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Halophilous vegetation of Olbia pond system (NE-Sardinia)

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Abstract

Authors report some results about a phytosociological study concerning the wetlands to the south of Olbia (Gallura, north-eastern Sardinia).
Vegetation analysis allowed to detect 21 associations, among them two are new and denominated *Halimiono portulacoidis-Limoniastretum monopetali* ass. nova and *Ephedro fragilis-Pistacietum lentisci* ass. nova. Among them, the association *Halimiono portulacoidis-Limoniastretum monopetali* shows a particular phytogeographical interest, because it sets the *Limoniastrum monopetalum* vegetation in the only Sardinian station of this shrubby Plumbaginacea.
From a syntaxonomic point of view, described syntaxa are included in 9 vegetation classes.
Plant landscape of the area was reconstructed by the study of chain contacts among different communities, placed in space according to humidity and salinity gradients, determined by substratum texture and micromorphology. On the basis of phytocoenotic diversity stressed by this research, this study area is believed to be deserving of protection aiming at conserving and managing its populations and plant communities.

Key words:biodiversity, *Ephedro fragilis-Pistacietum lentisci* ass. nova, *Halimiono portulacoidis-Limoniastretum monopetali* ass. nova, halophilous vegetation, phytosociology, Sardinia, syntaxonomy.

Riassunto

Vegetazione alofila del sistema stagnale di Olbia (NE-Sardegna). Gli autori riportano i risultati di uno studio fitosociologico relativo alle zone umide salmastre situate a sud della città di Olbia (Gallura, Sardegna nord-orientale). L'analisi della vegetazione ha permesso di individuare 21 associazioni, tra le quali 2 nuove, denominate *Halimiono portulacoidis-Limoniastretum monopetali* ass. nova e *Ephedro fragilis-Pistacietum lentisci* ass. nova. Tra queste riveste particolare interesse fitogeografico l'ass. *Halimiono portulacoidis-Limoniastretum monopetali*, che inquadra la vegetazione a *Limoniastrum monopetalum* nell'unica stazione sarda di questa plumbaginacea arbustiva.
Dal punto di vista sintassonomico i sintaxa descritti ricadono in 9 classi di vegetazione. È stato ricostruito il paesaggio vegetale dell'area attraverso lo studio dei contatti catenali tra comunità diverse, disposte nello spazio secondo gradienti di umidità e salinità, determinati dalla tessitura del substrato e dalla micromorfologia. Si ritiene che in base alla diversità fitocenotica messa in risalto dalla presente ricerca, l'area in studio sia meritevole di misure di tutela, volte alla conservazione e alla gestione delle popolazioni e delle comunità vegetali presenti.

Parole chiave: biodiversità, *Ephedro fragilis-Pistacietum lentisci* ass. nova, fitosociologia, *Halimiono portulacoidis-Limoniastretum monopetali* ass. nova, Sardegna, sintassonomia, vegetazione alofila.

Introduction

The phytosociological study of halophilous and psammophile plant communities of wetlands to the south of Olbia (Gallura, north-eastern Sardinia, Fig. 1) is presented. These wetlands, reclaimed in 1931-1935, are linked to Padrogianus River and other streams flowing into the Gulf of Olbia: these wetlands derived from aeolian barrage and they are separated from the sea by dunal bars where the psammophile vegetation grows.

Padrogianus River is the end portion – close to the mouth – of Enas River, where it receives the right effluent Castagna River. This river flows into the internal side of the Gulf of Olbia, a ría creek developing in an east-western direction, after flowing through a flat area where some alluvions often terraced are present.

This flat area consists of current alluvions mainly composed of coarse sands deriving from the decay of granite rocks and often-cemented gravel. The river outlet is characterised by a delta area where various canals, currently optimised, filled during the Holocene (10,000 years) a southern portion of the ría. The delta area is superficially composed by deposits from brackish environments (sand and silt, where peat lenses are not rare). The extension northwards of this little delta can be considered stationary. Eastwards, the delta is completely isolated from the sea by some sandy bars obstructing lagoon and pond areas of a certain extension. The current configuration of the delta, even if modified

by anthropic interventions, did not experience significant modifications from the high standing of the sea reached by the Versilian transgression (Carmignani *et al*., 2001).

Thermo-pluviometrical data of Olbia station (15 m above sea level), gathered by Siddi (1981), were used for the phytoclimatic classification. This station shows an annual mean temperature of 16.3°C, with maxima of 20.9°C and minima of 11.7°C. The coldest month is January, with a mean temperature of 9.3°C; the warmest one is July, with 24.4°C. Annual mean precipitation is 636 mm in the fifty-year period 1921-1970. Phytoclimatic indices were calculated according to Rivas-Martinez *et al*. (2002): annual positive temperature (Tp) is 1,951; continentality index (Ic) is 15.1; thermicity index (It) is 349; ombrothermic index (Io) is 3.26. On the basis of these indices, Olbia station is included in the Mediterranean pluviseasonal-oceanic bioclimatic region, lower mesomediterranean phytoclimatic belt, upper dry ombrotype.

Phytosociological investigation concerned annual and perennial plant communities growing on salty soils, flooded during more or less long annual period, and the ones of coastal dunes. Relevées were also carried out in areas to the north and south of Olbia, close to the study site.

Materials and methods

Vegetation analysis was carried out according to the phytosociological Zurich-Montpellier School's method (Braun-Blanquet, 1951). Reference for the phytosociological nomenclature was the 3rd Edition of the International Code of Phytosociological Nomenclature (Weber *et al*., 2000; 2002). References for the nomenclature were "Med-Checklist" (Greuter *et al*., 1984-89), "Flora Europaea" (Tutin *et al*., 1964-80; 1993), "Flora d'Italia" (Pignatti, 1982), "Le piante endemiche della Sardegna" (Arrigoni *et al*., 1976-1991), and Brummit & Powell (1992) was used for the abbreviation of authors' names. The biological form was directly verified in the field and expressed according to the acronyms reported by Pignatti (1982) and based on the classification by Raunkiaer (1934).

Vegetation

Phytosociological analysis allowed detecting some associations, understanding their ecological characteristics and defining their syntaxonomic position. The studied vegetation is referred to two major groups: halophilous and psammophile vegetation.

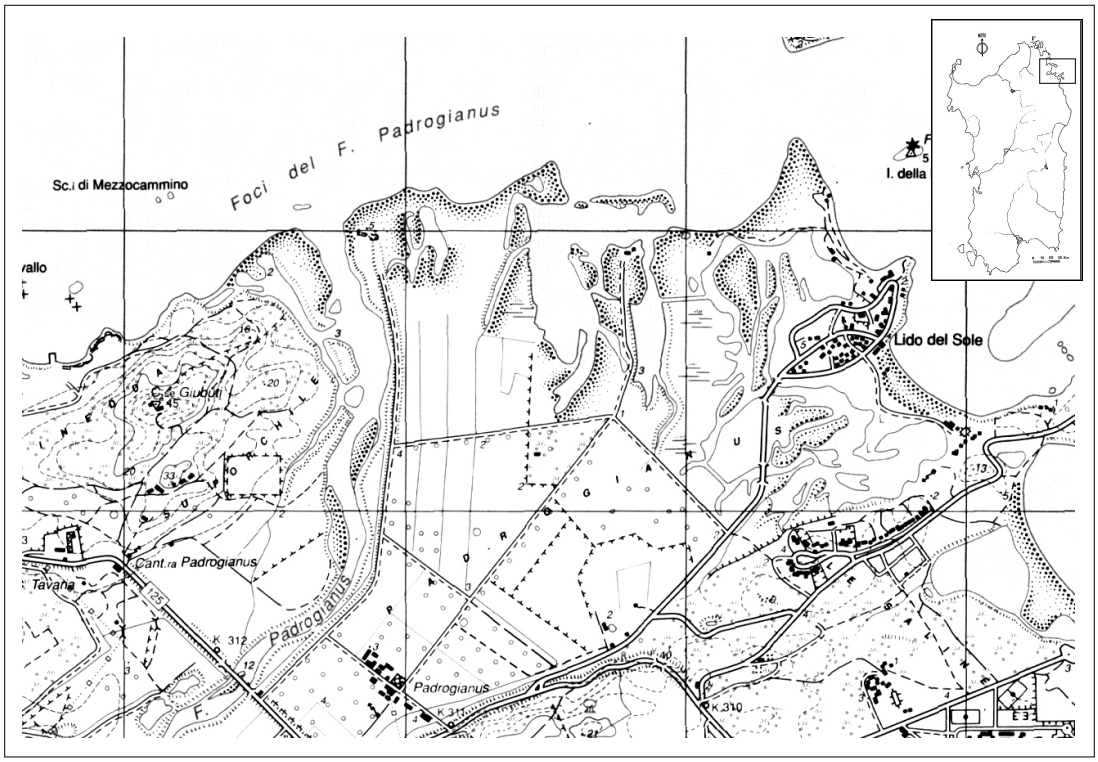

Fig. 1 - Study area

Vegetation of brackish environments

Specialised communities in areas flooded by brackish waters during variously long periods, on generally silty clay and insufficiently drained soils. They establish, in areas far from sea as well, according to salinity gradients (Fig. 2) mostly determined by natural and man-made canals allowing the communication with the sea.

Therophytic halophilous vegetation

Pioneer halophilous and halonitrophilous vegetation on surfaces flooded during nearly all the year round and dry in summer, more or less late according to the depth of flooded surface.

SUAEDO MARITIMAE-SALICORNIETUM PATULAE (Brullo & Furnari 1976) Géhu & Géhu-Franck 1984, Tab. 1.

Pioneer halophilous therophytic communities are present on the edge of ponds, in more internal depressions, and they can be ascribed to the association *Suaedo maritimae-Salicornietum patulae* covering slightly high substrata and consequently dry in summer and likely to be saltier. Halophilous therophytic communities were already detected in this area by Chiesura-Lorenzoni & Lorenzoni (1984, *sub Salicornietum herbaceae* Van Langendonck 1933).

SALICORNIETUM EMERICI (O. de Bolòs 1962) Brullo & Furnari 1976, Tab. 2.

Salicornia emerici mono/paucispecific association grows in areas flooded for a long time and open to the sea, which remains slightly wet in summer. It covers large surfaces in more internal and flat tanks of the study area. It was already detected in Sardinia: in some ponds of Cagliari and in the one of Marceddì (Géhu *et al*., 1984), in S'Ena Arrubia in the Province of Oristano (Filigheddu *et al*., 2000) and in north-western Sardinia (Biondi *et al*., 2001a).

SALSOLETUM SODAE Pignatti 1953, Tab. 3.

In areas periodically flooded releasing substantial deposits of organic material, a linear, paucispecific and therophytic vegetation of *Salsola soda* generally grows in contact with formation of halophilous camephytes.

Camephytic, nanophanerophytic and hemicryptophytic halophilous vegetation

This kind of vegetation covers large surfaces of the study area, whose morphology is defined by the ramifications of Padrogianus River forming a delta in the sea outflow. Furthermore, the present morphology is due to a canal system for the optimization of river waters allowing a direct connection with the sea. This river has currently a limited flow, concentrated into short periods, and both natural and man-made canals allow the upwelling of seawaters rather than the downflow of freshwaters. So the pond system is covered in its more internal areas by markedly halophilous vegetation established according to salinity gradients determined by the substratum micromorphology (Fig. 2).

CYNOMORIO COCCINAE-HALIMIONETUM PORTULACOIDIS Biondi 1992, Tab. 4.

The highest levels of salty soils, characterised by sandy granulometry and substantial zoogenic nitrification (rabbits, avifauna, etc.), are covered by aridophilous and nitrophilous vegetation that can be ascribed to *Cynomorio coccinae-Halimionetum portulacoidis*, described for La Maddalena Archipelago (Biondi, 1992) on islets where the avifauna nests, but also detected in other Sardinian wetlands, such as S'Ena Arrubia Lagoon in the Province of Oristano (Filigheddu *et al*., 2000). This association joins the merely halophilous camephytic communities to the halotolerant hemicriptophytic formations or the climacic shrubby

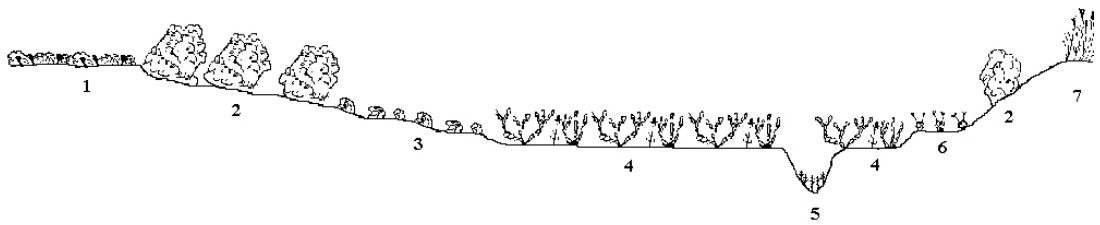

Fig. 2 – Transect of the halophilous vegetation in "Lido del Sole": 1. *Cynomorio coccinae-Halimionetum portulacoidis*; 2. *Halimiono portulacoidis-Limoniastretum monopetali iridetosum sisyrinchii*; 3. *Halimiono portulacoidis-Limoniastretum monopetali arthrocnemetosum macrostachyi*; 4. *Puccinellio festuciformis-Sarcocornietum fruticosae*; 5. *Salicornietum emerici*; 6. *Limonietum narbonense-glomerati*; 7. Psammophile vegetation

Tab. 1 - *Suaedo maritimae-Salicornietum patulae* (Brullo & Furnari 1976) Géhu & Géhu-Franck 1984

	Rel. n.	1	2	3	4	Pr
	Coverage (%)	70	80	80	80	e
	Area (m^2)	2	2	10	10	s.
	Charact. and diff. taxa of the ass.					
T scap	*Salicornia patula* Duval-Jouve	3.3	3.3	4.5	4.4	4
T scap	*Suaeda maritima* (L.) Dumort.	.	.	+.2	1.1	2
	Charact. and diff. taxa of the upper units					
T scap	*Salicornia emerici* Duval-Jouve	.	.	+	.	1
T scap	*Salsola soda* L.	.	.	.	+	1
	Other species					
H caesp	*Puccinellia palustris* (Seen.) Hayek	.	1.2	+.2	.	2
G bulb	*Triglochin bulbosum* L. ssp. *barrelieri* (Loisel.) Rouy	.	.	+	+	2
Ch frut	*Halimione portulacoides* (L.) Aellen	.	.	.	+.2	1
Ch succ	*Arthrocnemum macrostachyum* (Moric.) Moris	.	.	.	+.2	1
G rhiz	*Juncus maritimus* Lam.	.	.	+	.	1

Tab. 2 - *Salicornietum emerici* (O. de Bolòs 1962) Brullo & Furnari 1976

	Rel. n.	1	2	3	4	5	6	7	Pr
	Coverage (%)	80	80	40	50	80	85	85	e
	Area (m^2)	4	4	5	5	10	10	10	s.
	Charact. and diff. taxa of the ass.								
T scap	*Salicornia emerici* Duval-Jouve	5.5	5.5	3.3	3.2	4.4	4.5	5.5	7
	Charact. and diff. taxa of the upper units								
T scap	*Suaeda maritima* (L.) Dumort.	.	.	+.2	1.2	.	.	.	2
	Sporadic species	0	0	0	1	0	0	0	

communities. Contacts with the more halophilous camephytic associations and the halotolerant hemicriptophytic ones are showed in Tab. 4.

PUCCINELLIO FESTUCIFORMIS-HALIMIONETUM PORTULACOIDIS Géhu, Biondi, Géhu-Franck & Costa 1992, Tab. 5.
agropyretosum elongati Biondi, Filigheddu & Farris 2001, Tab. 5.

On rarely flooded silty sandy soils of the edges of depressions and canals, slightly higher than other formations constituting the halophilous grasslands, vegetation dominated by *Halimione portulacoides*, that can be ascribed to the association *Puccinellio festuciformis-Halimionetum portulacoidis*, in the subass. *agropyretosum elongati*, is found. It was recently described (Biondi *et al*., 2001a) under condition of lower edaphic salinity than the typical subassociation, as highlighted by the lack of *Puccinellia festuciformis* ssp. *festuciformis* and the presence of *Agropyron elongatum* and *Iris sisyrinchium*. In the area of Lido del Sole, this association is found only in narrow strips near the sandy dune.

PUCCINELLIO CONVOLUTAE-ARTHROCNEMETUM MACROSTACHYI [Br.-Bl. (1928) 1933] Géhu ex Géhu, Costa, Scoppola, Biondi, Marchiori, Peris, Géhu-Franck, Caniglia & Veri 1984, Tab. 6.

Camephytic communities dominated by *Arthrocnemum macrostachyum* cover the mean high levels of salty depressions and the banks of canals, on substrata being wet in winter and dry in summer, always located at mean lower height than the ones covered by the previous association of *H. portulacoides*. These communities are ascribed to the association *Puccinellio convolutae-Arthrocnemetum macrostachyi*, already known in Sardinia (Géhu *et al*., 1984; Filigheddu *et al*., 2000; Biondi *et al*., 2001a).

HALIMIONO PORTUCALOIDIS-LIMONIASTRETUM MONOPETALI ass. nova hoc loco (typus rel. n. 8, Tab. 7).
iridetosum sisyrinchii subass. nova hoc loco (typus rel. n. 8, Tab. 7), rel. 1-10, Tab. 7.
arthrocnemetosum macrostachyi subass. nova hoc loco (typus rel. n. 17, Tab. 7), rel. 11-23, Tab. 7.

A population of *Limoniastrum monopetalum* is present in the area of Padrogianus, Gravile and Saline ponds, currently known as “Lido del Sole”. In Italy, this species, having a Mediterranean distribution (Greuter *et al*., 1984-89), is present in Sardinia, Sicily, Salentina Peninsula and Calabria (Pignatti, 1982). In the study area *L. monopetalum* finds its optimum because of the particular morphologic configuration of the area, characterised by sandy substrata being salty due to the presence of canals that flow deeply and allow the supply of salt by moderate floodings. In fact, a halophilous and hygrophilous habitat originates, so as it occurs along the Atlantic coasts of Portugal, where the association *Polygono equisetiformis-Limoniastretum monopetali* Rivas-Martìnez & Costa 1980 is reported and where the seawater comes up only on the occasion of very high tide (Costa & Lousa, 1989). Braun-Blanquet *et al*. (1952) also report the association *Limoniastro-Staticetum lychnidifoliae* Br.-Bl. 1931 in southern France, on dry soils of the highest surfaces. Under these ecological conditions, *L. monopetalum* establishes with high values in the belt of *Halimione portulacoides*, where it acts as a nanophanerophyte getting slightly

Tab. 3 - *Salsoletum sodae* Pignatti 1953

	Rel. n.	1	2
	Coverage (%)	70	70
	Area (m^2)	5	5
	Charact. and diff. taxa of the ass.		
T scap	*Salsola soda* L.	4.4	2.3
	Other species		
T scap	*Atriplex tatarica* L.	+.2	1.2
T scap	*Atriplex latifolia* Wahlenb.	1.1	1.1

Tab. 4 - *Cynomorio coccinae-Halimionetum portulacoidis* Biondi 1992

	Rel. n.	1	2	3	Pres.
	Coverage (%)	100	100	90	
	Area (m^2)	40	50	10	
	Charact. and diff. taxa of the ass.				
Ch frut	*Halimione portulacoides* (L.) Aellen	5.5	5.5	4.4	3
G rhiz	*Cynomorium coccineum* L.	2.1	2.2	+	3
	Charact. and diff. taxa of the upper units				
Ch succ	*Arthrocnemum macrostachyum* (Moric.) Moris	+	+.2	.	2
NP	*Limoniastrum monopetalum* (L.) Boiss.	.	+.2	.	1
	Other species				
G bulb	*Iris sisyrinchium* L.	2.3	2.3	.	2
H caesp	*Juncus acutus* L.	+.2	1.2	.	2
H ros	*Limonium narbonense* Miller	.	.	+.2	1

lower than 2 m high.

In the study area, vegetation of *L. monopetalum* is set in the new association *Halimiono portulacoidis-Limoniastretum monopetali* ass. nova, which here substitutes for the association *Limoniastro monopetali-Arthrocnemetum macrostachyi* Tadros 1952, described in the area of Mareotis in Egypt (Tadros, 1952) and already detected in this area by Valsecchi & Diana-Corrias (1973). The new association *Halimiono portulacoidis-Limoniastretum monopetali* ass. nova is differentiated by the presence of *Puccinellia palustris* and *Agropyron elongatum* and the absence of *Halocnemum strobilaceum*, *Juncus maritimus* var. *arabicus*, *Suaeda fruticosa*, *Statice pruinosa* and *Cressa cretica*. It gets in the *Limoniastrion monopetali* alliance, which includes the centre-western Mediterranean associations dominated by *L. monopetalum* (Biondi & Géhu, 1995).

On rarely flooded sandy substrata, at mean levels of salty depressions and banks of salt marshes, on clay soils being wet in winter but dry in summer, where it is linked to always hypersalty soils, the psammophile subassociation *iridetosum sisyrinchii* subass. nova was detected, which is the typical of the association.

On winterly flooded sandy silty substrata, *L. monopetalum* never reaches cover values higher than the ones of the *Arthrocnemum macrostachyum* species: under these ecological conditions, already documented by previous studies (Tab. 5 in Valsecchi & Diana-Corrias, 1973), the subassociation *arthrocnemetosum macrostachyi* subass. nova differentiates as more hygrophilous and halophilous than the typical one.

The association *Halimiono portulacoidis-Limoniastretum monopetali* ass. nova is in chain contact with the halonitrophilous and aridophilous association of *Cynomorium coccineum* and *H. portulacoides* (*Cynomorio coccinae-Halimionetum portulacoidis*) and with the hemicriptophytic grasslands of *Juncetea maritimi* class, which grow on constantly wet sandy soils.

PUCCINELLIO FESTUCIFORMIS-SARCOCORNIETUM FRUTICOSAE (Br.-Bl. 1928) 1952 Géhu 1976, Tab. 8.

Mean low levels of salty depressions, on hyperaline clay soils being wet in summer, are covered by the vegetatin of *Sarcocornia fruticosa* that can be ascribed to the association *Puccinellio festuciformis-Sarcocornietum fruticosae*, already found in this area [Valsecchi & Diana-Corrias, 1973 *sub Salicornietum fruticosae* Br.-Bl. 1928; Chiesura-Lorenzoni & Lorenzoni, 1984 *sub Salicornietum fruticosae* (Br.-Bl. 1928 em. 1933) Pignatti 1953].

SARCOCORNIETUM DEFLEXAE (Br.-Bl. 1931) Lahondère, Géhu & Paradis 1992, Tab. 9.

In depressed areas, not directly exposed to the inflow of seawater, submerged for a long time in winter but with a completely dry and therefore hypersalty substratum in summer, the monospecific prostrate vegetation of *Sarcocornia fruticosa* var. *deflexa* grows, ascribed to the association *Sarcocornietum deflexae*.

LIMONIETUM NARBONENSE-GLOMERATI Biondi, Diana, Farris & Filigheddu 2001, Tab. 10.
limonietosum glomerati Biondi, Diana, Farris & Filigheddu 2001, rel. 1-5, Tab. 10.
limonietosum virgati Biondi, Diana, Farris & Filigheddu 2001, rel. 6-7, Tab. 10.

On the sea slope of ponds and lagoons, on flat surfaces usually very narrow, in dunal bars where the sandy matrix interacts with the silty one, halophilous grasslands of *Limonium* are found, because they stand short periods of submersion and join the more hygrophilous camephytic formation of *Arthrocnemum macrostachyum* with the more aridophilous one of *Halimione portulacoides*. These coenoses can be

ascribed to the association *Limonietum narbonense-glomerati*, recently described (Biondi *et al*., 2001b). The subassociation *limonietosum virgati* differentiates on sandier substrata.

Hemicriptophytic subhalophilous vegetation

On silty sandy soils being constantly wet and periodically flooded, three types of communities are found. They are dominated by hemicriptophytes and geophytes, which mark the variation in the salinity gradients passing from the area of merely halophilous to the one of halotolerant communities. These communities are not very represented in this area.

SCIRPO-JUNCETUM SUBULATI Géhu, Biondi, Géhu-Franck & Costa 1992, Tab. 11.

On soils being flooded in winter but dry in summer with consequent raising of salinity, beds of rushes grow with a paucispecific composition, where *Juncus subulatus* dominates. This community was found in the same area by Valsecchi & Diana-Corrias (1973), who reported a grouping of *Juncus subulatus.*

INULO-JUNCETUM MARITIMI Brullo *in* Brullo, De Sanctis, Furnari, Longhitano & Ronsisvalle 1988, Tab. 12.

The vegetation physiognomically dominated by *Juncus maritimus*, placed in retrodunal depressions experiencing a prolonged flooding and in canals of salty marsh, on sandy soils being wet in summer, to the Mediterranean association *Inulo-Juncetum maritimi* is referred. The beds of rushes of *Juncus maritimus* already detected in this area (Valsecchi & Diana-Corrias, 1973; Chiesura-Lorenzoni & Lorenzoni 1984) and ascribed to the centre-european association *Juncetum maritimi* (Rübel 1930) Pignatti 1953 are to be ascribed to this association.

JUNCO ACUTI-SCHOENETUM NIGRICANTIS Géhu, Biondi, Géhu-Franck & Taffetani 1987, Tab. 13.

On the edges of salty depressions, on soils higher than the above ones and wet in winter but relatively dry in summer, characterised by low salinity and moderate supplies of freshwater, thick grasslands of *Schoenus nigricans* grow, sometimes subjected to pasturage and ascribed to the association *Junco acuti-Schoenetum nigricantis*. These grassland communities mark the passage between halotolerant and freshwater anthropogenic coenoses of the order *Agropyretalia repentis* Oberdorfer, Müller & Görs *in* Oberdorfer, Görs, Korneck, Lohmeyer, Müller, Philippi & Seibert 1967. Two variants were detected: *Inula viscosa* and *Carex distans* variant (rel. 1-3) typical in more freshwater environments, and the more halotolerant *Limonium narbonense* and *L. virgatum* variant (rel. 4-5).

This association was already found in La Maddalena Archipelago (Biondi, 1992) and Corsica (Géhu & Biondi, 1994a). Relevées showed in Table 7 in Chiesura-Lorenzoni & Lorenzoni (1984) are to be ascribed to this association.

Tab. 5 - *Puccinellio festuciformis-Halimionetum portulacoidis* Géhu, Biondi, Géhu-Franck & Costa 1992 *agropyretosum elongati* Biondi, Filigheddu & Farris 2001

	Rel. n.	1	2	3	4	P r e s.
	Coverage (%)	95	85	100	100	
	Area (m^2)	40	20	40	15	
	Charact. and diff. taxa of the ass. and of the *agropyretosum elongati* subass.					
Ch frut	*Halimione portulacoides* (L.) Aellen	5.5	4.4	5.5	5.5	4
H caesp	*Agropyron elongatum* (Host) Beauv.	.	.	1.1	1.2	2
	Diff. taxa of the variant					
G bulb	*Iris sisyrinchium* L.	3.3	3.3	3.3	.	3
	Charact. and diff. taxa of the upper units					
Ch succ	*Arthrocnemum macrostachyum* (Moric.) Moris	1.2	+.2	+	.	3
Ch succ	*Sarcocornia fruticosa* (L.) A.J. Scott	.	.	+	2.2	2
H ros	*Limonium virgatum* (Willd.) Fourr.	.	.	.	+.2	1
NP	*Limoniastrum monopetalum* (L.) Boiss.	.	.	+	.	1
	Sporadic species	1	2	2	0	

Tab. 6 - *Puccinellio convolutae-Arthrocnemetum macrostachyi* [Br.-Bl. (1928) 1933] Géhu ex Géhu, Costa, Scoppola, Biondi, Marchiori, Peris, Géhu-Franck, Caniglia & Veri 1984

	Rel. n.	1	2	3	4	5	P r e s.
	Coverage (%)	100	100	100	100	70	
	Area (m^2)	10	10	10	15	12	
	Charact. and diff. taxa of the ass.						
Ch succ	*Arthrocnemum macrostachyum* (Moric.) Moris	3.4	5.5	5.5	4.5	4.5	5
H caesp	*Puccinellia convoluta* (Hornem.) Hayek	1.2	2.3	1.2	+	.	4
	Charact. and diff. taxa of the upper units						
Ch frut	*Halimione portulacoides* (L.) Aellen	2.3	.	2.2	+	.	3
	Charact. and diff. taxa of the *Juncetea maritimi* class						
H ros	*Limonium narbonense* Miller	.	.	.	1.2	.	1
Ch suffr	*Inula crithmoides* L.	.	.	.	+	.	1
G rhiz	*Juncus maritimus* Lam.	+	.	.	.	.	1

Tab. 7 - *Halimiono portulacoidis-Limoniastretum monopetali* ass. nova (typus rel. n. 8)
iridetosum sisyrinchii subass. nova (typus rel. n. 8)
arthrocnemetosum macrostachyi subass. nova (typus rel. n. 17)

	Rel. n.	1	2	3	4	5	6	7	8*	9	10	11	12	13	14	15	16	17*	18	19	20	21	22	23	Pr
	Coverage (%)	100	100	100	100	90	100	100	100	20	20	15	20	15	15	10	15	10	15	15	15	15	15	10	e
	Area (m²)	40	40	20	70	50	40	80	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	s.
	Charact. and diff. taxa of the ass. and of the *iridetosum sisyrinchii* subass.																								
NP	*Limoniastrum monopetalum* (L.) Boiss.	1.1	3.4	4.4	5.5	4.5	5.5	5.5	5.5	4.5	4.4	4.4	2.3	4.4	3.4	4.4	+.2	2.3	4.4	2.3	3.3	3.3	4.3	3.3	23
Ch frut	*Halimione portulacoides* (L.) Aellen	5.5	4.4	4.5	4.4	3.4	2.3	2.3	2.3	2.3	1.2	.	2.3	2.3	2.3	2.3	2.3	2.3	+.2	1.2	1.2	1.2	+	.	21
H caesp	*Puccinellia palustris* (Seen.) Hayek	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	1.2	1.2	1.2	.	.	.	.	.	4
G bulb	*Iris sisyrinchium* L.	3.3	2.2	2.2	2.2	2.3	+.2	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
H caesp	*Agropyron elongatum* (Host) Beauv.	1.1	.	.	1.2	.	.	.	+	1.1	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	5
	Diff. taxa of the *arthrocnemetosum macrostachyi* subass.																								
Ch succ	*Arthrocnemum macrostachyum* (Moric.) Moris	+	.	+	.	+.2	.	.	1.2	.	.	4.4	4.4	4.5	4.4	2.3	5.5	3.4	3.4	3.3	3.3	4.3	4.4	3.3	17
	Charact. and diff. taxa of the upper units																								
Ch succ	*Sarcocornia fruticosa* (L.) A.J. Scott	+	+.2	+	.	.	.	.	.	2.2	3.3	.	.	.	.	.	.	.	.	1.2	+.2	.	.	.	7
H ros	*Limonium glomeratum* (Tausch) Erben	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	1
	Other species																								
H caesp	*Juncus acutus* L.	.	+.2	.	.	1.2	1.2	1.2	.	.	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.	5
T scap	*Cynosurus echinatus* L.	+	.	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
	Sporadic species	1	0	1	1	0	1	0	1	1	2	0	0	0	0	0	2	1	1	0	0	0	0	0	

Tab. 8 - *Puccinellio festuciformis-Sarcocornietum fruticosae* (Br.-Bl. 1928) 1952 Géhu 1976

	Rel. n.	1	2	3	4	5	Pr
	Coverage (%)	100	100	100	100	100	e
	Area (m²)	10	10	15	15	15	s.
	Charact. and diff. taxa of the ass.						
Ch succ	*Sarcocornia fruticosa* (L.) A.J. Scott	5.4	5.5	5.5	4.5	5.5	5
H caesp	*Puccinellia palustris* (Seen.) Hayek	1.2	2.1	2.2	1.2	2.2	5
	Charact. and diff. taxa of the upper units						
Ch frut	*Halimione portulacoides* (L.) Aellen	+.2	.	.	2.3	.	2
Ch succ	*Arthrocnemum macrostachyum* (Moric.) Moris	+	+.2	.	.	.	2
	Other species						
H ros	*Limonium narbonense* Miller	.	1.2	.	.	.	1
G rhiz	*Juncus maritimus* Lam.	+.2	.	.	.	.	1
Ch suffr	*Inula crithmoides* L.	.	+	.	.	.	1

Tab. 9 - *Sarcocornietum deflexae* (Br.-Bl. 1931)
Lahondère, Géhu & Paradis 1992

	Rel. n.	1	2
	Coverage (%)	80	100
	Area (m²)	2	5
	Charact. and diff. taxa of the ass.		
Ch succ	*Sarcocornia fruticosa* (L.) A.J. Scott var. *deflexa*	5.5	5.5

Xero-halophilous therophytic vegetation

Halotolerant therophytic communities grow on glades of perennial halophilous vegetation, during periods of spring/summer desiccation.

PARAPHOLIDO INCURVAE-CATAPODIETUM BALEARICI Rivas-Martínez, Lousã, Dìaz, Fernàndez-Gonzàlez & Costa 1990 *corr.* Brullo & Giusso Del Galdo 2003, Tab. 14.

On cumulated clay sandy soils being dry in summer and subjected to trampling, therophytic communties with spring flowering are present, generally as a mosaic with hemicriptophytic formations. They can be ascribed to the association *Parapholido incurvae-Catapodietum balearici* Rivas-Martínez, Lousã, Dìaz, Fernàndez-Gonzàlez & Costa 1990 *corr.* Brullo & Giusso Del Galdo 2003 of the *Saginetea maritimae* class. Grouping of *Pholiurus incurvus* (L.) Schinz. *et* Tell. was reported for this area by Valsecchi & Diana-Corrias (1973).

Vegetation of dunes

Various kinds of vegetation tending to spread parallel to the shoreline under different ecological conditions, according to the zonation pattern by Géhu & Biondi (1994b), are considered. Spatial distribution is presented in the Fig. 3.

Halo-nitrophilous therophytic psammophile vegetation

Annual communities growing on the beach area flooded in winter, where breaking sea releases substantial deposits of organic material, especially remains of *Posidonia oceanica* (L.) Delile, are here considered.

SALSOLO KALI-CAKILETUM MARITIMAE Costa & Manz. 1981 *corr*. Rivas-Martìnez *et al*. 1992, Tab. 15.

This is a paucispecific association with open structure and consisting of ephemeral annual plants, typical of

Tab. 10 - *Limonietum narbonense-glomerati* Biondi, Diana, Farris & Filigheddu 2001
limonietosum glomerati Biondi, Diana, Farris & Filigheddu 2001
limonietosum virgati Biondi, Diana, Farris & Filigheddu 2001

	Rel. n.	1	2	3	4	5	6	7	Pr
	Coverage (%)	60	90	90	70	60	60	80	e
	Area (m^2)	5	3	4	5	20	4	5	s.
	Charact. and diff. taxa of the ass. and of the *limonietosum glomerati* subass.								
H ros	*Limonium glomeratum* (Tausch) Erben	3.3	4.5	4.5	4.5	3.4	3.4	4.5	7
H ros	*Limonium narbonense* Miller	.	2.2	2.3	+	2.2	.	1.2	5
	Diff. taxa of the *limonietosum virgati* subass.								
H ros	*Limonium virgatum* (Willd.) Fourr.	.	.	.	.	.	2.2	3.3	2
	Charact. and diff. taxa of the upper units								
Ch frut	*Halimione portulacoides* (L.) Aellen	1.2	.	+	1.2	+.2	2.2	1.2	6
Ch succ	*Sarcocornia fruticosa* (L.) A.J. Scott	.	1.2	1.2	+.2	1.2	.	+.2	5
G bulb	*Triglochin bulbosum* L. ssp. *barrelieri* (Loisel.) Rouy	+.2	.	.	1.2	1.2	1.1	.	4
H caesp	*Puccinellia palustris* (Seen.) Hayek	.	.	.	+	+	+	.	3
Ch succ	*Arthrocnemum macrostachyum* (Moric.) Moris	+	.	.	.	.	+.2	.	2
NP	*Limoniastrum monopetalum* (L.) Boiss.	.	.	.	.	.	.	+	1
	Sporadic species	0	3	4	0	0	0	1	

Tab. 11 - *Scirpo-Juncetum subulati* Géhu,
Biondi, Géhu-Franck & Costa 1992

	Rel. n.	1	2
	Coverage (%)	100	100
	Area (m^2)	10	2
	Charact. and diff. taxa of the ass.		
G rhiz	*Juncus subulatus* Forsskal	5.5	5.5
	Other species		
Ch frut	*Halimione portulacoides* (L.) Aellen	3.4	2.2
Ch succ	*Arthrocnemum macrostachyum* (Moric.) Moris	1.2	.
T scap	*Sonchus oleraceus* L.	+	.

Tab. 12 - *Inulo-Juncetum maritimi* Brullo *in* Brullo,
De Sanctis, Furnari, Longhitano & Ronsisvalle 1988

	Rel. n.	1
	Coverage (%)	90
	Area (m2)	10
	Charact. and diff. taxa of the ass. and of the upper units	
G rhiz	*Juncus maritimus* Lam.	5.5
H ros	*Limonium narbonense* Miller	+
Ch suffr	*Inula crithmoides* L.	+
	Other species	
Ch frut	*Halimione portulacoides* (L.) Aellen	1.2

the first portion of the emerged beach, where winter breaking sea releases substantial deposits of organic substance. Communities of *Cakile maritima* were already reported for the coast between Olbia and S. Teodoro [Chiesura-Lorenzoni & Lorenzoni, 1984 *sub Cakileto-Xanthietum italici* (Bég. 1941) Pign. 1953].

ATRIPLICETUM HASTATO-TORNABAENI O. Bolòs 1962, Tab. 16.

This therophytic and halo-nitrophilous association being considered rare throughout the Mediterranean (Géhu & Biondi, 1994a) grows every year in the same location, near cumulations of organic substances, and shows a larger covering than the above one.

Hemicriptophytic and geophytic psammophile vegetation

Perennial communities dominated by specialised plants, which can be ascribed to the same higher units of vegetation (*Ammophiletea* class) but covering

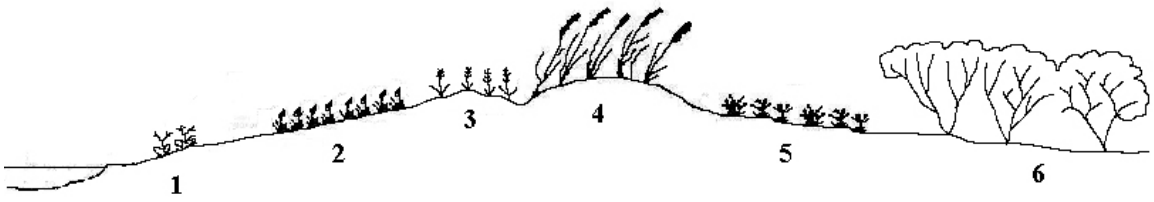

Fig. 3 – Transect of the psammophile vegetation in "Lido del Sole": 1. *Salsolo kali-Cakiletum maritimae*; 2. *Sporoboletum arenarii elymetosum farcti*; 3. *Sileno corsicae-Elytrigetum junceae*; 4. *Sileno corsicae-Ammophiletum arundinaceae*; 5. *Crucianello-Helichrysetum microphylli*; 6. *Ephedro fragilis-Pistacietum lentisci*

ecologically different environment. They are affected by a decreasing gradient of salinity and an increasing gradient of dune evolution and distance from the sea and by a different granulometry of the substratum (Fig. 3).

SPOROBOLETUM ARENARII (Arènes 1924) Géhu & Biondi 1994, Tab. 17.

elymetosum farcti Géhu & Biondi 1994

This paucispecific association dominated by *Sporobolus pungens* is present in the first portion of the emerged beach, when its morphology presents some temporary marine ingressions. The progressive regression of the coastal line, due to erosion phenomena, leads to the growth of the subassociation *elymetosum farcti* (Géhu & Biondi, 1994a), index of destructuration of the dune, which is here in the high side of the beach.

Tab. 13 - *Junco acuti-Schoenetum nigricantis* Géhu, Biondi, Géhu-Franck & Taffetani 1987

	Rel. n.	1	2	3	4	5	P r e s.
	Coverage (%)	100	100	100	100	100	
	Area (m²)	50	50	50	30	30	
	Charact. and diff. taxa of the ass.						
H caesp	*Schoenus nigricans* L.	4.5	2.2	5.5	5.5	4.5	5
H caesp	*Juncus acutus* L.	+.2	.	.	+.2	3.3	3
	Diff. taxa of the variant						
H scap	*Inula viscosa* (L.) Aiton	+	+	+	.	.	3
H caesp	*Carex distans* L.	2.3	3.3	.	.	.	2
	Diff. taxa of the variant						
H ros	*Limonium virgatum* (Willd.) Fourr.	.	.	.	1.2	1.2	2
H ros	*Limonium narbonense* Miller	.	.	.	1.2	+	2
	Charact. and diff. taxa of the upper units						
Ch suffr	*Inula crithmoides* L.	1.2	1.2	1.1	2.2	1.2	5
G rhiz	*Juncus maritimus* Lam.	3.3	4.4	+	3.3	1.2	5
	Other species						
G rhiz	*Agropyron pungens* (Pers.) R. *et* S.	1.1	+	.	2.2	1.2	4
	Sporadic species	2	0	0	1	0	

SILENO CORSICAE-ELYTRIGETUM JUNCEAE (Malcuit 1926) Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992 *corr*. Géhu 1996, Tab. 18.

glaucietosum flavi Biondi, Filigheddu & Farris 2001, rel. 1-3, Tab. 18.

silenetosum corsicae Biondi, Filigheddu & Farris 2001, rel. 4-8, Tab. 18.

This Sardinian-Corsican endemic association is present throughout the sandy coasts of western and north-western Sardinia. Tables 10 and 11 by Chiesura-Lorenzoni & Lorenzoni (1984) show the presence of the differential species *Silene corsica* DC. (sub *S. succulenta* Forsskål), which allows ascribing to the Sardinian-Corsican association *Sileno corsicae-Elytrigetum junceae* the vegetation dominated by *Agropyron junceum* (= *Elytrigia juncea*) of this coast, already ascribed to the association *Agropyretum mediterraneum* (Kühnh) Br.-Bl. 1933. On sandy pebbly substrata of the dune of Lido del Sole (rel. 1-3 of Tab. 18), the subassociation *glaucietosum flavi* is present.

SILENO CORSICAE-AMMOPHILETUM ARUNDI-NACEAE Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992, Tab. 19.

This Sardinian-Corsican association grows on dunes prone to strong and constant winds, which also cause a relative instability detectable by the mixture with species belonging to the *Crucianellion maritimae* alliance. Thus, these are conditions of natural disturbance strongly deteriorated by the anthropic action. The same association, *sub Ammophiletum arundinaceae* Br.-Bl. (1921) 1933 was detected on coasts to the south of Olbia (Chiesura-Lorenzoni & Lorenzoni, 1984).

Tab. 14 - *Parapholido incurvae-catapodietum balearici* Rivas-Martínez, Lousã, Dìaz, Fernàndez-Gonzàlez & Costa 1990 *corr.* Brullo & Giusso Del Galdo 2003

	Rel. n.	1	2	3	4	P r e s.
	Coverage (%)	100	100	90	80	
	Area (m²)	5	4	2	0,5	
	Charact. and diff. taxa of the ass. and of the upper units					
T scap	*Parapholis incurva* (L.) Hubbard	5.5	5.5	4.4	3.3	4
T scap	*Sagina maritima* G. Don	1.2	.	2.2	4.4	3
T scap	*Polypogon subspathaceus* Req.	1.2	.	.	.	1
T scap	*Plantago coronopus* L. ssp. *commutata* (Guss.) Pilger	2.2	.	.	.	1
T scap	*Centaurium pulchellum* (Swartz) Druce	+	.	.	.	1
T scap	*Galium verrucosum* Hudson var. *halophilum* (Ponzo) Natali *et* Jeanmonod	.	.	+	.	1
	Sporadic species	2	1	2	4	

Tab. 15 - *Salsolo kali-Cakiletum maritimae* Costa & Mansanet 1981 corr. Rivas-Martìnez *et al* . 1992

	Rel. n.	1	2	3	4	Pr
	Coverage (%)	30	30	50	60	e
	Area (m²)	5	10	2	10	s.
	Charact. and diff. taxa of the ass.					
T scap	*Cakile maritima* Scop.	2.3	2.1	3.3	3.3	4
T scap	*Salsola kali* L.	2.2	+	2.2	+	4
	Charact. and diff. taxa of the upper units					
T scap	*Atriplex latifolia* Wahlenb.	+	.	+	.	2
H rept	*Polygonum maritimum* L.	.	.	+	+	2
	Other species					
G rhiz	*Elymus farctus* (Viv.) Runemark *ex* Melderis ssp. *farctus*	+	+	+.2	1.1	4
H scap	*Glaucium flavum* Crantz	.	+	+	.	2
G rhiz	*Sporobolus pungens* (Schreber) Kunth	.	1.2	.	.	1
G rhiz	*Eryngium maritimum* L.	.	.	+	.	1
T scap	*Matthiola tricuspidata* (L.) R. Br.	.	.	.	+	1

Tab. 16 - *Atriplicetum hastato-tornabeni* O. Bolòs 1962

	Rel. n.	1	2	3	4	5	6	Pr
	Coverage (%)	90	90	30	60	70	70	e
	Area (m²)	5	10	3	5	5	5	s.
	Charact. and diff. taxa of the ass.							
T scap	*Atriplex tatarica* L.	4.5	4.5	+.2	2.3	3.3	3.3	6
T scap	*Atriplex latifolia* Wahlenb.	+	1.2	1.1	.	+	1.1	5
	Charact. and diff. taxa of the upper units							
T scap	*Cakile maritima* Scop.	1.2	3.3	2.2	1.2	.	.	4
T scap	*Salsola kali* L.	.	.	+.2	1.2	.	.	2
H rept	*Polygonum maritimum* L.	.	.	+	+	.	.	2
	Other species							
T scap	*Salsola soda* L.	2.3	1.1	.	.	1.2	1.1	4
G rhiz	*Sporobolus pungens* (Schreber) Kunth	.	(+.2)	+	.	.	.	2
G rhiz	*Eryngium maritimum* L.	.	.	.	+	.	.	1
G rhiz	*Elymus farctus* (Viv.) Runemark *ex* Melderis ssp. *farctus*	.	.	.	+	.	.	1

Tab. 17 - *Sporoboletum arenarii* (Arènes 1924) Géhu & Biondi 1994
elymetosum farcti Géhu & Biondi 1994

	Rel. n.	1	2	3	4	5	Pr
	Coverage (%)	50	70	70	75	50	e
	Area (m²)	10	10	10	10	10	s.
	Charact. and diff. taxa of the ass. and of the *elymetosum farcti* subass.						
G rhiz	*Sporobolus pungens* (Schreber) Kunth	3.2	3.4	3.3	4.4	3.3	5
G rhiz	*Elymus farctus* (Viv.) Runemark *ex* Melderis ssp. *farctus*	+	.	+	.	+.2	3
	Charact. and diff. taxa of the upper units						
G bulb	*Pancratium maritimum* L.	+	+	.	.	.	2
G rhiz	*Eryngium maritimum* L.	+	+	.	.	.	2
H scap	*Anthemis maritima* L.	.	1.2	.	.	.	1
	Sporadic species	6	3	2	2	2	

Camephytic psammophile vegetation

The camephytic psammophile vegetation, detectable on steady or grey dunes, is referable to the association *Crucianello-Helichrysetum microphylli*. Chiesura-Lorenzoni & Lorenzoni, (1984) reported the association *Crucianelletum maritimae* Br.-Bl. for the coasts to the south of Olbia.

CRUCIANELLO-HELICHRYSETUM MICROPHYLLI Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992, Tab. 20.

This association is found on the continental slope of the littoral dune of Lido del Sole, on fine, steady and relatively wet sands. The presence of species belonging to the *Ammophiletea* class and especially of *Anthemis maritima*, reveals the state of destructuration and

Tab. 18 - *Sileno corsicae-Elytrigetum junceae* (Malcuit 1926) Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992 corr. Géhu 1996
silenetosum corsicae Biondi, Filigheddu & Farris 2001
glaucietosum flavii Biondi, Filigheddu & Farris 2001

	Rel. n.	1	2	3	4	5	6	7	8	Pres.
	Coverage (%)	60	80	50	70	70	80	70	80	
	Area (m^2)	5	10	10	15	10	10	10	10	
	Charact. and diff. taxa of the ass. and of the *silenetosum corsicae* subass.									
G rhiz	*Elymus farctus* (Viv.) Runemark *ex* Melderis ssp. *farctus*	2.2	4.4	3.2	3.4	3.3	4.4	3.4	4.4	8
G rhiz	*Silene corsica* DC.	+	+	+	.	.	.	.	.	3
	Diff. taxa of the *glaucietosum flavii* subass.									
H scap	*Glaucium flavum* Crantz	+.2	+.2	1.2	.	.	.	.	.	3
	Charact. and diff. taxa of the upper units									
G rhiz	*Eryngium maritimum* L.	+	+	+	+	+	1.2	1.2	+	8
Ch suffr	*Otanthus maritimus* (L.) Hoffmgg. et Link	1.2	+	2.3	2.3	1.2	.	2.3	1.2	7
H scap	*Anthemis maritima* L.	+.2	2.3	1.2	+.2	+	1.2	.	.	6
G rhiz	*Calystegia soldanella* (L.) R. Br.	.	.	+	1.2	1.2	1.2	+.2	.	5
G rhiz	*Sporobolus pungens* (Schreber) Kunth	+	+	+	.	.	.	+.2	1.2	5
G bulb	*Pancratium maritimum* L.	+	1.1	+	.	.	.	1.1	.	4
Ch rept	*Medicago marina* L.	.	.	.	.	.	1.1	.	.	1
Ch frut	*Euphorbia paralias* L.	.	.	.	.	.	.	.	+.2	1
G rhiz	*Ammophila littoralis* (Beauv.) Rothm.	.	.	+.2	.	.	.	.	.	1
	Other species									
H scap	*Lotus cytisoides* L.	+	+	1.1	+	1.1	1.2	+	1.2	8
H rept	*Polygonum maritimum* L.	1.2	+	+	.	.	1.2	.	.	4
T scap	*Cakile maritima* Scop.	.	+.2	+	+	.	.	.	+	4
	Sporadic species	3	2	1	1	2	0	0	0	

Tab. 19 - *Sileno corsicae-Ammophiletum arundinaceae* Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992

	Rel. n.	1	2	3	4	5	6	Pres.
	Coverage (%)	100	85	70	90	95	30	
	Area (m^2)	3	10	10	10	60	20	
	Charact. and diff. taxa of the ass.							
G rhiz	*Ammophila littoralis* (Beauv.) Rothm.	5.5	4.4	4.4	4.5	5.5	2.2	6
H scap	*Silene corsica* DC.	.	.	.	.	.	+.2	1
	Charact. and diff. taxa of the upper units							
H scap	*Anthemis maritima* L.	1.2	1.2	1.2	.	1.2	+	5
Ch suffr	*Otanthus maritimus* (L.) Hoffmgg. et Link	1.2	+.2	+.2	1.2	.	+	5
G bulb	*Pancratium maritimum* L.	.	2.1	+	+	+.2	1.1	5
G rhiz	*Eryngium maritimum* L.	.	1.1	+	+	+	.	4
G rhiz	*Sporobolus pungens* (Schreber) Kunth	.	+	1.2	.	.	.	2
G rhiz	*Elymus farctus* (Viv.) Runemark *ex* Melderis ssp. *farctus*	.	+	+	.	.	.	2
G rhiz	*Calystegia soldanella* (L.) R. Br.	.	.	+.2	.	.	.	1
H scap	*Echinophora spinosa* L.	.	.	.	+	.	.	1
	Other species							
H scap	*Lotus cytisoides* L.	.	+.2	+	.	1.2	.	3
T scap	*Lagurus ovatus* L.	.	+	+	.	1.1	.	3
Ch suffr	*Crucianella maritima* L.	.	.	.	2.2	1.2	+	3
	Sporadic species	0	2	2	0	0	2	

nitrification of the dune (Géhu & Biondi, 1994b). This is the second detection of this association in northern Sardina, after the one in Porto Ferro – SS (Biondi *et al*., 2001a).

Nanophanerophytic and phanerophytic psammophile vegetation

The continental slope of the dune, less exposed to sea aerosol, is colonised by phanerophytic vegetation of *Juniperus turbinata* and *Pistacia lentiscus*, of which only some strips remain, whereas the regressive successional stages are more common and consisting mainly of shrub communities dominated by *Pistacia lentiscus*.

EPHEDRO FRAGILIS-PISTACIETUM LENTISCI ass. nova hoc loco (typus rel. n. 3, Tab. 21).

On continental slopes of the dunes of “Lido del Sole”, a shrub vegetation dynamically linked to juniper groves

Tab. 20 - *Crucianello-Helichrysetum microphylli* Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992

	Rel. n.	1	2	3	4	5	6	7	Pres.
	Coverage (%)	80	70	70	80	70	85	70	
	Area (m²)	15	20	20	30	30	20	50	
	Charact. and diff. taxa of the ass.								
Ch suffr	*Crucianella maritima* L.	3.3	3.3	3.3	1.2	1.1	4.4	2.3	7
Ch suffr	*Helichrysum italicum* (Roth) Don ssp. *microphyllum* (Willd.) Nyman	2.2	3.4	2.2	3.4	2.2	1.2	2.3	7
	Charact. and diff. taxa of the *Ammophiletea* class								
H scap	*Anthemis maritima*	+	1.2	+.2	.	1.1	1.2	+	6
G bulb	*Pancratium maritimum* L.	.	+	1.1	1.1	+	+	1.1	6
G rhiz	*Ammophila littoralis* (Beauv.) Rothm.	+	.	1.2	.	.	.	+	3
G rhiz	*Elymus farctus* (Viv.) Runemark *ex* Melderis ssp. *farctus*	+	.	1.1	+	.	.	.	3
Ch suffr	*Otanthus maritimus* (L.) Hoffmgg. *et* Link	.	.	1.1	.	.	.	.	1
G rhiz	*Sporobolus pungens* (Schreber) Kunth	.	.	.	.	.	.	+	1
	Other species								
H suffr	*Lotus cytisoides* L.	.	.	2.2	1.2	.	+.2	+.2	4
NP	*Osyris alba* L.	.	2.2	.	1.2	3.3	.	.	3
G rhiz	*Holoschoenus romanus* (L.) Fritsch	.	.	.	.	2.2	2.2	.	2
T scap	*Reseda alba* L.	.	.	.	.	.	+.2	+	2
T scap	*Lagurus ovatus* L.	.	.	.	.	+	+	.	2
	Sporadic species	0	0	0	0	2	0	2	

Tab. 21 - *Ephedro fragilis-Pistacietum lentisci* ass. nova (typus rel. n. 3)

	Rel. n.	1	2	3*	4	5	Pres.
	Coverage (%)	90	98	100	100	100	
	Area (m²)	20	20	10	10	50	
	Charact. and diff. taxa of the ass. and of the upper units						
P caesp	*Pistacia lentiscus* L.	1.2	1.2	3.4	4.5	5.5	5
NP	*Ephedra fragilis* Desf.	3.3	3.3	2.3	1.2	+.2	5
NP	*Osyris alba* L.	2.3	1.2	1.2	+.2	1.1	5
G rhiz	*Asparagus acutifolius* L.	+	.	1.2	2.2	1.1	4
P lian	*Rubia peregrina* L.	.	.	2.2	+.2	+.2	3
G rhiz	*Ruscus aculeatus* L.	.	.	+.2	.	1.1	2
	Other species						
H scap	*Carlina corymbosa* L.	2.2	2.2	+	1.2	.	4
H bienn	*Daucus carota* L.	+.1	1.2	1.1	1.1	.	4
H scap	*Reichardia picroides* (L.) Roth	1.2	+	+	+	.	4
H scap	*Lotus cytisoides* L.	+.2	+.2	+.2	.	+	4
Ch suffr	*Helichrysum italicum* (Roth) Don ssp. *microphyllum* (Willd.) Nyman	2.2	2.3	.	.	1.2	3
T scap	*Lagurus ovatus* L.	1.1	.	+	1.1	.	3
T scap	*Reseda alba* L.	.	+	1.1	1.1	.	3
H caesp	*Melica arrecta* O. Kuntze	.	+	+	+	.	3
	Sporadic species	1	3	1	0	4	

was detected. It is dominated by *Pistacia lentiscus* and characterised by *Ephedra fragilis*, a Mediterranean entity present in Italy in Calabria, Sicily and Sardinia (Pignatti, 1982), island where, on the contrary, it would be absent according to Greuter *et al.* (1984) and present as introduced species according to Arrigoni in Greuter (1981).

The studied community is included in the new association *Ephedro fragilis-Pistacietum lentisci*: here, a pioneer stage of *Ephedra fragilis* and *Helichrysum microphyllum* (rel. 1 and 2) and a more advanced stage marked by the presence of *Rubia peregrina* (rel. 3-5) can be distinguished. This association is believed to be a dynamic stage towards psammophile phanerophytic formations.

Discussion

Spatial distribution analysis of halophilous plant communities (Fig. 2) allows highlighting the variation in salinity gradient due to the microtopography, and this confirms what already observed in Andreucci *et al.* (1998) and Biondi & Zuccarello (2000). In particular, the current study allows explaining better the ecological and syntaxonomic aspects of halophilous coenoses characterised by the presence of *L. monopetalum*. This species finds its optimum at mean high levels of salty grasslands, on rarely flooded sandy soils, by joining in *A. macrostachyum* or *H. portulacoides*: however, in the first case, *L. monopetalum* never reaches covering

values higher than the ones of *A. macrostachyum* species, which dominates this coenosis not only in our table but also according to the results showed in previous studies (Tab. 5 in Valsecchi & Diana-Corrias, 1973). This community grows on sandy silty soils, prone to flooding in winter, ecological conditions that limits the development of *L. monopetalum*. When it joins in *H. portulacoides*, on the contrary, *L. monopetalum* shows high covering values and becomes dominant, characterising thereby the new association *Halimiono portulacoidis-Limoniastretum monopetali*, which grows on sandy substrata rarely flooded: under these ecological conditions, *L. monopetalum* acts as a nanophanerophyte getting slightly lower than 2 m high.

This topographic contacts are pointed out in the transect of Fig. 2. In addition, the study allows highlighting a tighter affinity, within the *Salicornietea fruticosae* class, of the coenoses of *L. monopetalum* together with the ones of perennial saltworts: the *Limoniastrion monopetali* alliance in the order *Salicornietalia fruticosae* is therefore confirmed (Biondi & Géhu, 1995; Golub *et al*., 2001).

The phytosociologic analysis of psammophile vegetation, together with the utilisation of the transect method (Fig. 3), allows – referring to the zonation patterns by Géhu & Biondi (1994b) – to express some evaluations about the level of anthropization of these dunal systems. Although the presence of all the segments of vegetation, being typical of micro-geosigmetum, represents an index of good conservation, it is necessary to observe that, in the harbour of Olbia, the merely eutrophic association *Atriplicetum hastato-tornabaeni* has replaced the association *Salsolo kali-Cakiletum maritimae*, being typical of the first portion of the beach in every coast of Mediterranean. The perennial vegetation of rhizomatous graminaceous plants appears destructured and often lacking in more valuable species, such as *Silene corsica*, index of a good quality of the community. Finally, in the continental side of the dune, juniper groves are everywhere replaced by the shrub vegetation, represented in this context by the association *Ephedro fragilis-Pistacietum lentisci*.

Thus, because of its bioindication property given by plant communities and stressed by their floristic composition, the phytosociological method can be useful in monitoring the coastal ecosystem prone to strong anthropic impacts, due either to fishing, reclamation and optimization of the regime or tourist activities on sandy shores.

Syntaxonomic scheme

PHRAGMITO-MAGNOCARICETEA Klika in Klika & Novàk 1941
- Scirpetalia compacti Hejny in Holub, Hejny, Moravec & Neuhäusl 1967 corr. Rivas-Martìnez, Costa, Castroviejo & E. Valdés 1980
  - Scirpion compacti Dahl & Hadac 1941 corr. Rivas-Martìnez, Costa, Castroviejo & E. Valdés 1980
    - *Scirpo-Juncetum subulati* Géhu, Biondi, Géhu-Franck & Costa 1992

AMMOPHILETEA Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946
- Ammophiletalia Br.-Bl. 1933
  - Ammophilion australis Br.-Bl. 1921 corr. Rivas-Martìnez, Costa & Izco in Rivas-Martìnez, Lousã, T. E. Dìaz, Fernàndez-Gonzàlez & J. C. Costa 1990
    - Ammophilenion australis
      - *Sileno corsicae-Ammophiletum arundinaceae* Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992
    - Sporobolo arenarii-Elytrigenion junceae Géhu 1988 corr. Géhu 1996
      - *Sileno corsicae-Elytrigetum junceae* (Malcuit 1926) Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992 corr. Géhu 1996
        - *glaucietosum flavi* Biondi, Filigheddu & Farris 2001
        - *silenetosum corsicae* Biondi, Filigheddu & Farris 2001
  - Sporobolion arenarii (Géhu & Géhu-Franck ex Géhu & Biondi 1994) Rivas-Martìnez, Fernàndez-Gonzàlez, Loidi, Lousã & Penas 2001
    - Sporobolenion arenarii Géhu 1988
      - *Sporoboletum arenarii* (Arènes 1924) Géhu & Biondi 1994
        - *elymetosum farcti* Géhu & Biondi 1994

CAKILETEA MARITIMAE Tüxen & Preising. ex Br.-Bl. & Tüxen 1952
- Cakiletalia integrifoliae Tüxen ex Oberdorfer 1949 corr. Rivas-Martìnez, Costa & Loidi 1992

Cakilion maritimae Pignatti 1953
Salsolo kali-Cakiletum maritimae Costa & Mansanet 1981 corr. Rivas-Martìnez *et al.* 1992
Atriplicetum hastato-tornabeni O. Bolòs 1962

JUNCETEA MARITIMI Br.-Bl. in Br.-Bl., Roussine & Nègre 1952
Juncetalia maritimi Br.-Bl. ex Horvatic 1934
Juncion maritimi Br.-Bl. ex Horvatic 1934
Inulo-Juncetum maritimi Brullo in Brullo, De Sanctis, Furnari, Longhitano & Ronsisvalle 1988
Plantaginion crassifoliae Br.-Bl. in Br.-Bl., Roussine & Nègre 1952
Junco acuti-Schoenetum nigricantis Géhu, Biondi, Géhu-Franck & Taffetani 1987

SAGINETEA MARITIMAE Westhoff, Van Leeuwen & Adriani 1962
Frankenietalia pulverulentae Rivas-Martìnez ex Castroviejo & Porta 1976
Frankenion pulverulentae Rivas-Martìnez ex Castroviejo & Porta 1976
Parapholido incurvae-catapodietum balearici Rivas-Martínez, Lousã, Dìaz, Fernàndez-Gonzàlez & Costa 1990 *corr.* Brullo & Giusso Del Galdo 2003

SALICORNIETEA FRUTICOSAE Br.-Bl. & Tüxen ex A. & O. Bolòs 1950
Salicornietalia fruticosae Br.-Bl. 1933
Arthrocnemion glauci Rivas-Martìnez & Costa 1984
Puccinellio convolutae-Arthrocnemetum macrostachyi (Br.-Bl. (1928) 1933) Géhu ex Géhu, Costa, Scoppola, Biondi, Marchiori, Peris, Géhu-Franck, Caniglia & Veri 1984
Salicornion fruticosae Br.-Bl. 1933
Puccinellio festuciformis-Halimionetum portulacoidis Géhu, Biondi, Géhu-Franck & Costa 1992
agropyretosum elongati Biondi, Filigheddu & Farris 2001
Cynomorio coccinae-Halimionetum portulacoidis Biondi 1992
Puccinellio festuciformis-Sarcocornietum fruticosae (Br.-Bl. 1928) 1952 Géhu 1976
Sarcocornietum deflexae (Br.-Bl. 1931) Lahondère, Géhu & Paradis 1992
Limoniastrion monopetali Pignatti 1953
Halimiono portulacoidis-Limoniastretum monopetali ass. nova
iridetosum sisyrinchii subass. nova
arthrocnemetosum macrostachyi subass. nova
Limonietalia Br.-Bl. & O. Bolòs 1958
Triglochino barrelieri-Limonion glomerati Biondi, Diana, Farris & Filigheddu 2001
Limonietum narbonense-glomerati Biondi, Diana, Farris & Filigheddu 2001
limonietosum glomerati Biondi, Diana, Farris & Filigheddu 2001
limonietosum virgati Biondi, Diana, Farris & Filigheddu 2001

THERO-SUAEDETEA Rivas-Martìnez 1972
Thero-Salicornietalia Tüxen in Tüxen & Oberdorfer ex Géhu & Géhu-Franck 1984
Salicornion patulae Géhu & Géhu-Franck 1984
Suaedo maritimae-Salicornietum patulae (Brullo & Furnari 1976) Géhu & Géhu-Franck 1984
Salicornietum emerici (O. de Bolòs 1962) Brullo & Furnari 1976
Thero-Suaedetalia Br.-Bl. & O. Bolòs 1958
Thero-Suaedion Br.-Bl. in Br.-Bl., Roussine & Nègre 1952
Salsoletum sodae Pignatti 1953

HELICHRYSO-CRUCIANELLETEA Géhu, Rivas-Martìnez & Tüxen in Géhu 1975
Crucianelletalia maritimae Sissingh 1974
Crucianellion maritimae Rivas Goday & Rivas-Martìnez 1958
Crucianello-Helichrysetum microphylli Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992

QUERCETEA ILICIS Br.-Bl. ex A. & O. Bolòs 1950
Pistacio lentisci-Rhamnetalia alaterni Rivas-Martìnez
Oleo-Ceratonion siliquae Br.-Bl. ex Guinochet & Drouineau 1944 em. Rivas-Martínez 1975
Ephedro fragilis-Pistacietum lentisci ass. nova

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Sites and dates of relevées

Tab. 1
Rel. 1, 2 - 19/6/91 Lido del Sole (Olbia – SS); rel. 3, 4 - 25/8/01 Lido del Sole (Olbia – SS).

Tab. 2
Rel. 1, 2, 3 - 9/8/01 Lido del Sole (Olbia – SS); rel. 4, 5 - 25/8/01 Lido del Sole (Olbia – SS); rel. 6, 7 - 5/8/94 Lido del Sole (Olbia – SS).

Tab. 3
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Tab. 4
Rel. 1, 2 - 9/8/01 Lido del Sole (Olbia – SS); rel. 3 - 25/8/01 Lido del Sole (Olbia – SS).

Tab. 5
Rel. 1, 2 - 8/8/01 loc. Li Cuncheddi (Olbia – SS); rel. 3 - 9/8/01 Lido del Sole (Olbia – SS); rel. 4 - 10/8/01 loc. Punta delle Saline (Olbia – SS).

Tab. 6
Rel. 1, 2, 3, 4 - 19/6/91 Lido del Sole (Olbia – SS); rel. 5 - 5/8/94 Lido del Sole (Olbia – SS).

Tab. 7
Rel. 1, 2, 3, 4, 5, 6, 7, 8 - 9/8/01 Lido del Sole (Olbia – SS); rel. 9-10 - 6/8/94 Lido del Sole (Olbia – SS); rel. 11-18 - 19/6/91 Lido del Sole (Olbia – SS); rel. 19-23 - 5/8/94 Lido del Sole (Olbia – SS).

Tab. 8
Rel. 1, 2 - 25/8/01 Lido del Sole (Olbia – SS); rel. 3, 4, 5 - 5/8/94 Lido del Sole (Olbia – SS).

Tab. 9
Rel. 1, 2 - 19/6/91 Lido del Sole (Olbia – SS).

Tab. 10
Rel. 1 = rel. n. 3, Tab. 1 di Biondi *et al*., 2001b; rel. 2 = rel. n. 4, Tab. 1 di Biondi *et al*., 2001b; rel. 3 = rel. n. 5, Tab. 1 di Biondi *et al*., 2001b; rel. 4 = rel. n. 6, Tab. 1 di Biondi *et al*., 2001b; rel. 5 = rel. n. 7, Tab. 1 di Biondi *et al*., 2001b; rel. 6 = rel. n. 12, Tab. 1 di Biondi *et al*., 2001b; rel. 7 = rel. n. 13, Tab. 1 di Biondi *et al*., 2001b.

Tab. 11
Rel. 1, 2 - 19/6/91 Lido del Sole (Olbia – SS).

Tab. 12
Rel. 1 - 25/8/01 Lido del Sole (Olbia – SS).

Tab. 13
Rel. 1, 2 - 5/8/94 Lido del Sole (Olbia – SS); rel. 3 - 13/3/02 Lido del Sole (Olbia – SS); rel. 4, 5 - 6/8/94 Lido del Sole (Olbia – SS).

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Tab. 16
Rel. 1, 2 - 9/8/01 duna bassa, su resti di *Zostera noltii* Hornem., Lido del Sole, uscita dal porto di Olbia (SS); rel. 3, 4 - 25/8/01 Lido del Sole (Olbia – SS); rel. 5, 6 - 6/8/94 Lido del Sole (Olbia – SS).

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Tab. 19
Rel. 1 - 19/6/91 Lido del Sole (Olbia – SS); rel. 2, 3 - 25/8/01 Lido del Sole (Olbia – SS); rel. 4 - 1/8/94 loc. Marina Maria, Costa Turchese (Olbia – SS); rel. 5 - 3/8/94 loc. Li Cuncheddi (Olbia – SS); rel. 6 - 13/3/02 loc. Le Saline (Olbia – SS).

Tab. 20
Rel. 1, 2 - 19/6/91 Lido del Sole (Olbia – SS); rel. 3, 4, 5 - 1/8/94 loc. Marina Maria, Costa Turchese (Olbia – SS); rel. 6 - 3/8/94 Punta delle Saline (Olbia – SS); rel. 7 - 13/3/02 loc. Le Saline (Olbia – SS).

Tab. 21
Rel. 1, 2, 3, 4, 5 - 8/12/03 Lido del Sole (Olbia – SS).

Sporadic species

Tab. 2
Rel. 4: *Arthrocnemum macrostachyum* (Moric.) Moris +.

Tab. 5
Rel. 1: *Juncus acutus* L. 1.2; rel. 2: *Juncus acutus* L. +, *Sporobolus pungens* (Schreber) Kunth 1.2; rel. 3: *Cynosurus echinatus* L. +, *Lagurus ovatus* L. +.

Tab. 7
Rel. 1: *Lagurus ovatus* L. +; rel. 3: *Lagurus ovatus* L. +; rel. 4: *Lagurus ovatus* L. +; rel. 6: *Juncus subulatus* Forsskal 1.2; rel. 8: *Pistacia lentiscus* L. 1.2; rel. 9: *Inula crithmoides* L. 1.2; rel. 10: *Inula crithmoides* L. 1.2, *Limonium narbonense* Miller +; rel. 16: *Juncus maritimus* Lam. +, *Limonium narbonense* Miller +; rel. 17: *Juncus maritimus* Lam. +; rel. 18: *Juncus maritimus* Lam. 1.2.

Tab. 10
Rel. 2: *Juncus maritimus* Lam. 1.2, *Agropyron elongatum* (Host) Beauv. +.2, *Inula crithmoides* L. 1.2; rel. 3: *Juncus maritimus* Lam. 1.2, *Inula crithmoides* L. +.2, *Sporobolus pungens* (Schreber) Kunth 2.2, *Plantago coronopus* L. 1.2; rel. 7: *Agropyron elongatum* (Host) Beauv. 1.2.

Tab. 13
Rel. 1: *Centaurium pulchellum* (Swartz) Druce +, *Blackstonia perfoliata* (L.) Hudson +; rel. 4: *Centaurium pulchellum* (Swartz) Druce +.

Tab. 14
Rel. 1: *Triglochin bulbosum* L. +, *Gaudinia fragilis* (L.) Beauv. +; rel. 2: *Triglochin bulbosum* L. 1.1; rel. 3: *Triglochin bulbosum* L. +, *Limonium glomeratum* (Tausch) Erben +; rel. 4: *Bellis annua* L. +.2, *Iris sisyrinchium* L. +, *Romulea requienii* Parl. 1.1, *Anagallis* sp. +.2.

Tab. 17
Rel. 1: *Crithmum maritimum* L. 2.2, *Cakile maritima* Scop. +.2, *Salsola kali* L. +, *Atriplex latifolia* Wahlenb. +, *Lagurus ovatus* L. +, *Glaucium flavum* Crantz +; rel. 2: *Crithmum maritimum* L. 1.2, *Cakile maritima* Scop. +.2, *Salsola kali* L. +; rel. 3: *Polygonum maritimum* L. 1.1, *Holoschoenus romanus* (L.) Fritsch 2.2; rel. 4: *Salsola soda* L. 1.1, *Matthiola tricuspidata* (L.) R. Br. 1.1; rel. 5: *Polygonum maritimum* L. +, *Lotus cytisoides* L. +.

Tab. 18
Rel. 1: *Salsola kali* L. +, *Inula crithmoides* L. +, *Crithmum maritimum* L. +; rel. 2: *Salsola kali* L. +, *Atriplex tatarica* L. +; rel. 3: *Lagurus ovatus* L. +; rel. 4: *Reseda alba* L. +; rel. 5: *Silene nicaeensis* All. +, *Cutandia maritima* (L.) Richter +.

Tab. 19
Rel. 2: *Crithmum maritimum* L. +.2, *Glaucium flavum* Crantz +; rel. 3: *Cakile maritima* Scop. +, *Silene nummica* Vals. +; rel. 6: *Aetheorrhiza bulbosa* (L.) Cass. 1.2, *Reseda alba* L. +.

Tab. 20
Rel. 5: *Daucus carota* L. +, *Corynephorus divaricatus* (Pourr.) Breistr. +; rel. 7: *Aetheorrhiza bulbosa* (L.) Cass. 1.2, *Carpobrotus acinaciformis* (L.) L. Bolus +.

Tab. 21
Rel. 1: *Matthiola tricuspidata* (L.) R. Br. +; rel. 2: *Anthemis maritima* L. 1.1, *Ferula arrigoni* Bocchieri +, *Sporobolus pungens* (Schreber) Kunth +; rel. 3: *Smyrnium rotundifolium* Miller 1.1; rel. 5: *Calicotome villosa* (Poiret) Link 1.2, *Oryzopsis miliacea* (L.) Asch. *et* Schweinf. +, *Arisarum vulgare* Targ.-Tozz. +, *Cistus salvifolius* L. +.2.