Fitosociologia vol. 41 (1) suppl. 1: 109-116, 2004

Cartography and diachronic analysis of the vegetation of S'Ena Arrubia Lagoon (Centre-Western Sardinia)*

E. Biondi[1], R. Filigheddu[2] & E. Farris[2]

[1] *Dipartimento di Scienze Ambientali e delle Produzioni Vegetali, Università Politecnica delle Marche, via Brecce Bianche, I-60131 Ancona; e-mail: e.biondi@univpm.it*

[2] *Dipartimento di Botanica ed Ecologia vegetale, Università degli Studi di Sassari, via Muroni 25, I-07100 Sassari; e-mail: filighed@uniss.it; emfa@uniss.it*

Abstract

The vegetation map of S'Ena Arrubia Lagoon in centre-western Sardinia (1: 2,500 scale) is presented and some diachronic remarks are made by referring to historical data available. The main object of this cartography, after a research on the biotope vegetation, is to allow the biomonitoring of an extremely important site for the biodiversity conservation (Protected Area: S.I.C., Z.P.S., I.B.A.), which is to use for an ecologically aware management.

Key words: biodiversity, biomonitoring, diachronic analysis, freshwater vegetation, habitat management, halophilous vegetation, lagoon management, Sardinia, S.I.C., vegetation cartography.

Riassunto

Cartografia ed analisi diacronica della vegetazione della Laguna di S'Ena Arrubia (Sardegna centro-occidentale). Viene presentata la carta della vegetazione della Laguna di S'Ena Arrubia, nella Sardegna centro-occidentale (scala 1: 2.500) ed avanzate alcune considerazioni di tipo diacronico facendo riferimento ai dati storici di cui si dispone. Scopo principale della realizzazione cartografica effettuata, successiva ad una ricerca sulla vegetazione del biotopo, è di consentire il biomonitoraggio di un sito estremamente importante per la conservazione della biodiversità (Area Protetta: S.I.C., Z.P.S., I.B.A.), da utilizzare per una gestione consapevole in termini ecologici.

Parole chiave: analisi diacroniche, biodiversità, biomonitoraggio, cartografia della vegetazione, gestione degli habitat, gestione della laguna, Sardegna, S.I.C., vegetazione alofila, vegetazione dulciaquicola.

Introduction

S'Ena Arrubia Lagoon, located in centre-western Sardinia (Fig. 1), is a wetland characterised by a considerable floristic-vegetational and faunal biodiversity. This is particularly due to specific variations of ecological gradients directly and mainly connectable with the variations of geomorphology and granulometric features of substrata, as observed in previous studies (Biondi & Calandra, 1998; Biondi & Zuccarello, 2000). In particular, the vegetation is an important reference of bioindication, when it is properly investigated according to its distribution and qualitative and quantitative characterisation of ecological factors, and it is very useful to monitor the environment and address the management of sites.

This work is a part of an ecological research, included in LIFE Nature 2000 project, promoted by the Province of Oristano: since 1997 it has been carrying out by the Department of Botany and Plant Ecology of the University of Sassari. The general object is the integrated management and protection of the lagoon, and this research deals with the phytosociological study aimed at drawing up the vegetation map on a 1: 2,500 scale.

Within LIFE Nature 2000 project, some specific investigations concerning the phytosociologic analysis of vegetation (Filigheddu *et al.*, 2000), the drawing up of a map of the vegetal community and the determination of its ecological variability were of overriding importance. The vegetation map is presented together with this contribution (1: 2,500 scale) and some diachronic analyses of populations and habitats, determined by the management variation of the biotope, were made by referring to historical data available.

Environmental characteristics

The lagoon is a PA (Protected Area) and is classified as: Special Protection Zone (Z.P.S.) according to EEC Directive 79/409, community importance site (S.I.C.)

* This work was financially supported by the LIFE Nature 2000 Project "Progetto di gestione integrata della laguna di S'Ena Arrubia"

ITB 030016, according to EEC Directive 92/43, I.B.A. (Important Birds Area) site, fixed oasis of fauna protection and natural reserve.

S'Ena Arrubia lagoon is the residual of the wider Sassu pond, reclaimed in 1934 together with its adjacent wetlands. Formerly, the pond was connected to the sea through a wide natural inlet. In consequence of the land reclamation, it received supplies from its catchment area through some man-made canals currently flowing into the south-eastern shore and pouring into the lagoon rain and waste waters. These supplies caused the obstruction of the natural inlet, so that during the Seventies a canal was built in the coastal dune to get the lagoon to communicate permanently with the sea. Moreover, a bottom canal running along the main axis of the lagoon starts from the sea inlet and reaches the freshwater inlet area. Its building had the aim to allow an efficient upwelling of seawaters during the tide and a fast removal of waters coming from the watershed. Before these human interventions, lagoon waters had a low salinity. This is demonstrated by vegetation studies where the presence of freshwater community and, to a smaller extent, of halo-tolerant and halophile ones is described

Fig. 1 – Study area

(Valsecchi, 1972; Corbetta & Lorenzoni, 1976).

At present S'Ena Arrubia lagoon, which is part of a wet land system facing the Gulf of Oristano, extends over about 1.43 Km^2; its depth ranges between 30 and 150 cm, with a mean depth of 45 cm, while the water volume is about 1.2 x 10^6 m^3 (Sechi, 1982).

Climate

Thermal rain gage data related to the thirty-year period 1951-1981 (Annali Idrologici del Servizio Idrografico) at the thermometric station of S. Giusta and rain gage station of Sassu show that precipitation has a typically seasonal trend and is concentrated between October and March. The most rain month is December, with a mean of 99.6 mm, the driest one is July with 3,6 mm. Diurnal mean temperature is 16.9°C, the maximum mean of the warmest month (July) is 32.3°C, the minimum mean of the coldest month (January) is 5.2°C. The absolute maximum is 39.8°C, the absolute minimum is 1.6°C; annual thermal range is 10.4°C. The area is affected by a Thermo-Mediterranean dry climate, with warm and not very rainy summers and relatively rainy and not very cold winters.

Geology

The Gulf of Oristano, characterised by low and sandy shores, is the sea mouth of a tectonic depression linked with the NNW trending normal fault system, which caused the deepening and the fill of the Campidano Graben during the Pliocene and the Pleistocene. The centre of the great scythe-like inlet forming the coast of the Gulf is the consequence of Pleistocene eustatic dynamics and shows a plane and depressed morphology, where the main wetlands are located. The most spread quaternary deposits are old terraced floods, recent and current sandy dunes, mud-sandy and subordinately pebbly floods of Tirso delta, sand- and mud-clayey lagoon and brackish facies and recent marine sands (Carmignani *et al.*, 2001).

S'Ena Arrubia Lagoon derives from formation of littoral dune barriers. They are large depressions in plain alluvial and aeolian soils, flooded by the abundant inland freshwaters, communicating today with the sea through suitable and often man-made canals.

In Quaternary, especially during the last glaciation, wind accumulated very large quantities of sand nearly everywhere on the western coast. Their origin is known and it concerns the Versilian marine ingression in the last millennia of Quaternary (Barca *et al*., 1996).

S'Ena Arrubia Lagoon experienced various morphological modifications through time, because of some human interventions for checking the action of natural modelling factors (especially on the northern shore), such as the sea wave motion, sediment transport by inland waters and the consequent filling up with dirt of the lagoon (opening of the sea-mouth regulated by metal floodgate).

Soils

The typology of the main spread soils shows a very considerable evolution, with formation of well-defined clayey profiles, high depth, scanty organic matter and lack of carbonates, mean to high permeability. Predominant soils are Typic, Aquic and Ultic Palexeralf, while the subordinate ones are Xerofluvents and Ochraqualfs. The present use is mainly agricultural, with restrictions due to the excess of skeleton, slow to very slow drainage and moderate danger of erosion.

In the perilagoonal area, five pedologic units can be observed (Arangino *et al*., 1986), and are actually in study (Vacca *et al*., in press):

M3 unit. This is the area from coast to NNW and it consists of Palexeralf Aquici, derived from dissolved or slightly cemented sands and integrated in the 3rd class of irrigability. In this unit, soils are deep A-B2t-C profile, sandy clay loam with angular or prismatic polyhedral aggregation. Drainage is slow or moderately fast to very slow or fast, with a deep and permanent aquifer and a sub-superficial temporary aquifer. The substratum consists of ancient sediments, whereas the morphology is flat or slightly sloped (slope less than 10%). According to Soil Taxonomy (USDA, 1999), these soils are classified as Aquic Palexeralfs, while they are classifiable as Eutric and Dystric Planosols according to FAO Classification (1998).

A1 unit. It extends to the eastern side of the lagoon (Reclamation of Sassu), where soils are classifiable as Typic Fluvaquents and subordinately tops derived from recent floods and integrated in the 3rd class of irrigability. Soils of this unit are deep and clay A-C profile, with sub-angular or angular polyhedral aggregation. Drainage is slow, with a superficial permanent aquifer. Morphology is generally flat, but some depressions more or less marked can be present. Substratum consists of recent sediments. Soil Taxonomy (USDA, 1999) classifies these soils as Typic Fluvaquents, while they can be ascribed to Eutric Gleysols according to FAO Classification (1998).

M1 unit. This unit extends on the southern side of the lagoon. Soils can be ascribed to Typic Palexeralfs derived from dissolved or slightly cemented sands and integrated in the 2nd class of irrigability. These soils are deep A-B2t-C profile, sandy clay loam and clay, having variously a skeleton, with angular or prismatic polyhedral aggregation. Drainage is normal to slow. These soils generally derive from ancient sediments, whose morphology is flat or slightly sloped (slope less than 10%). Hydromorphology shows a deep and permanent aquifer and a temporary aquifer (4 to 6 months) at mean depth. According to Soil Taxonomy (USDA, 1999), these soils are classified as Typic Palexeralf, while they can be ascribed to Orthic Luvisds according to FAO Classification (1998).

S1 Unit. These soils belong to the coastal strip of the lagoon and the areal of the beach. Substratum consists of aeolian sands of Holocene, with a flat to undulating morphology. These soils are generally deep and have a sandy to sandy loam texture, with sub-angular polyhedral structure and dissolved granules. Drainage is excessive, slow in depth at intervals, with sandy texture and serious danger of erosion. In many cases, there are very large sandy fields inlandwards. The characteristic psammophile vegetation is present in this area, with reforestation (especially conifers) for protection. According to Soil Taxonomy (USDA, 1999), these soils are classifiable as Typic and Aquic Xeropsamments. It is important to report that some tourist settlings were built in this unit, causing a serious environmental impact with regard to soil conservation, dunal and vegetation balance.

Materials and methods

The vegetation study by the phytosociologic method led to detect different associations and their syntaxonomic classification (Filigheddu *et al*., 2000). The vegetation map was carried out by photo-interpretation and photo-restitution of an orthophotomap made in December 1998 (1: 13,000 scale), which led through inspections to the mapping of plant communities previously typified. So, a vegetation map on a 1: 2,500 scale was drawn up and it shows the distribution of the various associations, differentiated in the legend by ecological categories: halophilous communities, halotolerant and freshwater communities, communities not directly linked to the aquifer.

Explanatory transects of plant community spatial succession and topographic factors of its presence were presented with the vegetation map.

Vegetation map

The distribution of associations according to their ecological typology was pointed out in the map (see legend in the annexe), referring particularly to the tolerance level to water salinity. We can distinguish three main groups:

- Halophilous associations: *Salsoletum sodae*, *Suaedo maritimae-Salicornietum patulae*, *Salicornietum emerici*, *Salicornietum venetae*, *Sarcocornietum deflexae*, *Puccinellio festuciformis-Sarcocornietum fruticosae*, *Cynomorio coccinae-Halimionetum portulacoidis*, *Puccinellio convolutae-Arthrocnemetum macrostachyi*, *Inulo crithmoidis-Paspaletum vaginati*, *Junco maritimi-Spartinetum junceae*, *Limonio narbonensis-Juncetum gerardii*, *Juncus maritimus* community, *Schoeno nigricantis-Plantaginetum crassifoliae*;
- Halotolerant and freshwater associations: *Astero tripolii-Bolboschoenetum maritimi*, *Scirpo-Juncetum subulati*, *Loto tenuis-Agropyretum repentis*, *Phragmitetum communis*, *Lemnetum minoris*, *Tamarix africana* community, *Arundini donacis-Convolvuletum sepii*;
- Associations not directly linked to the aquifer: *Resedo albae-Chrysanthemetum coronarii*, *Inulo viscosae-Oryzopsietum miliaceae*, *Ephedro-Helichrysetum microphylli*, *Myrto communis-Pistacietum lentisci*.

The map shows the distribution of merely halophilous communities close to the lagoon sea-mouth and shores directly affected by saltwater flows, the distribution of sub-halophilous communities on farther shores and, finally, the residual freshwater communities near the tributary channels.

Four transects were placed to display the spatial relationships among some associations. Two transects were placed on the northern shore, one on the southern shore and one on the western shore.

The first transect, close to the sea-mouth, highlights the distribution of annual and perennial halophilous communities, on both clay-mud and sand-clay substrata, according to the direct action of the seawater. The association of *Inulo crithmoidis-Paspaletum vaginati* establishes on salty and constantly wet mud and is dominated by the neophyte *Paspalum vaginatum*. This hemicryptophytic community forms a mosaic with the therophytic community of *Salicornietum emerici* association, which establishes on micro-depressions directly open to the seawater flow. *Cynomorio coccinae-Halimionetum portulacoidis* association covers higher lands, which are dry in summer and show a sand-clay matrix, whereas the association of *Junco maritimi-Spartinetum junceae* covers constantly wet sand depositions coming from the dredging on the bottom of the lagoon. The halotolerant association of *Astero tripolii-Bolboschoenetum maritimi* covers only muddy and higher areas, which are less subject to seawater effect.

The second transect, on the peninsula side and not exposed to the sea-mouth, allows detecting, within the association distribution, wider spatial scales than the previous transect does, due to a weaker anthropic action. Chamaephytic communities of *Salicornietea fruticosae* class cover the internal peninsula clay surfaces: with *Halimione portulacoides* on higher levels, with *Arthrocnemum macrostachyum* on intermediate ones and with *Sarcocornia fruticosa* on the lowest and constantly wet ones. *Spartina juncea* grows again on wet sand depositions, whereas the halotolerant association of *Astero tripolii-Bolboschoenetum maritimi* is present on the mud around the edge of the pond. Annual communities cover wide internal depressions: *Suaedo maritimae-Salicornietum patulae* association on dry mud in summer, *Salicornietum emerici* on wet mud at the bottom of depressions.

The third transect, near the channel of “Acque Medie”, shows the spatial succession from the residual freshwater communities on the continental slope to the halotolerant and merely halophilous ones. These are close to the shore of the lagoon and so they are more subject to salinity raising of the water body, occurred over the last decades. The last strip of the freshwater reed bed, reported as *Phragmitetum communis* association, cover clay lands, about ten centimeters higher and therefore generally not submerged by seawaters. The geophytic association of *Junco maritimi-Spartinetum junceae* covers sandy substrata, whereas the hemicryptophytic association of *Limonio narbonensis-Juncetum gerardii* establishes at lower level on wet sands. The halotolerant association of *Astero tripolii-Bolboschoenetum maritimi* covers clay-mud surfaces on the edge of the pond: it forms a mosaic with the annual association of *Suaedo maritimae-Salicornietum patulae* on dry depressions in summer and with *Salicornietum emerici* on perennially wet mud.

The fourth transect is placed on the western shore and is affected by the presence in the substratum of the sandy matrix of the dune, which separates the lagoon from the sea. *Cynomorio coccinae-Halimionetum portulacoidis* association covers again higher lands, dry in summer, with a sand-clay matrix, whereas *Junco maritimi-Spartinetum junceae* association covers the constantly wet sand depositions. The halotolerant association of *Astero tripoilii-Bolboschoenetum maritimi* is found only on higher muddy lands, whereas the chamaephytic communities of *Salicornietea fruticosae* class prevail on salty mud: with *Arthrocnemum macrostachyum* on higher substrata, with *Sarcocornia fruticosa* on wet mud and with *Sarcocornia fruticosa* var. *deflexa* on internal and close depressions that are flooded in winter. The therophytic and mono-specific association of *Salicornietum emerici* covers micro-depressions directly open to the seawater flow.

Diachronic analysis and dynamics of plant landscape

These transects allow estimating the large changes that have affected the ecosystem, especially when they are compared with the situation during Seventies (Valsecchi, 1972).

At that moment, the presence of freshwater communities now very receded was predominant, such as *Phragmitetum communis* in typical aspects or *Typha latifolia* in a variant form. Today, among the freshwater entities, *Typha latifolia* results to be extinct in the biotope together with some species of *Potametalia* and *Lemnetalia* orders: *Potamogeton crispus*, *P. pectinatus*, *Ceratophyllum demersum*, *Myriophyllum verticillatum* and *Lemna gibba*.

Salicornietum fruticosae association was reported within the perennial halophilous vegetation, where the presence of *Puccinellia festuciformis* (sub *P. distans*) – now not detected in the area – was considerable. On the contrary, halophilous therophyte communities – now very represented – were not reported. The large increase in *Spartina juncea* communities must be reported too: they also establish on salty substratum and were reported by Valsecchi (1972) as rare in pure communities on the edges of irrigation channels.

The analysis of typological and quantitative variation in associations points out high increase in salinity and therefore a transformation of plant communities following the change of the habitat. The most relevant aspect is the extreme reduction of freshwater coenoses referred to *Phragmitetum communis* association. Phytosociologic study and vegetation map highlighted a conversion of freshwater reed beds into sub-halophilous coenoses, referred to the new association of *Astero tripolii-Bolboschoenetum maritimi*. However, *Phragmites australis*, because of its large ecological valence, is still present (even if reduced) within some halophilous communities, such as *Puccinellio festuciformis-Sarcocornietum fruticosae* and *Puccinellio convolutae-Arthrocnemetum macrostachyi*, or halotolerant communities. The high increase in salinity was the cause of extinction of freshwater helophytic communities on wide surfaces and also allowed both pioneer communities of halophilous communities and hemicryptophytic communities dominated by the neophyte *Paspalum vaginatum* to develop on the previous ones. This grass has a tropical origin and, although present in the lagoon since 1968 (Filigheddu & Farris, 2000) at least, it has largely increased during the last few years, becoming part of the lagoon vegetation landscape and forming the new *Inulo crithmoidis-Paspaletum vaginati* association. This actively recovers lands where the helophytic communities has receded after the increase in salinity (Filigheddu *et al*., 2001).

Conclusions

The vegetation cartography of S'Ena Arrubia Lagoon is one of the few map representations drawn up in Italy for lagoon brackish environments (Piccoli, 1995). These habitats are difficult to express and represent cartographically. In fact, some mappings on a detailed scale are necessary, because different typologies can be present within very limited areas. Nevertheless, this kind of representation, when detailed, is an effective tool to monitor the environmental conditions of the biotope and a predictive tool, too, able to give information on the effects of anthropic stresses on environments, inferable by the variations of serial and topographic relationships between vegetational typologies. Under these conditions, extremely sensitive communities characterised by a limited ecological valence – as the most of associations in brackish environment are (Biondi & Zuccarello, 2000) – can offer rapid indications on the variation of ecological parameters, becoming thereby an important tool to manage very sensitive areas.

References

Arangino F., Baldaccini P., Vacca S. & Aru A., 1986. Carta dei suoli delle aree irrigabili della Sardegna scala 1:

100.000. S.EL.CA., Firenze.
Barca S., Carmignani L., Oggiano G., Pertusati P.C. & Salvatori I., 1996. Carta Geologica della Sardegna, Servizio Geologico Nazionale, Carmignani L. (ed.)., Litografia Artistica Cartografica, Firenze.
Biondi E. & Calandra R., 1998. La cartographie phytoécologique du paysage. Ecologie 29 (1-2): 145-148.
Biondi E. & Zuccarello V., 2000. Correlation between ecological parameters and symphytosociological dynamic models. Coll. Phytosoc. 27: 741-766.
Carmignani L., Oggiano G., Barca S., Conti P., Salvadori I., Eltrudis A., Funedda A. & Pasci S., 2001. Memorie descrittive della Carta Geologica d'Italia, vol. LX. Note illustrative della Carta Geologica della Sardegna a scala 1:200.000. Istituto Poligrafico e Zecca dello Stato, Roma.
Corbetta F. & Lorenzoni G.G., 1976. La vegetazione degli stagni del golfo di Oristano (Sardegna) Suppl. Ric. Biol. Selvaggina 7: 271: 319.
FAO, ISSS & ISRIC, 1998. World Reference Base for Soil Resources. World Soil Resource Report n. 84, Roma.
Filigheddu R., Farris E. & Biondi E., 2000. The vegetation of S'Ena Arrubia lagoon (centre-western Sardinia). Fitosociologia 37 (1): 39-59.
Filigheddu R. & Farris E., 2001. *Paspalum vaginatum* Swartz in Sardegna. Inf. Bot. Ital. 33 (2): 13-15.
Filigheddu R., Farris E. & Trebini F., 2001. *Paspalum vaginatum* Swartz, neophyte in a Sardinian (Italy) brackish environment: 83-87. In: Brundu G., Brock J., Camarda I., Child L., Wade M. (Eds.): Plant invasions: species ecology and ecosystem management. Backhuys Publishers, Leiden, The Netherlands.
Piccoli F., 1995. Elementi per una carta della vegetazione del Parco Regionale del Delta del Po (Regione Emilia-Romagna). Fitosociologia 30: 213-219.
Sechi N., 1982. Lo stato trofico di alcuni stagni salmastri costieri della Sardegna. Boll. Soc. Sarda Sci. Nat. 21: 285-295.
Soil Survey Staff, Soil Conservation Service, U. S. Dept. of Agricolture, 1999. Soil Taxonomy. Agricolture Handbook n. 436, 2nd ed., Washington D.C.
Vacca, S., Capra G., Padedda B., & Solinas G. Phisical and chemical characteristics of soils in the lagoon area of S'Ena Arrubia (Middle-West Sardinia, Italy). Geooko (in press).
Valsecchi F., 1972. La vegetazione dello stagno di S'Ena Arrubia nel Golfo di Oristano. Boll. Soc. Sarda Sci. Nat. 10: 89-107.

Annexe: Legend of the map

Halophilous vegetation

THEROPHYTIC VEGETATION
COMMUNITIES OF ANNUAL SALTWORTS, OFTEN DISPOSED AS A MOSAIC WITH PERENNIAL VEGETATION

Sp — Vegetation dominated by *Salicornia patula*, a diploid plant covering the higher edge of salty depressions drying up more quickly in summer.
Suaedo maritimae-Salicornietum patulae (Brullo & Furnari 1976) Géhu & Géhu-Franck 1984

Se — Vegetation dominated by *Salicornia emerici*, a tetraploid plant covering long-flooded depressions generally open to the sea.
Salicornietum emerici (O. de Bolòs 1962) Brullo & Furnari 1976

Sv — Vegetation dominated by *Salicornia veneta*, a tetraploid plant covering channels open to the sea in areas that are also flooded in summer.
Salicornietum venetae Pignatti 1966

Ss — NITROHALOPHILOUS THEROPHYTIC VEGETATION
Vegetation dominated by *Salsola soda* developing on the edges of brackish depressions, on clay-sandy soils that are also wet in summer and rich in organic substances.
Salsoletum sodae Pignatti 1953

CHAMAEPHYTIC OR NANOPHANEROPHYTIC VEGETATION
VEGETATION OF PERENNIAL SALTWORTS, ESTABLISHED ON SANDBANKS AND SALTY DEPRESSIONS

Sd — Prostrate vegetation of *Sarcocornia fruticosa* var. *deflexa* developing on the bottom of depressions with euhaline to hyperhaline substrata, under marked hygrophilous conditions during most of the year, but exhibiting a complete summer drying up.
Sarcocornietum deflexae (Br.-Bl. 1931) Lahondère, Géhu & Paradis 1992

Sf — Nanophanerophytic vegetation of

Sarcocornia fruticosa on quite high, polihaline soils that are also wet in summer, often disposed as a mosaic with the association of *Salicornietum emerici*.
Puccinellio festuciformis-Sarcocornietum fruticosae (Br.-Bl. 1928) J. M. Géhu 1976

Am Nanophanerophytic vegetation of *Arthrocnemum macrostachyum* on hyperhaline soils drying up completely in summer.
Puccinellio convolutae-Arthrocnemetum macrostachyi Géhu ex Géhu, Costa, Scoppola, Biondi, Marchiori, Peris, Géhu-Franck, Caniglia & Veri 1984

Hp Suffruticose vegetation of *Halimione portulacoides*, parasited by *Cynomorium coccineum*, which develops on the edge of depressions.
Cynomorio coccinae-Halimionetum portulacoidis Biondi 1992

HEMICRYPTOPHYTIC VEGETATION
GRASSLANDS PREVALENTLY DOMINATED BY HEMICRYPTOPHYTES ON WET TO PERIODICALLY FLOODED SOILS WITH DIFFERENT SALINITY DEGREE, NEVER COMPLETELY DRY IN SUMMER

Pv Mosaic halophilous vegetation, "spotted" with *Salicornietum emerici* association, which develops in slightly depressed areas and prevalently consists of hemicryptophytic grasslands of *Paspalum vaginatum*, on mud-sandy soils in areas directly exposed to the seawater inlet.
Inulo crithmoidis-Paspaletum vaginati Filigheddu, Farris & Biondi 2000

Sj Dense and high grasslands of *Spartina juncea*, on sandy soils partially derived from mechanical surfacing, with high water table, which are also wet in summer.
Junco maritimi-Spartinetum junceae O. de Bòlos 1962 nom. inv. prop. Filigheddu, Farris & Biondi 2000

Jg Low grassland of *Juncus gerardi* exhibiting a dot-like distribution on a prevalently sandy substratum.
Limonio narbonensis-Juncetum gerardii Géhu & Biondi 1994

Pcr Low grassland of *Plantago crassifolia* developing on the edge of the halophilous area on sandy substratum, wet only in winter, which shows generally a chain contact with psammophile formations of dunal bars.
Schoeno nigricantis-Plantaginetum crassifoliae Br. Bl. (1931) 1952

Jm Physiognomically uniform paucispecific vegetation of *Juncus maritimus* covering sandy depressions that are long flooded by brackish waters.
Juncus maritimus community

Freshwater and sub-halophilous vegetation

HELOPHYTIC VEGETATION
REED AND RUSH BEDS DEVELOPING ON SOILS SUBJECT TO STRATUM CHANGES, CLOSE TO THE TRIBUTARIES, WHICH ARE PERENNIALLY OR LONG FLOODED BUT CAN DRY IN SUMMER AND MARK THE TRANSITION FROM FRESHWATER TO BRACKISH ENVIRONMENT

Js Rush bed of *Juncus subulatus* on flat, brackish, flooded in winter but completely dry in summer depressions.
Scirpo compacti-Juncetum subulati Géhu et al. 1992

Bm Reed bed of *Bolboschoenus maritimus* var. *compactus*, occasionally dominated by *Phragmites australis*, which develops on more flooded and less salty soils than *Scirpo compacti-Juncetum subulati* does, subject to summer drying up in any way and never directly exposed to seawater supplies.
Astero tripolii-Bolboschoenetum maritimi Filigheddu, Farris & Biondi 2000

Pc Dense reed bed of *Phragmites australis* on deep soils with considerable freshwater supply and prevalently spread along tributaries and side channels.
Phragmitetum communis (Koch 1926) Schmale 1939

HEMICRYPTOPHYTIC VEGETATION

Ar Perennial grasslands of *Agropyron repens* on deep and wet soils in flat areas, with

freshwater table, once used as agricultural and zootechnical regions and now abandoned.
Loto tenuis-Agropyretum repentis Biondi, Vagge, Baldoni & Taffetani 1997

FLOATING VEGETATION

Lm Floating vegetation of *Lemna minor* on fresh, oligotrophic to mesotrophic waters.
Lemnetum minoris Oberdorfer ex Th. Müller & Gärs 1960

ANTHROPOGENIC VEGETATION

ANNUAL OR PERENNIAL VEGETATION ON THE FRINGE OF THE LAGOON, CLOSE TO THE PERIMETRIC ROADS, NOT DIRECTLY AFFECTED BY SALT- OR FRESHWATER OF THE AQUIFER

Cc Heliophilous and nitrophilous therophytic vegetation dominated by *Chrysanthemum coronarium*, on anthropogenic and zoogenic surfacing substrata.
Resedo albae-Chrysanthemetum coronarii O. de Bòlos & Molinier 1958

Om Hemicryptophytic and nanophanerophytic perennial grasslands of *Inula viscosa*, *Foeniculum vulgaris* subsp. *piperitum* and *Oryzopsis miliacea* on dry substrata and ruderal regions.
Inulo viscosae-Oryzopsietum miliaceae (A. & O. de Bolòs 1950) O. de Bolòs 1957

Ad Vegetation dominated by *Arundo donax* on edges close to tilled lands, road edges and embankments on soils that are also wet in summer, planted with an anthropic view and become spontaneous.
Arundini donacis-Convolvuletum sepii Tüxen & Oberdorfer ex O. Bolòs 1962

PSAMMOPHILE VEGETATION

Ed Sporadic chamaephytic vegetation of *Ephedra distachya* on sandy and compact soils, residual of the dunal bars that enclosed the lagoon, on south-western and northern shores.
Ephedro-Helichrysetum microphylli Valsecchi & Bagella 1991

PHANEROPHYTIC VEGETATION

Mi Mediterranean scrub strips of *Pistacia lentiscus* on the highest regions around the basin in areas in contact with the psammophile series.
Myrto communis-Pistacietum lentisci (Molinier 1954) Rivas-Martìnez 1975

Ta Arboreal vegetation mainly composed of *Tamarix africana*, on sandy surfacing soils, with deep aquifer.
Tamarix africana community

RB Reforestation with *Pinus* sp.

RE Reforestation with *Eucalyptus* sp.

□ Isolated trees of *Eucalyptus* sp.

P Floodgate

S Road

0,15 Altitude (in meters)

asb Stripping area

A Area without vegetation

▭ Stretches of waters

AX-AY Transects