THE HALOPHYTIC VEGETATION ALONG THE COASTAL ZONE OF THE DANUBE DELTA BIOSPHERE RESERVE

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ABSTRACT

In the coastal area of the Danube Delta Biosphere Reserve, the halophytic vegetation of the classes *Puccinellio-Salicornietea* Țopa 1939 and *Juncetea maritimi* Br.-Bl. 1931 is well developed on the salty soils, in the moist or marshy areas of the beaches, on the marine sandbanks, and around the saltwater lakes and ponds. This type of vegetation belongs to certain habitat types with conservation significance for European Community, according to Annex I of the Directive 92/43/EEC. Salinization of the substrate is sulfate-chloride type, due to the strongly mineralized groundwater and to the hyper-saline lakes from the coastal area. Details regarding the floristic structure of the most important halophilic plant communities of the alliance *Juncion maritimi* Br.-Bl. 1931 and the soil particularities within their specific habitat are highlighted in the paper. Grazing is the main threat to the halophytic vegetation of the alliance *Juncion maritimi* along the coastal area of the Danube Delta Biosphere Reserve.

Keywords: halophytic vegetation, coastal area, Danube Delta Biosphere Reserve.

INTRODUCTION

The northern coast of Romania, with a length of 164 km [1], is included wholly within the Danube Delta Biosphere Reserve. Here, on the marine sandbanks (Sărăturile, Buhazului, Crucea, Perișor), on the sandy belt between Perișor and Periteașca, and on the wide beach Corbu-Cape Midia, there are large surfaces with salty soils covered by halophytic vegetation. This type of vegetation is also widespread on the sandbanks Chituc, Lupilor and Saele (Istria) which are part of the Razelm-Sinoe Lagoon complex, known as Southern Delta (Fig. 1). The shallow and strongly mineralized groundwater, as well as the microrelief with wide depressions, sandy substrate and intense evaporation in the summer period are the main factors which contributed to the formation of the salty soils of the sandbanks and of the sand belts. The soil salinization is generally of sulfate-chloride type. The most widespread saline soil types on the coast of the Black Sea are the solonchaks and the solonetz [2].

Halophytic plant communities of the classes *Puccinellio-Salicornietea* Țopa 1939 and *Juncetea maritimae* Br.-Bl. 1931 are well developed on the low salty surfaces behind the sand dunes and around the saltwater lakes and swamps. This type of vegetation belongs to some habitat types with conservation significance for the European Community, according to Annex I of the Directive 92/43/EEC: *Salicornia* and other annuals colonizing mud and sand (code 1310) and Mediterranean salt meadows from *Juncetalia maritimi* (code 1410).

On the southern coast of Romania, halophytic vegetation occurs only sporadically around Lake Techirghiol, the saltiest lake on the Romanian Black Sea coast.

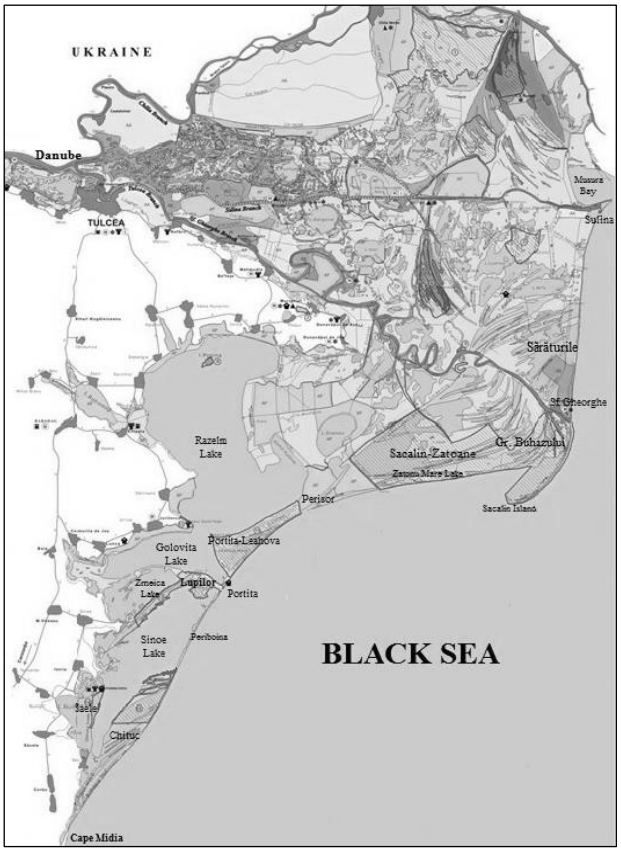

Fig. 1. Coastal area of the Danube Delta Biosphere Reserve

A detailed description of some coastal halophytic plant communities from the Danube Delta Biosphere Reserve was accomplished by Țopa [3], Sanda et Popescu [4], Sârbu et al. [5], Popescu et al. [6], Sârbu et al. [7].

Due to the considerable diversity of the halophytic vegetation in the coastal area of the Danube Delta Biosphere Reserve, only the plant communities of the alliance *Juncion maritimi* Br.-Bl. 1931 will be described in this paper.

MATERIAL AND METHODS

Field observations and phytosociological relevés were achieved in accordance with the methodology of Braun-Blanquet, and by taking into account the recommendations of Borza et Boşcaiu [8]. Syntaxonomic affiliation and the name of the halophytic plant communities are according to the book "Phytocoenoses from Romania" [9]. The nomenclature of the species from the floristic composition of the association is in concordance with Flora Europaea [10] and with the book Vascular plants of Romania [11]. Soil samples were collected from different depths (0-20 cm, 20-40 cm) with the soil sampling probe. Soil samples were analyzed at the accredited laboratory EN ISO 17025 for soil analyses.

RESULTS AND DISCUSSIONS

There is a correlation between different types of salty soils and the halophytic vegetation [12]. The plant communities of the class *Puccinellio-Salicornietea* Ţopa 1939 are made up of compulsory halophytes and they generally grow on the strongly salty soils (especially on solonchaks) around the hyper-saline lakes or on the place of former saline lakes from the sandbanks area. Plant associations of the class *Juncetea maritimi* Br.-Bl. 1931 have preferences for more advanced sandy soils, slightly to medium salinized and they are widespread along the coastal area, within the marshy areas of the beaches (generally flooded in spring), and in the low areas of the sandbanks, between the sandy belts.

The most common plant communities of the alliance *Juncion maritimi* Br.-Bl. 1931 noticed in the coastal area of Danube Delta are the following: *Juncetum maritimi* (Rübel 1930) Pignatti 1953, *Artemisio santonici-Juncetum littoralis* (Popescu et Sanda 1976) Géhu et al., 1994 (syn. *Juncetum acuti* Popescu et Sanda 1976) and *Teucrio-Schoenetum nigricantis* Sanda et Popescu 2002. These plant associations are widespread on the sandbanks Sărăturile (between Sulina and Sf. Gheorghe), Perişor, Chituc and on the Cape Midia-Corbu beach. But large surfaces covered by this type of vegetation are also on the sandbanks Lupilor and Saele (Istria), sandbanks of the former coastal zone of the Black Sea and which are included nowadays in the Razelm-Sinoe Lagoon complex.

The typical habitat for these plant associations is ”Mediterranean salt meadows from *Juncetalia maritimi”* (code 1410). This type of habitat has some particularities regarding the microclimate and soil conditions. The substrate is sandy-clayey, weakly cohesive, with fine glomerular structure, poor in crushed shells. Analysis of the soil samples revealed a content of 75.3% fine sand, 1.5% coarse sand, 8.9% dust and 14.3% clay. The blackish-gray color and odor of the soil are given by the decaying organic matter. The soils are slightly to strongly salty in the first soil profile (0-20 centimeters). The salinization of the substrate is sulfate-chloride type, due to the mineralized groundwater or to the saline waters of the lakes and ponds from the coastal area. High permeability of sandy soils and intense evaporation in summer, determine the accumulation of salts in the surface layer of the soil.

Analysis of the soil samples collected within the habitat of the plant community *Juncetum maritimi* indicates small up to medium values of nitrogen (0.112 to 0.241%), a high up to very high content in phosphates (49-245 ppm) and a very high value of potassium (344-354 ppm). The humus content is also high (2.15-4.93%) and it is in direct relationship with the soil trophicity. The values of the total soluble salts (245.16-2050 mg/100 g soil) correspond to the slightly to strongly salty soils. Soil reaction is moderately alkaline because the pH values vary in the analyzed samples between 8 and 8.2 (Table 1).

The plant association *Juncetum littoralis* occupies in the coastal area of the Danube Delta the surfaces with slightly to moderately salty soils (310-405 mg/100 g soil), with a poor content in humus (0.58-0.61), nitrogen salts (0.02-0.03%) and potassium (15-40 ppm) (Table 1). The values of the pH in the analyzed samples (8.7-8.8) are corresponding to the strong alkaline soils.

The soil samples collected from the 0-20 cm profile of the plant community *Teucrio-Schoenetum nigricantis* have indicated a strongly alkaline pH (8.5), poor content in

humus (0.7%), and a very low content in nitrogenous salts (0.035%), in phosphorus (15 ppm) and in potassium (188 ppm). The soil salinization is poor to moderate, the content of soluble salts being 372 mg/100 g soil. Through all these soil characteristics, the plant association *Teucrio-Schoenetum nigricantis* resembles *Juncetum littoralis.* Moreover, the diagnostic species of these associations frequently occur together in the coastal area of Romania.

The data in Table 1 show that the values of nutrients and humus on the Chituc sandbank are lower compared to those of Saele sandbank and this can be explain by the more recent origin of the Chituc sandbank whose formation began 1000-1100 years ago [13]. These data also indicate the tolerance of the characteristic plant species of the alliance *Juncion maritimi* to the variable content of salt and nutrient of the soils.

Table 1. Physicochemical characteristics of the soils within the plant communities of the alliance *Juncion maritimi*

Coastal areas of the DDBR	Plant community	Soil profile	pH	Humus content (%)	N (%)	K (ppm)	P (ppm)	Total soluble salts (mg/100 g soil)	Soil moist-ure (%)
Saele 24.07.2014	*Juncetum maritimi*	0-20	8.0	4.93	0.241	354	245	274.40	32.27
Saele 24.07.2014	*Juncetum maritimi*	0-20	8.1	4.22	0.199	350	106	245.16	32.98
Chituc 28.07.2014	*Juncetum maritimi*	0-20	8.2	2.15	0.106	344	49	2050	21.76
Saele 24.07.2014	*Juncetum maritimi*	0-20	8.2	-	-	-	-	783.5	26.16
Chituc 28.07.2014	*Juncetum littoralis*	0-20	8.8	0.61	0.03	40	126	310	15.69
Chituc 28.07.2014	*Juncetum littoralis*	0-20	8.7	0.58	0.029	15	148	405	8.58
Chituc 28.07.2014	*Teucrio-Schoenetum nigricantis*	0-20	8.5	0.70	0.035	15	188	372	14.3 11.6

Despite the strong insolation in the summer period and the high caloric conductivity of the sandy soils, the dense and tall vegetation (70-110 cm) of the alliance *Juncion maritimi*, but also the prevalence of the gleic soils, water evaporation is limited and therefore, the soil remains moist even after long periods of high temperatures. The analysis of the soil samples collected on Chituc and Saele sandbanks in July 2014 highlighted values of the soil moisture between 21.76% and 32.98% (in the 0-20 cm profile) within the plant community *Juncetum maritimi* and lower values in the case of the associations *Juncetum littoralis* (8.58 -15.69%) and *Teucrio-Schoenetum nigricantis* (11.6 -14.3%).

The plant association *Juncetum maritimi* (Rübel 1930) Pignatti 1953 can be noticed along the coastal zone of the Danube Delta Biosphere Reserve in swampy depressions of the beaches or of the sandbanks, flooded until the beginning of summer due to the gleic substrate. Typical soils are generally medium to strongly salty and rich in humus and nutrients. *Juncus maritimus* grows vigorously and covers almost completely the salty substrate (90-100%). The high number of halophilic plant species within the

composition of the association (Table 2) is a consequence of the strong salinization of the substrate. Many species are compulsory halophytes and belong to the orders *Salicornietalia* Br.-Bl. (1928) 1933 and *Puccinellietalia limosae* (Soó 1968) Géhu et Rivas-Martinez 1982 (Table 2). Species such as *Limonium meyeri, Limonium bellidifolium, Centaurium spicatum, Carex extensa, Cirsium elatum,* are listed in the Red Book of Vascular Plants from Romania [14] as vulnerable or endangered.

On the Bulgarian Black Sea coast, the alliance *Juncion maritimi* is represented only by the plant association *Juncetum maritimi*. It has a scattered distribution along the Black Sea coast, in the proximity of some saline lakes (Lake Atanassovsko, Lake Beloslav, Lake Mandra, Lake Varna, Lake Dourankoulak) or of some marshy areas (Chengene skele Bay, Karaach marsh and the mouth of the Ripotamo River) [15]. The floristic structure of this plant community contains compulsory halophytes such as *Salicornia europaea, Suaeda maritima, Puccinellia convoluta* but also some hydrophytes like *Phragmites australis* [15].

The plant community *Artemisio santonici-Juncetum littoralis* (Popescu et Sanda 1976) Géhu et al., 1994 occupies the moist sandy soils of the beaches and of the sandbanks, with slight to moderate salinity and with a poor content in humus and nutrients. *Juncus littoralis* grows in clusters of 70-95 individuals/square meter and it has a medium coverage of the substrate (60-70%). The gaps between the clusters are occupied by *Artemisia santonica* and various compulsory and optional halophilic plant species which form a 50-60 cm high layer and which raises the vegetation coverage to 85-100%.

The plant association *Teucrio-Schoenetum nigricantis* (Sanda et Popescu 2002) occurs frequently on Chituc and Saele sandbanks, on the low surfaces with moderate moisture between dunes, sometimes even on the low sand dunes. Typical phytocoenoses were also observed on the beach between Corbu and Cape Midia, the southernmost beach of the Danube Delta Biosphere Reserve. The height of the vegetation dominated by *Schoenus nigricans* is generally 70-80 cm and the coverage varies between 90 and 100%.

Despite the protection status of the Danube Delta Biosphere Reserve, the halophytic vegetation of the alliance *Juncion maritimi* is seriously affected by grazing, mainly close to villages and farms. Another risk for the hygro-halophytic coastal vegetation is the climate warming that entails the gradual disappearance of salted marshes.

CONCLUSIONS

The halophytic plant communities of the alliance *Juncion maritimi* are widespread along the coastal zone of the Danube Delta Biosphere Reserve in the moist and marshy areas of the beaches, of the marine sandbanks and the sand belts.

The plant communities of the alliance *Juncion maritimi* occupy the salty surfaces of the beaches and marine sandbanks depending on soil salinity and moisture but also depending on soil type and its content in humus and nutrients. *Juncetum littoralis* and *Teucrio-Schoenetum nigricantis* occupy the moist soils, slightly or medium salinized, poor in humus and nutrients. Instead, the plant community *Juncetum maritimi* prefers the medium or strongly salty marshy surfaces of the beaches and of the maritime sandbanks.

Grazing and climate warming are the main threats to the halophytic vegetation of the alliance *Juncion maritimi* from the coastal area of the Danube Delta Biosphere Reserve.

The strengthening of the protection measures of the habitat 1410 and also of other types of coastal habitats is necessary for the protection of the halophytic plant communities and of the rare halophilic plant species.

AKNOWLEDGEMENTS

The study has been supported by the grant PN–II–PT–PCCA–2011–3.2–1427 No.69/2012 (ECOMAGIS) developed by INCDM „Grigore Antipa" Constanța and Ovidius University of Constanța, and financed by the UEFISCDI.

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Table 2. Alliance *Juncion maritimi* Br.-Bl. 1931;
Plant associations: *Juncetum maritimi* (Rubel 130) Pign. 1953 (R1-8), *Artemisio santonici-Juncetum littoralis* (Popescu et Sanda 1976) Géhu et al., 1994 (R9-14); *Teucrio-Schoenetum nigricantis* Sanda et Popescu 2002

Relevé number	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	K
Sample surface (m^2)	100	50	100	50	50	100	100	100	100	100	50	100	50	100	50	100	100	100	
Vegetation height (cm)	90	100	90	90	90	90	90	100	110	100	110	120	110	100	70	80	70	70	
Coverage (%)	90	100	95	100	100	90	95	90	90	100	90	95	85	100	90	90	95	100	
Diagnostic species																			
Juncus maritimus	**4**	**5**	**4**	**5**	**4**	**4**	**4**	**5**	.	1	.	.	.	+	1	.	.	1	IV
Juncus littoralis	.	.	.	.	.	.	2	.	**4**	**5**	**5**	**4**	**4**	**4**	2	1	1	2	IV
Schoenus nigricans	.	.	.	.	.	.	.	+	.	1	+	.	.	3	**4**	**5**	**4**	**4**	III
Juncetalia maritimi																			
Carex extensa	.	+	.	.	+	.	.	.	1	.	+	.	+	+	.	.	+	.	II
Althaea officinalis ssp. *officinalis*	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	I
Cirsium alatum	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I
Triglochin maritima	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Puccinellietalia																			
Aeluropus littoralis	.	.	2	1	+	+	.	.	+	+	.	1	.	.	+	1	.	.	III
Aster tripolium ssp. *pannonicus*	2	+	.	+	1	.	.	.	.	.	+	1	.	+	+	.	.	1	III
Agrostis gigantea ssp. *pontica*	.	.	.	.	.	1	1	.	.	+	1	.	.	.	+	+	1	1	III
Puccinellia distans ssp. *limosa*	1	+	.	.	+	.	+	.	+	.	.	.	.	.	.	+	+	.	II
Elymus elongatus ssp. *elongatus*	+	+	+	.	.	.	.	+	.	.	+	1	.	.	.	.	.	.	II
Limonium meyeri	.	+	.	.	.	+	.	+	.	+	.	1	.	+	.	.	.		II
Centaurium spicatum	.	.	.	.	.	+	.	.	+	.	.	+	.	.	+	+	.	+	II
Puccinellia distans ssp. *distans*	.	.	1	+	.	.	.	.	.	+	.	.	1	.	.	.	.	+	II
Plantago cornuti	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	+	2	.	II
Chenopodium glaucum	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	I
Atriplex prostrata	.	+	.	+	.	.	.	.	.	.	.	.	.	..	.	.	.	+	I
Festuca arundinacea	.	.	.	.	.	.	.	+	.	1	.	.	.		.	.	+	.	I
Taraxacum bessarabicum	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	I
Puccinellia convoluta	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Lepidium latifolium	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	I
Centaurium pulchellum	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	I
Limonium bellidifolium	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	I
Lotus tenuis	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Salicornietalia																			
Artemisia santonica ssp. *santonica*	.	+	+	1	.	+	1	.	.	.	.	1	.	+	.	.	1	+	III
Suaeda maritima	+	.	.	+	2	2	.	.	.	.	.	.	+	.	+	.	+	1	III

Salicornia europaea	+	.	1	.	+	+	.	1	.	.	.	+	+	.	.	.	.	.	II
Spergularia media	.	+	+	.	+	.	.	.	+	.	.	.	.	.	.	.	.	+	II
Plantago maritima	+	.	.	.	+	.	.	.	+	.	.	.	.	+	.	.	.	.	II
Juncus gerardi	+	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	1	II
Peucedanum latifolium	.	.	.	.	.	.	.	+	.	.	+	.	.	.	+	.	+	.	II
Plantago major ssp. *winteri*	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	+	.	I
Samolus valerandi	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	I
Odontites vernus ssp. *serotinus*	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	I
Scorzonera parviflora	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Agrostion stoloniferae																			
Carex distans	+	.	.	+	.	+	.	.	+	.	.	+	.	+	.	.	.	+	II
Teucrium scordium ssp. *scordium*	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	I
Bidentetea tripartiti																			
Trifolium fragiferum	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	+	.	I
Rumex maritimus	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Rumex crispus	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Potentilla reptans	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Polypogon monspeliensis	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Phragmitetea australis																			
Phragmites australis	+	.	.	.	.	.	.	.	.	+	.	.	1	.	.	+	.	.	II
Lythrum virgatum	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	I
Bolboschoenus maritimus	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Pulicaria dysenterica	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Mentha aquatica	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Other taxons																			
Orchis laxiflora ssp. *elegans*	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	+	.	+	II
Scirpoides holoschoenus	.	.	.	.	.	.	.	.	2	.	+	.	.	+		.	.	1	II
Sonchus arvensis ssp. *uliginosus*	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	I
Cynanchum acutum	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	I
Atriplex rosea	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	I
Xanthium italicum	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Plantago media	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I
Tamarix ramosissima	.	.	.	.	.	.	.	+	.	.	.	.	+.	.	.	.	.	.	I
Elaeagnus angustifolia	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I

Location of releves: **Chituc sandbank** – R1, R2, R8-10, R12, R14, R15, R17; **Saele Sandbank** – R3-6, R13, R16; Cape Midia-Corbu beach – R7, R11, R18.