely developed than in Blace bay, with numerous characteristic species and their higher abundance-cover indices. High frequencies of *Elymus farctus*, *Eryngium maritimum*, *Pancratium maritimum*, *Medicago marina*, *Cyperus capitatus*, *Calystegia soldanella* and others are significant. The portion of the species from nitrophilous class *Cakiletea maritimae* is very low.

1.2. Fragmentarily developed ass. *Echinophoro-Elymetum farcti*

In contrast to this, there is no elevated dune in Blace bay. The beach has very low continuous slope, so the influence of the sea is much stronger. Consequently, the same association in Blace bay (1.2 in Figs 2, 3 and Tab. 1) is more distant from the sea (18–34 m) with modified composition of plant species. There are no strict qualitative differences in plant composition from that of the previous subgroup but it is evident that the presence and the abundance of characteristic

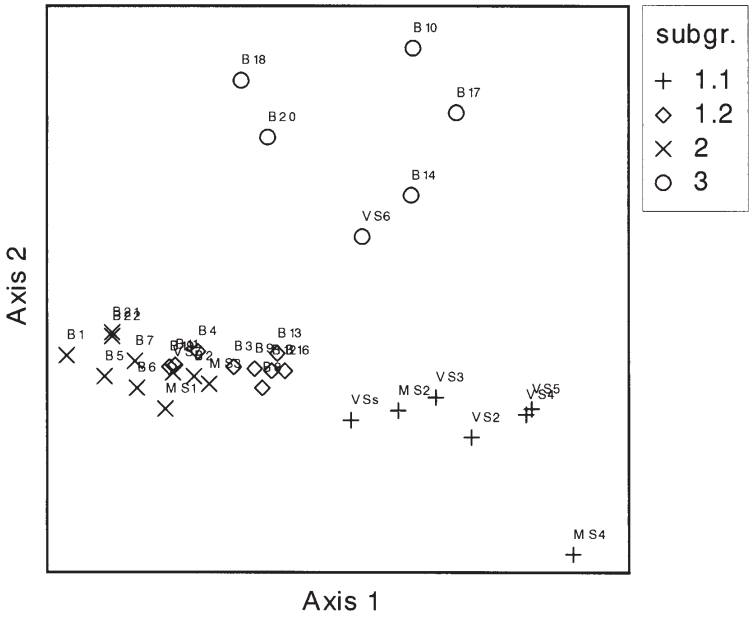

Fig. 3. PCA ordination graph of phytosociological relevés presented with first two axes. 1.1. Typically developed ass. *Echinophoro-Elymetum farcti*, 1.2. Fragmentarily developed ass. *Echinophoro-Elymetum farcti*, 2. Vegetation with prevalence of *Cakiletea* species, 3. Vegetation transitive to garrigues. (VS – Velika Saplunara; MS – Mala Saplunara; B – Blace)

species of the class *Ammophiletea* decrease and reversaly, the presence of characteristic species of the class *Cakiletea maritimae* increases. Some *Ammophiletea* species as *Calystegia soldanella*, *Pseudorlaya pumila* and *Lagurus ovatus* are completely absent while *Euphorbia peplis*, characteristic of the class *Cakiletea maritimae*, appears. This situation indicates higher level of salt, constant sand moistness and presence of an increased amount of decomposed organic material in the soil in comparison to the previous group.

2. Vegetation with prevalence of *Cakiletea maritimae* species

Finally, towards the sea, the characteristic species for the class *Cakiletea maritimae* become dominant (2 in Figs 2, 3 and Tab. 1) but the *Ammophiletea* species are also still present with low abundance and frequency. This vegetation type forms a zone 5–16 m distant from the sea. The sand stratum is only several decimeters deep, with terra rossa deposits below. Because of the terra rossa layer the soil is less permeable for water. Furthermore, the deposition of organic material from the sea is significant. The combination of higher moistness and presence of organic material allows forming of small amounts of humus. But, as a result of more intense influence of the sea (tides, waves, salt, mobility of sand) the abundance-cover indices are very low after all, and the vegetation has developed in small separate patches. *Xantium strumarium*, *Cakile maritime* and *Salsola kali* are present frequently. *Cakiletea maritimae* species are therophytes, i.e. summer annuals, indicating instability of this vegetation type developed in a relatively short period throughout the year when the sea is calm (cf. MERTZ, 2000). Furthermore, the vegetation of the class *Cakiletea maritimae* can be characterised as nitrophilous because of higher amount of organic material deposited by the sea.

3. Vegetation transitive to garrigues

On the inmost part of the beaches the direct influence of the sea gradually disappears and the soil becomes deeper, more immobile, out of direct influence of sea water (except sea water drops blown by the wind) and with larger amount of dry plant material (e.g. leaves, pine needles) originating from hinterland garrigues and macchias. Hence, this zone 25–50 m distant from the sea bears very impoverished vegetation of ass. *Echinophoro-Elymetum farcti* (3 in Figs 2, 3 and Tab. 1) without the species characteristic of the class *Cakiletea maritimae*. Plant species characteristic of garrigues (*Cisto-Ericetea*) and other types of eumediterranean vegetation (aleppo pine and holm oak woods: class *Quercetea ilicis*, and dry grasslands from the class *Thero-Brachypodietea*) are abundant. The most frequent species are *Cistus salviifolius*, *Calycotome infesta*, *Petrorhagia saxifrage*, *Brachypodium retusum* and young *Pinus halepensis*.

The results of PCA are presented in Fig. 3. The first two ordination axes explain cumulatively 32% of total variance. In this analysis only three groups are clearly recognised: typically developed ass. *Echinophoro-Elymetum farcti* from Velika and Mala Saplunara; the hinterland transitive vegetation with the garrigue elements; and the group with fragmentarily developed vegetation of ass. *Echinophoro-Elymetum farcti* with all transitions towards the vegetation of the class *Cakiletea maritimae*. These relevés are held together because of similar floristic composition with gradual differences only. The possible ecological explanation of the first ordination axis is a decrease of the influence of the sea (decrease of the amount of water and organic material in the sand). The second ordination axis could be explained by the decrease of sand mobility. Along the second axis two major groups can be recognised. One group comprises the vegetation of open sands and the second one the vegetation with plant species characteristic of garrigues and macchias, which grow only on immobile soil.

Discussion

In this study 33 phytosociological relevés were analysed, representing the most complete research of psammo-halophytic vegetation of the island of Mljet carried out until present (cf. TRINAJSTIĆ, 1989, 1995; TRINAJSTIĆ et al., 1998). In the previous papers it has only been stated that vegetation of sandy shores belongs to the ass. *Echinophoro-Elymetum farcti* without further analysis of structure and spatial distribution of this plant community. Here it is shown that, in spite of relatively small area covered with this type of vegetation, it is possible to recognise four zones, or four subunits within this association.

The central vegetation type in the studied area is a typically developed ass. *Echinophoro-Elymetum farcti* with abundantly present *Echinophora spinosa*, *Elymus farctus* and other species characteristic of the class *Ammophiletea* (including transgressive species). Presence of primary dunes, i. e. reduced influence of sea water, is important precondition for full development of this vegetation type. Therefore, this association is the most complete in Velika Saplunara where the dune is most prominent. For the same reason the community in Blace bay is floristically impoverished, but it comprises species which tolerate more direct sea influence and which are characteristic of the class *Cakiletea maritimae*.

Of particular interest is the clear prevalence of the species characteristic of the nitrophilous class *Cakiletea maritimae* in the zone nearest to the sea. According to floristic composition it could be classified as ass. *Salsola kali-Xanthium strumarium* OBERD. et TX. 1956, or *Salsolo kali-Cakiletum maritimae* COSTA et MANZ. 1981. Because of the clinal transition to the ass. *Echinophoro-Elymetum farcti* as well as the small area on which both of them occur it is hard to distinguish it as a special community (cf. HORVAT et al., 1974). This standpoint is also confirmed by PCA, where the data on fragmentarily developed ass. *Echinophoro-Elymetum farcti* form a unique group with all transitional relevés to the class *Cakiletea maritimae*. It is also interesting that species characteristic of the ass. *Euphorbio-Glaucietum petrosum* HORVATIĆ (1934) 1950 have not been found although this plant community is common along the whole Croatian coast in the midlittoral zone on sandy and gravely substrates (HORVATIĆ, 1963) embracing many species from the class *Cakiletea maritimae* in its floristic composition.

As the studied sandy beaches are relatively narrow, the formation of secondary, more stable dunes does not occur. Therefore, the zone with *Ammophila arenaria* as a dominant and characteristic species does not develop. This zone is common on broader beaches (within the area of the class *Ammophiletea*) with fully developed psammophytic vegetation (WILMANNS, 1998; MERTZ, 2000). Instead of this, ass. *Echinophoro-Elymetum farcti* transfers directly into climatogenic vegetation (woods of *Quercus ilex* and *Pinus halepensis* from the class *Quercetea ilicis*) and their degradation forms (garrigues from the alliance *Cisto-Ericion* predominantly). This vegetation type is floristically most distant from other types of the studied vegetation what is clearly noticeable in the PCA graph as well as in the cluster dendrogram.

The zones 1.1., 2., and 3. can be characterised and differentiated by presence or absence of characteristic species as shown in Tab. 2. The zone 1.2. must be considered as transitional between the zones 1.1. and 2. due to lack of characteristic species. It can be recognised only quantitatively, based on the different abundances and frequencies of species characteristic of floristically well defined zones 1.1. and 2.

Because of gradual transitions in floristic composition between the zones and generally small area covered with sandy vegetation it is difficult to give them a legal status of subassociation. Therefore, division in subunits without official syntaxonomical level is retained.

All relevés show the recent state of psammo-halophytic vegetation on the island of Mljet. In comparison to the last published data from the island of Mljet (TRINAJSTIĆ, 1995) it is evident that in the studied area there was no extinction of specific plant species strictly restricted to this type of habitat, which comprises many rare and endangered species of the Croatian flora. A number of this species is designated as critically endangered in the new Red Data Book of Croatian Flora (NIKOLIĆ & TOPIĆ eds., in press): *Calystegia soldanella, Echinophora spinosa*, *Pancratium maritimum*, *Saccharum ravennae, Imperata cylindrica*, *Sporobolus pungens*, *Cyperus capitatus*, *Elymus farctus*. For years, the vegetation has been preserved due to the nearby military objects and poor road connections. In contrast to this, the sand vegetation on the other parts of Croatian coast is vanishing because of very intensive tourism in the last decades. The area of Velika and Mala Saplunara and Blace bay is protected in the category of the Protected Landscape Area since 1965. However, this category does not provide sufficient active protection. For this reason there is an objective need to raise the level of protection to the Special Botanical Reserve.

In spite of the fact that the psammo-halophytic vegetation of the class *Ammophiletea* is commonly widespread along the European coastline, from Pontus to Scotland and the Baltic region (cf. WILMANNS, 1998), it is very scarcely developed on the karstic Croatian coast. While the vegetation of this class on the Italian part of the Adriatic coast is represented with five associations (GÉHU & BIONDI, 1996), on the Tyrrhenian costal region (including Corsica, Sardinia and Sicily) with five (GÉHU & BIONDI, 1994), on the Greek coast with four (HORVAT et al., 1974), on the Croatian part of Adriatic coast only one association can be recognised. For comparison with other Mediterranean psammophytic vegetation, in the synthetic table (Tab. 2.) the columns 4, 5 and 6 refer to Corsica (BRULLO & FURNARI, 1970) and 7, 8 to Sicily (BRULLO et al., 1974). The main characteristic of Croatian *Ammophiletea* vegetation is its occurrence on relatively narrow sand belt (average width 15–20 m) without the possibility of formation of secondary dunes, caused by steep and rocky orography. Comparatively, the sandy shores on the Greek, Sicilian, Corsican and Italian coast can be wide up to 1 km. As a consequence, some characteristic plant species that are listed in the synthetic table 2. as e.g. *Ammophila arenaria*, *Cutandia maritima*, *Anthemis maritima*, *Otanthus maritimus*, *Polygonum maritimum*, *Stachys maritima, Matthiola sinuata*, *Euphorbia terracina*, *Crucianella maritima* and *Chondrilla juncea* do not grow in the described area. However, the large number of typical Mediterranean species makes this vegetation floristically considerably different from Atlantic or Baltic communities.

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Received February 5, 2003
Accepted April 27, 2004