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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-Limonietum monopetali ass. nova and Ephedro fragilis-Pistacietum lentisci ass. nova. Among them, the association Halimiono portulacoidis-Limonietum monopetali shows a particular phytogeographical interest, because it sets the Limonietum monopetali 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-Limonietum monopetali ass. nova, halophilous vegetation, phytosociology, Sardinia, syntaxonomy.

Riassunto

Dal punto di vista sintassonomico i sintaxa descritti ricadono in 9 classi di vegetazione. 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 essere protetta a fini di conservazione e gestione delle popolazioni vegetali.


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 Padrognianus 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.

Padrognianus 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 ria 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 ria. 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.
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.

SUAEOD MARITIMAE-SALICORNIELTUM PATULAE

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).

SALICORNIELTUM EMERICI
(O. de Bolòs 1962) Brullo & Fumari 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 (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, NANOPHANEROPTHYC AND HEMICRYPTOPHTHYC HALOPHILOUS VEGETATION

This kind of vegetation covers large surfaces of the study area, whose morphology is defined by the ramifications of Padroianus 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 hemicryptophytic formations or the climacic shrubby

communities. Contacts with the more halophilous camephytic associations and the halotolerant hemicryptophytic 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**


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**
as 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, Salentia 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-Limoniastrum monopetalii* Rivas-Martínez & 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 *Limoniastrum-Staticeetum lychnidifolii* 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
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-Arthrocnemum macrostachyi* Tadros 1952, described in the area of Marcots 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 in chain contact with the halonitrophilous and aridophilous association of *Cynomorium coccineum* and *H. portulacoides* (*Cynomorium coccineum-Halimionetum portulacoidis*) and with the hemicriptophytic grasslands of *Juncetea maritimii* class, which grow on constantly wet sandy soils.

**PUCCINELLIO FESTUCIFORMIS-SARCOCORNIE-TUM 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 vegetation 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 hypersaline substratum in summer, the monospecific prostrate vegetation of *Sarcocornia fruticosa* var. *deflexa* grows, ascribed to the association *Sarcocornietum deflexae*.


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 Limonium narbonense-glomerati, recently described (Biondi et al., 2001b). The subassociation limonium 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.

**INUULO-JUNCETUM MARITIMI** Brullo in Brullo, De Sanctis, Furnari, Longhitano & Ronnisvalle 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 repentinis* 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). Relevés showed in Table 7 in Chiesura-Lorenzoni & Lorenzoni (1984) are to be ascribed to this association.

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

<table>
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<th>Rel. n.</th>
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<td>40</td>
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| Character and diff. taxa of the asso. and of the agropyretosum elongati subass. |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Ch frut | Halimion portulacoides (L.) Aellen | 5.5 | 4.4 | 5.5 | 5.5 | 4 |
| H caesp | Agropyron elongatum (Host) Beauv. | . | . | 1.1 | 1.2 | 2 |
| G bulb | Iris spargani L. | 3.3 | 3.3 | .3 | 3 |

| Character and diff. taxa of the upper units |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Ch succ | Arthrocnemum macrostachyum (Moric.) Moris | 1.2 | +.2 | + | .3 |
| Ch succ | Sarcocornia frutescens (L.) A.J. Scott | . | + | 2.2 | 2 |
| H ros | Limonium virgatum (Wild.) Fourn. | . | . | + | .2 | 1 |
| NP | Limoniastrum monopetalum (L.) Boiss. | . | . | + | .1 |

| Sporadic species | 1 | 2 | 0 |

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

<table>
<thead>
<tr>
<th>Rel. n.</th>
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| Character 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 (Homem.) Hayek | 1.2 | 2.1 | 1.2 | + | .4 |

| Character and diff. taxa of the upper units |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Ch frut | Halimion portulacoides (L.) Aellen | 2.3 | .2 | 2.2 | + | .3 |

| Character and diff. taxa of the *Juncetea maritimi* class |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| H ros | Limonium narbonense Miller | . | . | 1.2 | 1 |
| Ch sufr | Inula arnottiana L. | . | . | + | 1 |
| G rhiz | Juncus maritimus Lam. | . | . | . | 1 |
Tab. 7 - Halimiono portulacoides-Limoniaster montevidensis ass. nova (type raf. n. 8)  

<table>
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<tr>
<th>NP</th>
<th>Halimiono portulacoides (L.) Roth.</th>
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<td>Ch frut</td>
<td>Halimiono portulacoides (L.) Roth.</td>
</tr>
<tr>
<td>H caesp</td>
<td>Puccinellia palustris (Schn.) Hayek</td>
</tr>
<tr>
<td>G bulb</td>
<td>Iris spicata L.</td>
</tr>
<tr>
<td>H caesp</td>
<td>Agropyron elongatum (HosI.) Beauv.</td>
</tr>
</tbody>
</table>

Tab. 8 - Puccinellopsis festuciformis-Sarcocornium fruticosum (Br.-Bl. 1928) 1952 Géhu 1976  

| 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 | 24 | 25 | 26 |
| Coverage (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Area (m²) | 10 | 10 | 10 | 15 | 15 | 15 | 15 | 5 | 5 | 5 |

Xero-halophilous therophytic vegetation  

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


On cumulated clay sandy soils being dry in summer and subjected to trampling, therophytic communities with spring flowering are present, generally as a mosaic with hemirichrophic formations. They can be ascribed to the association PARAPHOLIUS INCURVAE-CATAPODIETUM BALEARIIC Rivas-Martínez, Lousá, Díaz, Fernández-González & 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.  


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

**ATRIPICETUM 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
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).

**SPOROBOLLETUM ARENARI** (Arènes 1924) Géhu & Biondi 1994, Tab. 17.

eymetosum 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 coastline, 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.

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**Tab. 13** - Junco acuti-Schoenetum nigricantis

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**Charact. and diff. taxa of the ass.**

- *Schoenus nigricans* L.: 5.5, 5.5, 5.5, 5.5
- *Juncus acutus* L.: +, +, +, +

**Charact. and diff. taxa of the upper units**

- *Inula crithmoides* L.: 1.2, 1.2
- *Juncus maritimus* Lam.: 3.3, 4.4

**Other species**

- *Agropyron pungens* (Pers.) R. et S.: 1.1

**Sporadic species**

- 2 0 0 1 0

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</tr>
<tr>
<td>Area (m²)</td>
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<td>4</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Charact. and diff. taxa of the ass. and of the upper units**

- *Parapholis incurva?* (L.) Hubbard: 5.5, 5.5, 4.4, 3.3
- *Sagina maritima* G. Don: 1.2, 1.2, 2.2, 4.4
- *Polypogon subathecatus* Req.: 1.2, 1.2
- *Plantago coronopus* L.: 2.2, 2.2
- *Centaurea pulchellum* (Swartz) Druce: +, +, +
- *Galium verum* Hudson var. halophilum (Ponzo) Natali et Jeanmonod: +, +, +, +

**Sporadic species**

- 2 1 2 4

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glaucietosum flavii 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 *Silene corsicae-Elytrigetum junceae* the vegetation dominated by *Agropyron junceum* (= *Elytrigia juncea*) of this coast, already ascribed to the association *Agropyretum maritimae* KükHn (1933). On sandy pebbly substrata of the dune of Lido del Sole (rel. 1-3 of Tab. 18), the subassociation *glaucietosum flavii* 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).

<table>
<thead>
<tr>
<th>Rel. n.</th>
<th>Coverage (%)</th>
<th>Area (m²)</th>
<th>P</th>
</tr>
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<tr>
<td></td>
<td>1</td>
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<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>2</td>
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</tbody>
</table>

Charact. and diff. taxa of the ass.

T scap  *Cakile maritima* Scop.  2.3  2.1  3.3  3.3  4  4
T scap  *Salsola kali* L.  2.2  +  2.2  +  4  4

Charact. and diff. taxa of the upper units

T scap  *Atriplex lanifolia* Wahlenb.  +  +  +  1  1  4
H rept  *Polygonum maritimum* L.  .  .  +  +  2  2

Other species

G rhiz  *Elymus farctus* (Viv.) Runemark ex Melderis spp.  +  +  +  2  1  4
H rhiz  *Sporobolus pungens* (Schreber) Kunth  .  .  +  .  1  1
G rhiz  *Eryngium maritimum* L.  .  .  +  +  1  1
T scap  *Matthiola tricuspidata* (L.) R. Br.  .  .  +  +  1  1

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

<table>
<thead>
<tr>
<th>Rel. n.</th>
<th>Coverage (%)</th>
<th>Area (m²)</th>
<th>P</th>
</tr>
</thead>
<tbody>
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<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

Charact. and diff. taxa of the ass.

T scap  *Atriplex tatarica* Lo  4.5  4.5  +  2.3  3.3  3.3  6
T scap  *Atriplex lanifolia* 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.  .  .  +  2.2  1.2  .  2
H rept  *Polygonum maritimum* L.  .  .  +  +  2  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  1
G rhiz  *Elymus farctus* (Viv.) Runemark ex Melderis spp.  +  +  +  .  1  1

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

<table>
<thead>
<tr>
<th>Rel. n.</th>
<th>Coverage (%)</th>
<th>Area (m²)</th>
<th>P</th>
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</thead>
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<tr>
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<tr>
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<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Charact. and diff. taxa of the ass. and of the *elymetosum farceti* subass.

G rhiz  *Sporobolus pungens* (Schreber) Kunth  3.2  3.4  3.3  4.4  3.3  5  3
G rhiz  *Elymus farctus* (Viv.) Runemark ex Melderis spp.  +  +  +  +  .  +  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 *Ammophiletetra* class and especially of *Anthemis maritima*, reveals the state of destructuration and...
nitrification of the dune (Géhu & Biondi, 1994b). This is the second detection of this association in northern Sardinia, after the one in Porto Ferro - SS (Biondi et al., 2001a).

Nanophanerophytic andphanerophytic psammophile vegetation

Thecontinental 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.

EPHEDE RO 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
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 *Ephedra 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 & Zucarello (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-Limoniastrum monopetalii*, 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 monopetalii* 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 microgeosigmetum, 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 *Salsole kali-Cakileteum 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

- Scirpio-Juncetum subulati Géhu, Biondi, Géhu-Franck & Costa 1992

**ammophiletæa** Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946

- Ammophiletalia Br.-Bl. 1933
- Ammophilienion australis
- *Sileno corsicae-Ammophiletum arundinaceae* Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992
- *glaucietosum flavi* Biondi, Filigheddu & Farris 2001
- *silenetosum corsicae* Biondi, Filigheddu & Farris 2001
- Sporobolenion arenarii Géhu 1988
- *elymetosum farcti* Géhu & Biondi 1994

**Cakileteæa Maritimæ** Tüxen & Preising, ex Br.-Bl. & Tüxen 1952

- Cakiletalia integrifolieæ Tüxen ex Oberdorfer 1949 corr. Rivas-Martinez, Costa & Loidi 1992
Cakilion maritimae Pignatti 1953
Atriplicetum hastato-tornabeni O. Bolòs 1962

JUNCETEA MARITIMI Br.-Bl. in Br.-Bl., Roussine & Nègre 1952
Juncetalia maritimae Br.-Bl. ex Horvatic 1934
Juncion maritimae Br.-Bl. ex Horvatic 1934

SAGINETEA MARITIMAE Westhoff, Van Leeuwen & Adriani 1962
Frankenietalia pulverulentae Rivas-Martínez ex Castroviejo & Porta 1976
Frankenion pulverulentae Rivas-Martínez ex Castroviejo & Porta 1976

PALEO-SALICERETEA Br.-Bl. & O. Bolòs 1950
Salsocereus maritimus Pignatti 1953

THERO-SUAEDETEA Rivas-Martínez 1972
Thero-Salicornietalia Tüxen in Tüxen & Oberdorfer ex Géhu & Géhu-Franck 1984
Salicornion glomerati Biondi, Diana, Farris & Filigheddu 2001
Limonioum glomerati Biondi, Diana, Farris & Filigheddu 2001
limonioum virgati Biondi, Diana, Farris & Filigheddu 2001

HELICHRYSO-CRUCIANELLETTEA Géhu, Rivas-Martínez & Tüxen in Géhu 1975
Crucianelletalia maritimae Sissingh 1974
Crucianellion maritimae Rivas Goday & Rivas-Martínez 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-Martínez
Oleo-Ceratonion siliquae Br.-Bl. ex Guinochet & Drouineau 1944 em. Rivas-Martínez 1975
Ephedro fragilis-Pistacietum lentisci ass. nova
References


### 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**
Rel. 1, 2 - 6/8/94 Lido del Sole (Olbia – SS).

**Tab. 4**
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. 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).

**Tab. 14**
Rel. 1, 2 - 9/8/01 su limo a mosaico con vegetazione a Limonium glomeratum, Lido del Sole (Olbia – SS); rel. 3 - 13/3/02 radure del Limonietum narbonense-glomerati, Lido del Sole (Olbia – SS); rel. 4 - 13/3/02 radure dell’obioneto, Lido del Sole (Olbia – SS).

**Tab. 15**
Rel. 1 - 19/6/91 Vecchie Saline (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).

**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).

**Tab. 17**
Rel. 1, 2 - 25/8/01 Lido del Sole (Olbia – SS); rel. 3 - 3/8/94 loc. Li Cuncheddi (Olbia – SS); rel. 4, 5, 6 - 6/8/94 Punta delle saline (Olbia – SS).

**Tab. 18**
Rel. 1, 2, 3 - 25/8/01 Lido del Sole (Olbia – SS); rel. 4 - 19/6/91 Lido del Sole (Olbia – SS); rel. 5 - 1/8/94 loc. Marina Maria, Costa Turchese (Olbia – SS); rel. 6 - 3/8/94 loc. Li Cuncheddi (Olbia – SS); rel. 7 - 3/8/94 Punta delle saline (Olbia – SS); rel. 8 - 6/8/94 Lido del Sole (Olbia – SS).

**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).
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: Puccinellia tenuiflora 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. +, Inula crithmoides L. 1.2; rel. 3: Juncus maritimus Lam. 1.2, Inula crithmoides L. +, 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. +, Gaudiinia fragilis (L.) Beauv. +; rel. 2: Triglochin bulbosum L. 1.1; rel. 3: Triglochin bulbosum L. +, Limonium glomeratum (Tausch) Erben +; rel. 4: Bellis annua L. +, Iris sisyrinchium L. +, Romulea requienii Parl. 1.1, Anagallis sp. +.

Tab. 17
Rel. 1: Cakile maritima Scop. +, Salsola kali L. +, Atriplex latifolia Wahlenb. +, Lagurus ovatus L. +, Glaucium flavum Crantz +; rel. 2: Cakile maritima Scop. +, 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

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

Tab. 20
Rel. 5: Daucus carota L. +, Corynephorus divaricatus (Poir.) Breistr. +; rel. 7: Aetehorrhiza bulbosa (L.) Cass. 1.2, Carpebroton acinaciformis (L.) L. Bolus +.

Tab. 21
Rel. 1: Matthiola tricuspidata (L.) R. Br. +; rel. 2: Anthemis maritima L. 1.1, Ferula arigoni Bocchieri +, Sporobolus pungens (Schreber) Kunth +; rel. 3: Sisymbrium rotundifolium Miller 1.1; rel. 5: Callitomina villosa (Poir.) Link 1.2, Orczyopsis miliciae (L.) Asch. et Schweinf. +, Arisarum vulgare Targ.-Toz. +, Cistus salvifolius L. +.