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## Contribution to the knowledge of the coastal vegetation of the SIC IT9110005 “Zone Umide della Capitanata” (Apulia, Italy)

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### Abstract

An overview of the coastal vegetation of Site of Community Importance “Zone Umide della Capitanata” (Puglia Region) is here presented. Original relevés were performed in different locations of the site. On the basis of the in-field observations (142 original relevés) and of literature data, 44 plant communities have been defined, belonging to the following classes: *Lemmetea minoris*, *Ruppiaetea maritimae*, *Potametea pectinati*, *Phragmito-Magnocaricetea*, *Cakiletea maritimae*, *Ammophiletea*, *Helichryso-Crucianelletea maritimae*, *Juncetea maritimi*, *Sarcocornietea fruticosae*, *Saginetea maritimae*, *Thero-Suaedetea*, *Tuberarietea guattatae*, *Nerio-Tamaricetea*. For each vegetation unit, the distribution area at local and regional level and the relation to habitat types of the 92/43 EEC Directive are provided.

**Keywords:** *Puglia, Capitanata, coastal vegetation, salt marshes, halophilous vegetation*

### Introduction

“Zone Umide della Capitanata” is one of the most extensive wetlands of the Italian peninsula. This site has been subjected to exploitation for a long time, mainly for agricultural purposes, resulting in the conversion of large part of the wetland areas in cultivated lands and the subsequent reduction and fragmentation of the original natural habitats. The humid area consists of a system of lagoons, characterized by brackish or salt water, depending on the specific water regime. The natural vegetation is represented mostly by halophytic scrub and by annual pioneer salt marsh communities. Despite the intense pressure of anthropogenic nature, such as agriculture, infrastructure and urbanization, the coastal wetland preserves natural habitats of high naturalistic and scientific values. The site is considered one of the most relevant coastal wetlands at national level, as crucial area to support several water bird species during annual migrations.

It has been designed as SCI (Site of Community Importance, according to the Habitat directive; code IT9110005), SPA (Special Protection Area, according to the Bird directive; code IT9110038), IBA (Important Bird Area) and, recently, IPA (Important Plants Area) (Blasi et al. 2010).

Characterization, distribution and ecology of coastal wetland vegetation in Apulia have been investigated by numerous authors (Corbetta 1970; Gèhu & Biondi 1988, 1996; Taffetani & Biondi 1989; Corbetta et al. 1992, 2006; Mariotti et al. 1992; Biondi 1999; Biondi et al. 2006; Biondi & Casavecchia 2010; Tomaselli et al. 2011). Some contributions have concerned the area of the SCI “Zone Umide della Capitanata” (Gèhu et al. 1984; Corbetta et al. 2006; Biondi & Casavecchia 2010; Sciandrello & Tomaselli 2014; Sciandrello et al. 2015), although even in terms of partial contributions and without providing a comprehensive picture of the whole study area. Therefore, objective of this study is to provide a framework, as comprehensive as possible, of the vegetation of the Capitanata wetlands and coastal areas.

### Study area

The SCI “Zone Umide della Capitanata” covers about 14.000 ha and is located in the north-eastern part of the Puglia Region (Figure 1) that, with its total coastline length of 865 km, is one of the most relevant regions in Italy as regards importance of the coasts (Bruno et al. 2008; Basso et al. 2013). It is

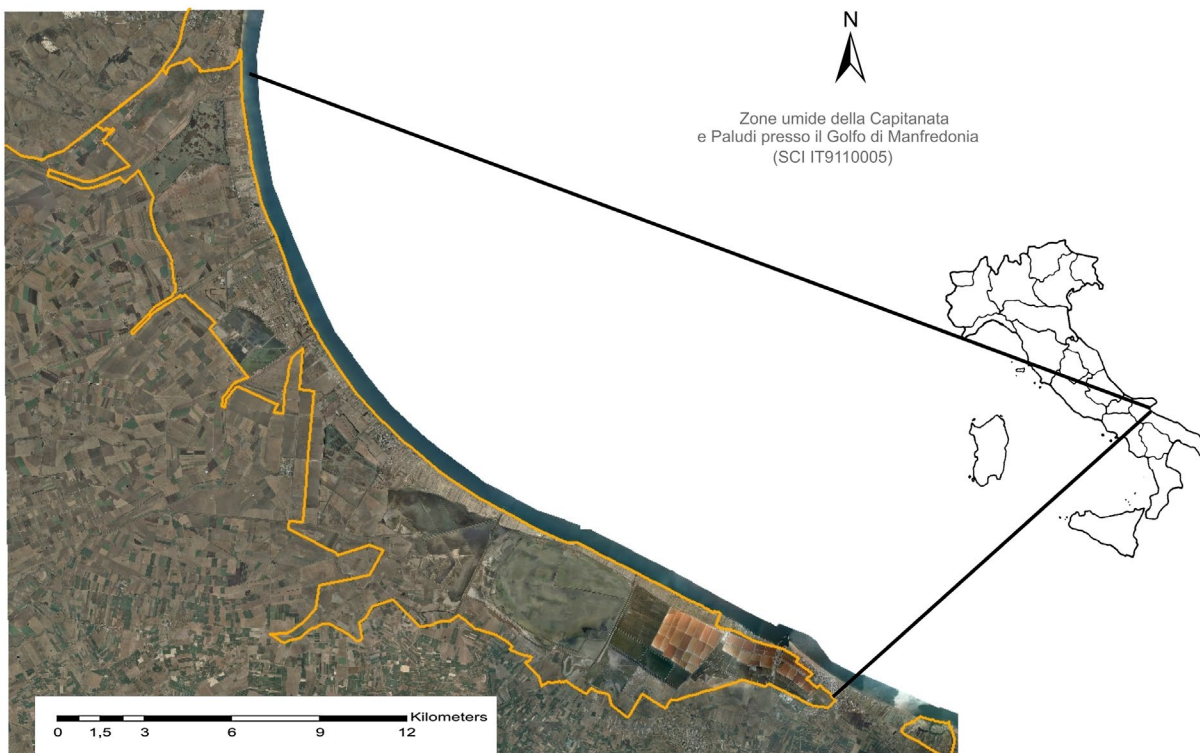


Figure 1. Study site.

delimited to the north by the Gargano promontory, to the south by the municipalities of Trinitapoli and Margherita di Savoia, to the west by extended agricultural areas and, to east, by the Adriatic Sea. Referring to the data of the pluviometric station of Manfredonia, the climate of the area is among the most arid of Apulia, with average annual rainfall of about 448 mm and average annual temperatures of 15.4°C. The bioclimate falls within the Mediterranean pluviseasonal oceanic with upper dry ombrotype (Rivas-Martinez et al. 2004). From a geological point of view, the area (floodplain) is formed by alluvial deposits consisting of a basic clay formation of varying thickness (Pliocene-Pleistocene), with clastic soils in outcropping: sandy clays (aged up to Pleistocene) and conglomeratic sands (Middle-Upper Pleistocene). In the lower part of the flood plain, extensive Pleistocene and Holocene alluvial covers appear, consisting of gravelly sandy and clayey deposits of continental facies (Boenzi et al. 1992; Delle Rose et al. 2004; Gallicchio et al. 2014).

The site is characterized by a complex of wetlands and wet areas. From south to north:

#### *Saline di Margherita di Savoia*

Extended for a length of about 20 km, the total area covers about 4500 ha. The wetland consists of large ponds of salt to brackish water used as evaporation

pools for salt extraction. It is currently the largest and most productive salt mines of Europe and is a State Nature Reserve, established in 1977.

#### *Palude di San Floriano*

The site covers an area of about 480 ha and consists of a system of pools fed by the Carapelle river, where a fish farm was created on previously reclaimed land. It is characterized by eutrophic, brackish or fresh waters.

#### *Palude Carapelle*

It consists of large pools of brackish water used for fishing, covering an area of 460 ha. The interest in the area is mostly related to its avifauna, because the area supports numerous water bird species.

#### *Lago Salso (or Daunia Risi)*

Lago Salso derives from a freshwater wetland that up to the end of nineteenth century covered an area of about 4000 ha and then was transformed and reduced as a result of a massive land reclamation. The whole area, including also fields and farmlands, covers approximately 1800 ha. The wetland area is represented by a dammed up area of about 541 ha

(created after the completion of the reclamation activities). The Candelaro river, to the west, separates Lago Salso by the Frattarolo swamp. The interest in the area is related mainly to its avifauna. The area is part of the Gargano National Park.

#### *Palude Frattarolo*

The Frattarolo swamp is a salt marsh adjacent to Lago Salso. This area represents the natural expansion basin of the river Candelaro. It covers a total area of 500 ha (including the mouth of Candelaro), of which 257 are protected as a Natural Reserve for animal populations.

#### Materials and methods

Original vegetation data were sampled in the field between 2011 and 2014. The vegetation relevés have been performed according to the phytosociological approach (Braun-Blanquet 1964).

A total of 142 original relevés were collected. Names of the plant species follow Tutin et al. (1964–1980, 1993) and Conti et al. (2005). Vegetation units (of higher level respect to association) were assigned to the different syntaxa according to the recent “Pro-dromo della Vegetazione d’Italia” (<http://www.pro-dromo-vegetazione-italia.org>, Biondi et al. 2014). For the correlation between vegetation types and habitat types, we referred to the Italian Interpretation Manual for the Habitats of Directive 92/43 EEC (Biondi et al. 2009).

#### Results and discussion

A total of 44 plant communities were identified, belonging to 13 syntaxonomic classes. The complete syntaxonomical scheme and the description of the plant communities are provided below. In the description, the code of the corresponding habitat type, according to the Annex I of the Habitat Directive (Natura 2000 Habitat), is provided.

**LEMNETEA MINORIS** R.Tx. ex O.Bolòs & Masclans 1955

LEMNETALIA MINORIS R.Tx. ex O.Bolòs & Masclans 1955

LEMNION MINORIS R.Tx. ex O.Bolòs & Masclans 1955

*Lemnetum minoris* Oberd. ex Müller & Görs 1960

**RUPPIETEA MARITIMAE** Tuxen ex Den Hartog & Segal 1964

RUPPIETALIA MARITIMAE Tuxen ex Den Hartog & Segal 1964

RUPPION MARITIMAE Br.-Bl. ex Br.-Bl., Roussine & Nègre 1952

*Enteromorpha intestinalidis-Ruppium maritima* Westhoff ex R.Tx. & Böckelmann 1957

**POTAMETEA PECTINATI** Klika in Klika & Novák 1941

POTAMETALIA PECTINATI Koch 1926

POTAMION PECTINATI (Koch 1926) Görs 1977

*Potametum pectinati* Cartensen 1955

UTRICULARIETALIA MINORIS Den Hartog & Segal 1964

UTRICULARION VULGARIS Passarge 1964

*Utricularietum australis* Müller et Görs 1960

**PHRAGMITO-MAGNOCARICETEA** Klika in Klika & Novák 1941

PHRAGMITETALIA Koch 1926

PHRAGMITION Koch 1926

*Phragmitetum communis* (Koch 1926) Schmale 1939

*Typhetum latifoliae* Lang 1973

*Iridetum pseudoacori* Krzywanski 1974

SCIRPETALIA COMPACTI Hejny in Holub et al. 1967 corr. Rivas et al. 1980

SCIRPION COMPACTI Dahl & Hadac 1941 corr. Rivas-Martínez et al. 1980

*Scirpo compacti-funcetum subulati* Géhu, Biondi, Géhu-Franck et Costa 1992

*Scirpetum compacto-litoralis* (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) O.Bolòs 1962 corr. Rivas-Martínez, Costa, Catroviejo & Valdès-Bermejo 1980

**EUPHORBIO PARALIAE-AMMOPHILETEA AUSTRALIS** Géhu & Rivas-Martínez in Rivas-Martínez, Asensi, Díez-Garretas, Molero, Valle, Cano, Costa & Díaz 2011

AMMOPHILETALIA AUSTRALIS Br.-Bl. 1933

AGROPYRION JUNCEI (Tüxen in Br.-Bl. & Tüxen 1952) Géhu, Rivas-Martínez & Tüxen 1972 in Géhu, Costa, Scoppola, Biondi, Marchiori, Peris, Franck, Caniglia & Veri 1984

*SPOROBOLENION ARENARII* Géhu ex Biondi & Galdenzi 2014

*Sporoboletum arenarii* (Arènes 1924) Géhu & Biondi 1994

AGROPYRENION FARCTI Rivas-Martínez, Costa, Catroviejo & Valdés 1980

*Echinophoro spinosae-Elymetum farcti* Géhu 1987

AMMOPHILION AUSTRALIS Br.-Bl. 1933 em. Géhu & Géhu-Franck 1988

*Echinophoro spinosae-Ammophiletum australis* (Br.-Bl. 1933) Géhu, Rivas-Martínez & R. Tx. 1972 in Géhu et al. 1984

**CAKILETEA MARITIMAE** Tüxen & Preising ex Br.-Bl. & Tüxen 1952

EUPHORBIETALIA PEPLIS Tüxen 1950

EUPHORBION PEPLIS Tüxen 1950



*Salsolo-Cakiletum maritimae* Costa & Mansanet 1981 corr. Rivas-Martínez et al. 1992

*Atriplicetum tataricae* Pignatti 1966

**HELICHRYSO-CRUCIANELLETEA MARITIMAE** (Sissingh 1974) Géhu, Rivas-Martínez & Tuxen in Géhu 1975 em. Biondi & Géhu in Géhu & Biondi 1994

HELICHRYSO-CRUCIANELLETTALIA MARITIMAE Géhu, Rivas-Martínez & Tuxen 1973 em. Sissingh 1974

CRUCIANELLION MARITIMAE Rivas Goday & Rivas-Martínez 1958

*Plantagini albicantis-Scabiosetum albae* Brullo et al. 2001

**JUNCETEA MARITIMI** Br.Bl. in Br.-Bl., Roussine & Nègre 1952

JUNCETALIA MARITIMI Br.Bl. ex Horvatic 1934

JUNCION MARITIMI Br.Bl. ex Horvatic 1934

*Juncetum maritimo-acuti* Horvatic 1934

*Junco maritimi-Caricetum extensae* Géhu 1976

PUCCINELLION FESTUCIFORMIS Géhu & Scoppola in Géhu et al. 1984

*Puccinellio festuciformis-Juncetum maritimi* (Pign. 1966) Géhu et al. 1984

HALO-ARTEMISION COERULESCENTIS Pignatti 1953

*Elymetum atherici* Pellizzari, Merloni et Piccoli 1998

**SARCOCORNIETEA FRUTICOSAE** Br.-Bl. & Tüxen ex A. Bolòs & O. Bolòs in A. Bolòs 1950 em. Biondi, Casavecchia, Estrelles & Soriano, 2013

SARCOCORNIETALIA FRUTICOSAE Br.-Bl. 1933 nom. mut. propos. Rivas-Martínez, T.E. Díaz, Fernandez-Gonzales, Izco, Loidi, Lousã & Penas 2002

SARCOCORNION FRUTICOSAE Br.-Bl. 1933 nom. mut. propos. Rivas-Martínez, T.E. Díaz, Fernandez-Gonzales, Izco, Loidi, Lousã & Penas 2002

*Puccinellio festuciformis-Sarcocornietum fruticosae* (Br.-Bl. 1928) J.M. Géhu 1976

SARCOCORNION ALPINI (Rivas-Martínez, Lousã, T.E. Díaz, Fernández-González & J.C. Costa 1990) Brullo, Giusso Del Galdo, Minissale, Siracusa & Spampinato 2002

*Puccinellio-Sarcocornietum alpini* Castroviejo & Cirujano 1980

ARTHROCORNEMION MACROSTACHYI Rivas-Martínez 1980 nom. mut. propos. Rivas-Martínez, T.E. Díaz, Fernandez-Gonzales, Izco, Loidi, Lousã & Penas 2002

*Puccinellio convolutae-Arthrocornietum macrostachyi* (Br.-Bl. 1928) Géhu ex Géhu et al. 1984

(a) subass. *typicum*

(b) subass. *limonietosum bellidifolii* Sciandrello & Tomaselli 2014

INULION CRITHMOIDIS Brullo & Furnari 1988

*Agropyro elongati-Imuletum crithmoidis* Br.-Bl. (1931) 1952

*Limonio-Artemisietum coerulescentis* (Pign. 1953) Géhu et Scopp. 1984

SUAEDION VERAЕ Brullo & Furnari 1988

*Halimiono-Suaedetum verae* Molinier & Tallon 1970 corr. Géhu 1984

HALOCNEMETALIA CRUCIATI Biondi, Casavecchia, Estrelles & Soriano 2013

HALOCNEMION CRUCIATI Biondi, Casavecchia, Estrelles & Soriano 2013

*Arthrocorno macrostachyi-Halocnemetum cruciati* Biondi, Casavecchia, Estrelles & Soriano 2013

**THERO-SUAEDITEA SPLENDENTIS** Rivas-Martínez 1972

THERO-SALICORNIALIA Tüxen in Tüxen & Oberdorfer ex Géhu & Géhu-Franck 1984

SALICORNION PATULAE Géhu & Géhu-Franck 1984

*Suaedo-Salicornietum patulae* Brullo & Furnari ex Géhu & Géhu-Franck 1984

*Salicornietum venetae* Pignatti 1966

*Suaedo splendidis-Salicornietum patulae* Rivas-Martínez, Costa, Castroviejo & E. Valdés 1980 corr. Rivas-Martínez 1991

*Suaedo splendidis-Salicornietum venetae* Biondi & Casavecchia 2010

*Suaedo splendidis-Salicornietum dolichostachyae* Biondi & Casavecchia 2010

THERO-SUAEDETALIA Br.-Bl. & O. Bolòs 1958

THERO-SUAEDION Br.-Bl. in Br.-Bl., Roussine & Nègre 1952

*Atriplici salinae-Suaedetum spicatae* O. Bolòs & Vigo 1984

*Salsoletum sodae* Pignatti 1953

*Salsolo sodae-Suaedetum splendidis* Br.-Bl. 1933

*Suaedo maritimae-Bassietum hirsutae* Braun-Blanquet 1928

*Bassio hirsutae-Suaedetum splendidis* Biondi & Casavecchia 2010

**SAGINETEA MARITIMAE** Westhoff, Van Leeuwen & Adriani 1962

FRANKENIETALIAPULVERULENTAE Rivas-Martínez ex Castroviejo & Porta 1976

FRANKENION PULVERULENTAE Rivas-Martínez ex Castroviejo & Porta 1976

*Parapholidetum filiformis* Brullo, Scelsi & Siracusa 1994

*Hordeo marini-Spergularietum marinae* Guarino, Minissale & Sciandrello 2008

GAUDINIO-PODOSPERMION CANI Brullo & Siracusa 2000

*Sphenopo divaricati-Scorzonoidetum muelleri* Sciandrello, Silletti & Tomaselli 2015

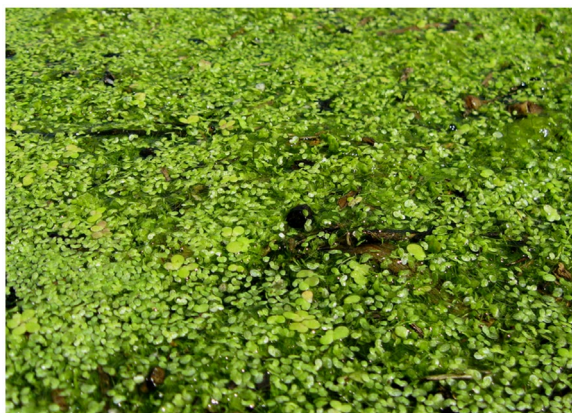


Figure 2. Annual pleustophytic vegetation (*Lemnetum minoris*).



Figure 3. Halo-hydrophyllous communities (*Enteromorpha-Ruppium maritima*).

LIMONION AVEI BRULLO 1988

*Sphenopo divaricati-Limonietum avei* **ass. nova prop.**

CRYPsidETALIA ACULEATAE Vicherek 1973

CRYPsidION ACULEATAE Pignatti 1954

*Crypsidetum aculeatae* (Bojko 1932 n.n.) Wenzl 1934

**TUBERARIETEA GUTTATAE** (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 nom. mut. propos. Rivas-Martínez, Diaz, Fernández-González, Izco, Loidi, Lousa & Penas 2002

CUTANDIETALIA MARITIMAE Rivas-Martínez, Díez-Garretas, and Asensi 2002

LAGURO OVATI-VULPION FASCICULATAE Géhu and Biondi 1994

*Sileno coloratae-Vulpietum membranaceae* (Pign. 1953) Géhu & Scoppola 1984

**NERIO-TAMARICETEA** Br.-Bl. & O.Bolòs 1958

TAMARICETALIA Br.-Bl. & O.Bolòs 1958

TAMARICION AFRICANAE Br.-Bl. & O.Bolòs 1958

*Tamarix africana* communities

**LEMNETEA MINORIS** R.Tx. ex O.Bolòs & Masclans 1955

*Lemnetea minoris* groups the annual pleustophytic vegetation that colonizes fresh or brackish waters. The vegetation found in Capitanata belongs to the alliance *Lemnion minoris* and to the association

*Lemnetum minoris* (= *Lemna minor* Phytocoenon, according to Sburlino et al. 2004). This association grows in fresh and eutrophic waters rich in organic matter. It is a typically species-poor plant community and is characterized by the dominance of *Lemna minor*, often associated with some green algae (Figure 2). This vegetation is widely distributed in Italy, where it grows in different conditions and also in anthropogenic habitats (Scoppola 1982; Sburlino et al. 2004; Biondi et al. 2009 etc.). As regards the coastal areas of Apulia, the association was observed in Le Cesine (Medagli et al. 2015) and Lago Salso.

**Natura 2000 Habitat:** 3150 “Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation”.

**RUPPIETEA MARITIMAE** Tuxen ex Den Hartog & Segal 1964

The salt-tolerant plant communities growing in shallow waters of saltmarshes belong to the *Ruppiaetea maritima* class. The plant communities recorded in Apulia fall into the *Ruppion maritima* alliance that includes the halo-hydrophyte communities of brackish water. In the area of Capitanata, the association *Enteromorpha intestinalidis-Ruppium maritima* (*Ruppion maritima*) was observed (Table I and Figure 3). This vegetation is distributed in brackish, more or less deep waters, and is dominated by *Ruppia maritima*, which sometimes is associated with green algae as *Enteromorpha intestinalis*

Table I. Halo-hydrophytic communities of *Enteromorpha intestinalidis-Ruppium maritima* (*Ruppiaetea maritima*).

<i>Enteromorpha intestinalidis-Ruppium maritima</i>					
Relevé number	1	2	3	4	
Surface (mq)	20	10	20	10	
Coverage(%)	90	85	80	90	Presence
<b>Char. Ass.</b>					
<i>Ruppia maritima</i> L.	5	4	4	5	4
<b>Other species</b>					
<i>Enteromorpha intestinalis</i> (L.) Nees	+	1	2	1	4
<i>Chara</i> sp.	1	+	1		3
Rel. 1–4, Frattarolo swamp, 12.05.2011					



(Sciandrello et al. 2014). In the area of Saline di Margherita di Savoia, this vegetation is favoured by the presence of water rich in nitrates originating from the agricultural activities in the surrounding areas. In Apulia, the association was observed, besides the Saline Margherita di Savoia, also in Torre Canne and Saline Punta della Contessa.

**Natura 2000 Habitat:** 1130 “Estuaries” or 1150\* “Coastal lagoons”.

**POTAMETEA PECTINATI** Klika in Klika & Novák 1941

*Potametea pectinati* class includes the perennial macrophytic plant communities of fresh or brackish, mesotrophic or eutrophic, running or standing waters of lakes, salines, salt marshes (Biondi et al. 2014). The class, in the Capitanata area, is represented by the two orders of *Potametalia* and *Utricularietalia minoris* and, respectively, by the two alliances *Potamion* (that groups the submerged vegetation of meso-eutrophic deep waters dominated by rooted macrophytes) and *Utricularion vulgaris* (growing in oligo-mesotrophic standing waters and including the plant communities dominated by species belonging to the genus *Utricularia*). The associations observed in the study area are *Potametum pectinati* and *Utricularietum australis*. ***Potametum pectinati*** tolerates waters poor in O<sub>2</sub> and rich in phosphates and nitrogen, from eutrophic to hypertrophic and its presence is an indicator of organic pollution (Brullo & Sciandrello 2006; Lastrucci et al. 2014). In Apulia, the *Potametum pectinati* has been observed in: Le Cesine, Torre Guaceto, Saline di Margherita di Savoia and Saline Punta della Contessa (Corbetta 1970; Tomaselli et al. 2011; Medagli et al. 2015). ***Utricularietum australis*** develops in shallow, oligotrophic or mesotrophic acidulous ponds. This plant community is dominated by *Utricularia australis*, which usually is accompanied by pleustonic species such as *Lemna minor*, *Lemna trisulca*, etc. (Sburlino et al. 2004; Lastrucci et al. 2014). The association is very localized and rare in Apulia, and has been observed in: Lago Salso and Le Cesine.

**Natura 2000 Habitat:** 1150\*: Coastal lagoons; 3150 “Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation”.

**PHRAGMITO-MAGNOCARICETEA** Klika in Klika & Novák 1941

This class groups the helophytic communities colonizing marshes, fens and fluvial areas, with brackish or fresh, eutrophic or meso-oligotrophic waters. The class, in the study area, is represented by the two alliances *Phragmition communis* (including the subhalophilous reed plant communities) and *Scirpion compacti* (that groups the hygrophilous marsh communities of brackish waters). Several associations were observed in the area. ***Phragmitetum communis*** is characterized



Figure 4. *Phragmitetum communis* in Lago Salso.

by the dominance of *Phragmites australis*, widely distributed in the wetlands of central and southern Italy (Landucci et al. 2013). It is widespread in the whole study area; in particular, it forms wide and dense populations in the areas of Lago Salso (Figure 4) and Palude di San Floriano. This vegetation is favoured by the presence of waters rich in nitrates originating from the surrounding agricultural areas and, because of its trend to rapidly expand in such altered environments, it represents a serious threat to the biodiversity of the coastal wetlands. ***Typhetum latifoliae***, characterized by the dominance of *Typha latifolia*, forms small patches or narrow belts in catenal contact with *Phragmitetum australis*. ***Iridetum pseudoacori*** is characterized by *Iris pseudoacorus* and occurs in the form of very small patches in the study area. The ***Scirpo compacti-Juncetum subulati*** usually grows in marsh areas, on shallow clay-silt soils, and tolerates short periods of aridity in summer. It is characterized by the dominance of *Bolboschoenus maritimus* var. *compactus* and *Juncus subulatus* (Table II). This vegetation covers large areas in the salt marshes of the Frattarolo swamp. ***Scirpetum compacto-litoralis*** is linked to brackish wetlands but does not tolerate soil desiccation, therefore, it grows in areas remaining wet even in summer. *Schoenoplectus litoralis* and *Bolboschoenus maritimus* var. *compactus* characterize this vegetation, that has a wide western Mediterranean distribution (Bolòs 1962; Rivas-Martínez et al. 1980, 2001; Brullo & Sciandrello 2006).

**EUPHORBIO PARALIAE-AMMOPHILETEA AUSTRALIS** Géhu & Rivas-Martínez in Rivas-Martínez, Asensi, Díez-Garretas, Molero, Valle, Cano, Costa & Díaz 2011.

The *Euphorbio-Ammophiletea australis* class includes the psammophilous perennial vegetation of coastal dunes with a Mediterranean, Atlantic and Macaronesian distribution. In the Mediterranean

Table II. *Scirpo compacti-Juncetum subulati* (Phragmito-Magocaricetea).

<i>Scirpo compacti-Juncetum subulati</i>	1	2	3	4	5	6	7	8	9	Presence
Relevé number	1	2	3	4	5	6	7	8	9	
Surface (mq)	60	100	100	100	100	40	200	100	100	
Coverage(%)	100	90	100	100	90	90	95	100	100	
<b>Char. Ass.</b>										
<i>Juncus subulatus</i> Forssk.	1	4	1	5	4	+	3	1	4	9
<i>Bolboschoenus maritimus</i> (L.) Palla	5	3	5	+	3	3	4	4	3	9
<i>Tripolium pannonicum</i> (Jacq.) Dobrocz.						4	2	1	1	4
<b>Char. Phragmito-Magocaricetea</b>										
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.					+		+		1	3
<i>Typha domingensis</i> Pers.	1				1					2
<b>Trasgr. Sarcocornietea fruticosae</b>										
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez		1	+		+	1				4
<i>Puccinellia festuciformis</i> (Host) Parl. subsp. <i>convoluta</i> (Hornem.) W.E. Hugues				+	+	2				3
<i>Aeluropus littoralis</i> (Gouan) Parl.							2	1	1	3
<i>Halimione portulacoides</i> (L.) Aellen				2		1				2
<i>Triglochin bulbosum</i> L. subsp. <i>barrelieri</i> (Loisel.) Rouy						1				1
<i>Suaeda vera</i> J. F. Gmelin						+				1
<i>Limbarda crithmoides</i> (L.) Dumort.									+	1
<b>Other species</b>										
<i>Tamarix africana</i> Poir.	+	+	+				1	+	3	6
<i>Rumex crispus</i> L.		+	+				+	+	+	5
<i>Polypogon monspeliensis</i> (L.) Desf.					1	1	+	+		4
<i>Hordeum marinum</i> Huds.		2	+			+				3
<i>Crypsis aculeata</i> (L.) Aiton.							+	+		2
<i>Parapholis filiformis</i> (Roth) C. E. Hubb.						1				1
<i>Juncus acutus</i> L.						+				1
<i>Juncus hybridus</i> Brot.						+				1
<i>Carex extensa</i> Good.						+				1
Rel. 1–5, Frattarolo swamp, 12.05.2011										
Rel. 6, mouth of the Candelaro river, 12.05.2011										
Rel. 7–9, Frattarolo swamp, 3.09.2011										

area, the class is present with the *Ammophiletalia australis* order and with the two alliances *Ammophilion australis* (psammophilous perennial herbaceous communities of mobile dunes) and *Agropyron juncei* (psammophilous perennial herbaceous communities of the embryonal dunes; Biondi & Galdenzi 2014). In the area of Capitanata, three associations were identified. *Sporobolium arenarii*, halo-subnitrophilous, pioneer perennial vegetation characterized by the dominance of *Sporobolus pungens* (Figure 5), growing on sandy soils rich in organic material (Brullo et al. 2001). *Echinophoro spinosae-Elymetum farcti*, perennial vegetation of embryonic shifting dunes, characterized by the dominance of *Elytrigia juncea* (Table III, rel. 2–5 and Figure 6). *Echinophoro spinosae-Ammophiletum australis*, herbaceous perennial plant community colonizing the white dunes and structurally characterized by *Ammophila australis* (Table III, rel. 6). In Apulia, due to the extensive human activities and the associated pressures that have been exerted for decades on coastal areas, this last association has gone through a strong reduction and fragmentation of its distribution area (Mariotti et al. 1992; Biondi et al. 2006).

**Natura 2000 Habitat:** 2110 “Embryonic shifting dunes”; 2120 “Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)”.


 Figure 5. *Sporobolium arenarii*.

#### CAKILETEA MARITIMAE Tüxen & Preisling ex Br.-Bl. & Tüxen 1952

Pioneer halo-nitrophilous therophytic vegetation of beaches and strandlines strongly influenced by the seawater and subject to the overwash effects. Its occurrence is favoured by the nutrient enrichment caused mainly by mineralizing organic matter. The *Euphorbion pepelis* alliance characterizes the coasts of Mediterranean and Cantabrian areas.

In the study area, the class it is represented by the *Salsolo-Cakiletum maritimae*, considered



Table III. Psammophilous perennial vegetation of *Euphorbio paraliae-Ammophiletea australis* (rel. 2–6) and of *Helichryso-Crucianelletea maritimae* (rel. 1, 7, 8).

<b>Plantagini albicantis-Scabiosetum albae</b> (ril. 1, 7–8)									
<b>Cypero capitati-Agrophyretum juncei</b> (ril. 2–5)									
<b>Medicagini marinae-Ammophiletum australis</b> (ril. 6)									
Relevé number	1	2	3	4	5	6	7	8	
Surface (mq)	50	100	100	60	60	50	50	50	
Coverage(%)	75	70	65	80	80	90	80	80	Presence
<b>Char. Ass.</b>									
<i>Elytrigia juncea</i> (L.) Nevski	+	3	3	4	2	1	+	+	8
<i>Lomelosia argentea</i> (L.) Greuter & Burdet	2						3	2	3
<i>Ammophila arenaria</i> (L.) Link subsp. <i>australis</i> (Mabille) Lainz						4			1
<b>Char. Ammophiletea and Helichryso-Crucianelletea</b>									
<i>Lotus commutatus</i> Guss.	+	1	2	1	1	+	1	1	8
<i>Echinophora spinosa</i> L.	2			2	3	+	1	1	6
<i>Cyperus capitatus</i> Vandel.	1				+		3	1	4
<i>Euphorbia terracina</i> L.	+	+	1						3
<i>Medicago marina</i> L.		1	1			+			3
<i>Pancreatium maritimum</i> L.	+			+					2
<i>Calystegia soldanella</i> (L.) Roem. & Schult.				+		+			2
<i>Scolymus hispanicus</i> L.					+				1
<b>Other species</b>									
<i>Rostraria litorea</i> (All.) Holub	1	+	+	+	+	+	+	+	8
<i>Hypochoeris radicata</i> L.	2			+	+	1	1	2	6
<i>Artemisia campestris</i> L. subsp. <i>variabilis</i> (Ten.) Greuter	+				2	+	1	+	5
<i>Orobancha</i> sp.				+	+	+	+	+	5
<i>Silene colorata</i> Poir.	+	+	1						3
<i>Xanthium orientale</i> L. subsp. <i>italicum</i> (Moretti) Greuter		+	2	+					3
<i>Limbarda crithmoides</i> (L.) Dumort.		+	+						2
<i>Cenchrus incertus</i> Curtis		+	1						2
<i>Asparagus maritimus</i> (L.) Mill.	+								1
<i>Vulpia fasciculata</i> (Forssk.) Fritsch	2								1
<i>Erodium laciniatum</i> (Cav.) Willd.	+								1
<i>Polygonum maritimum</i> L.				+					1
<i>Salsola kali</i> L.				+					1
Rel. 1, Mouth of the Candelaro river, 12.05.2011									
Rel. 2–3, Zapponeta, damp areas along the coast, 01.09.2011									
Rel. 4–8, Mouth of the Candelaro river, 03.09.2011									

Figure 6. Psammophilous perennial vegetation (*Echinophora spinosae-Elymetum farcti* and *Sporobolium arenarii*).

as the central association of the *Euphorbion peplis* alliance (Sýkora et al. 2003). This vegetation tends to extend considerably in those places where the plant communities of dune belts have been destroyed by tourism and other anthropogenic activities. Biondi & Casavecchia (2010) pointed out the presence of the *Atriplicetum tataricae* at the mouth of the Candelaro river, where it grows on the dense layers of organic material that have been carried by waves and accumulated on the higher parts of the beaches.

**Natura 2000 Habitat:** 1210 “Annual vegetation of drift lines”.

**HELICHRYSO-CRUCIANELLETEA MARITIMAE** (Sissingh 1974) Géhu, Rivas-Martínez & Tuxen in Géhu 1975 em. Biondi & Géhu in Géhu & Biondi 1994

The *Helichryso-Crucianelletea maritimae* class includes chamaephytic vegetation consisting of primary garrigues growing mainly on the inland-facing slope of mobile dunes, or also on rocky coastal sites. The vegetation of the inland-facing slope of semi-permanent dunes is included in the *Crucianellion maritimae* alliance (*Helichryso-Crucianelleteria maritimae*) (Biondi 2007).

In the study site, a chamaephytic plant community characterized by *Lomelosia argentea* and *Artemisia variabilis* was identified and referred to the **Plantagini albicantis-Scabiosetum albae** (Table III, rel. 1, 7–8). These communities appear altered, both in structure and in distribution, due to the strong reduction of their natural habitat. In Apulia, this association is very localized and circumscribed to a few sites (Corbetta et al. 1992; Brullo et al. 2001).

**Natura 2000 Habitat:** 2210 “*Crucianellion maritimae* fixed beach dunes”.

**JUNCETEA MARITIMI** Br.Bl. in Br.-Bl., Roussine & Nègre 1952

Table IV. Communities of the *Juncetea maritimi* class.

<i>Juncetum maritimi-acuti</i> (rel. 1–4)									
<i>Junco maritimi-Caricetum extensae</i> (rel. 5–6)									
<i>Elymetum atherici</i> (rel. 7–8)									
Relevé number	1	2	3	4	5	6	7	8	Presence
Surface (mq)	40	40	40	100	30	30	50	40	
Coverage(%)	100	100	100	95	90	85	100	100	
<b>Char. Ass.</b>									
<i>Juncus maritimus</i> Lam.	4	5	5	5	1	1			6
<i>Carex extensa</i> Gooden.				1	4	3			3
<i>Elymus athericus</i> (Link) Kerguélen							5	5	2
<b>Char. Juncion maritimi and Juncetea maritimi</b>									
<i>Juncus acutus</i> L.	1	2	+	2	+	+			6
<i>Tripolium pannonicum</i> (Jacq.) Dobroc.	3	2	3	1	1	+			6
<i>Juncus subulatus</i> Forssk.	1	1	+	+		1			5
<b>Trasgr. Sarcocornietea fruticosae</b>									
<i>Limbarda crithmoides</i> (L.) Dumort.				+	2	3			3
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez				1	2	1			3
<i>Limonium narbonense</i> Mill.				+	+	+			3
<i>Limonium virgatum</i> (Willd.) Fourr.					1	+			2
<i>Suaeda vera</i> J. F. Gmelin							1	+	2
<i>Halimione portulacoides</i> (L.) Aellen						+			1
<b>Other species</b>									
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	+		+	1					3
<i>Polypogon monspeliensis</i> (L.) Desf.	+	+	1						3
<i>Atriplex prostrata</i> Boucher ex DC. subsp. <i>latifolia</i> (Wahlenb.) Rauschert	+	+	+						3
<i>Galium aparine</i> L.	+	+	+						3
<i>Suaeda maritima</i> (L.) Dumort.				1	+	+			3
<i>Centaurium spicatum</i> (L.) Fritsch				+	+				2
<i>Sporobolus virginicus</i> Kunth					+	+			2
<i>Xanthium orientale</i> L. subsp. <i>italicum</i> (Moretti) Greuter					+	+			2
<i>Dittrichia viscosa</i> (L.) Greuter					+	+			2
<i>Avena sterilis</i> L.							1		1
<i>Allium ampeloprasum</i> L.							+		1
<i>Piptatherum miliaceum</i> (L.) Coss.							+		1
<i>Avena barbata</i> Pott ex Link							+		1
<i>Carpobrotus edulis</i> (L.) N.E. Br.								+	1
<i>Lagurus ovatus</i> L.								+	1
Rel. 1–3, Margherita di Savoia salt pans, 13.05.2011									
Rel. 4, 5, 6, Zapponeta, damp areas along the coast, 01.09.2011									
Rel. 7, Margherita di Savoia salt pans, 13.05.2011									
Rel. 8, Margherita di Savoia salt pans, 1.09.2011									

The perennial herbaceous vegetation dominated by tall rushes and forming extended and thick formations in wetlands and salt marshes, falls within the *Juncetea maritimi* class. It is represented by the *Juncetalia maritimi* order (with Mediterranean distribution) and by the alliances: *Juncion maritimi*, *Puccinellion festuciformis* and *Halo-Artemision coerulescentis*. In the study area, four associations were identified. The *Juncetum maritimo-acuti* is distributed in back dune areas, on sand-silty soils periodically flooded and is dominated by *Juncus maritimus* and *J. acutus*, often in association with *J. subulatus* and *Tripolium pannonicum* (Table IV, rel. 1–4 and Figure 7). This association is widely widespread along the coastal environments of the Italian peninsula, even if it is often subject to various pressures and disturbance factors determining alterations in its structure and floristic composition. (Biondi 1999; Frondoni & Iberite 2002; Pandža et al. 2007; Sciandrello et al. 2014). The *Junco maritimi-Caricetum extensae* association, dominated by *Carex extensa* and *Juncus maritimus*, replaces the *Juncetum maritimo-acuti* in areas subject to prolonged flooding periods (Table IV, rel. 5–6).


 Figure 7. *Juncetum maritimo-acuti*.

The *Puccinellion festuciformis-Juncetum maritimi* characterizes salt marshes periodically flooded by brackish-salt waters. Such halo-tolerant communities are often rich in halophilous species of other syntaxa, especially of the *Salicornietea fruticosae* class. This associations is quite rare and localized in Puglia, and has been previously identified by



Figure 8. *Puccinellio-Sarcocornietum alpini*.

other Authors at the mouth of the Candelaro river (Capitanata) and in Lago Salinella (TA) (Gèhu et al. 1984; Corbetta et al. 1992).

Marginal areas rarely subject to flooding are often covered by an herbaceous dense vegetation characterized by *Elytrygia atherica*, species that forms dense and pauci-specific populations. This vegetation, identified in the area of Saline di Margherita di Savoia, can be referred to the association *Elymetum atherici* (Table IV, rel. 7–8).

**Natura 2000 Habitat:** 1410 “Mediterranean salt meadows (*Juncetalia maritimi*)”.

**SARCOCORNIETEA FRUTICOSAE** Br.-Bl. & Tüxen ex A. Bolòs & O. Bolòs in A. Bolòs 1950 em. Biondi, Casavecchia, Estrelles & Soriano, 2013

The *Sarcocornietea fruticosae* class includes halophilous shrub plant communities of both coastal and inland areas, developing on halomorphic soils of salt marshes, estuaries, coastal lagoons. This vegetation is characterized by succulent *Chenopodiaceae* with a chamaephytic or nanophanerophytic *habitus*. In the area of Capitanata, several associations were identified, belonging to the following alliances: *Sarcocornion fruticosae* (halophilous shrub plant communities, subject to periodic flooding and dominated by *Sarcocornia fruticosa*), *Sarcocornion alpini* (halophilous shrub plant communities, subject to periodic flooding and dominated by *Sarcocornia alpini*), *Arthrocnemion macrostachyi* (hyper-halophylous shrub plant communities subject to periodic flooding and dominated by *Arthrocnemum macrostachyum*), *Inulion crithmoidis* (halophilous shrub communities subject to sporadic flooding), *Suaedion verae* (halo-nitrophilous shrub communities), *Halocnemion cruciati* (*Halocnemum cruciatum* communities).

The *Puccinellio-Sarcocornietum alpini* usually colonizes areas subject to long periods of submersion (Frondoni & Iberite 2002). It is

Table V. *Puccinellio-Sarcocornietum alpini* (*Sarcocornietea fruticosae* class, *Sarcocornion alpini* alliance).

(from Sciandrello & Tomaselli 2014, Tab.1)

<b>Puccinellio-Sarcocornietum alpini</b>		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
Relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
Surface (mq)		50	40	40	50	50	50	50	50	50	40	80	80	80	80	80	80	80	80	100	100	100	40	40	50	50	100	100	200	
Coverage (%)		95	100	100	80	100	100	100	100	100	100	100	90	90	100	90	95	95	100	100	90	95	90	90	100	100	100	100	95	
<b>Char. Ass.</b>		2	+	2	2	3	2	1	1	1	2	2	4	4	2	1	3	3	1	1	+	1	1	1	2	3	1	2	2	
<i>Puccinellia festuciformis</i> (Host)																														28
Parl. subsp. <i>convoluta</i> (Hor-nem.) W.E. Hugues																														2
<b>Char. Sarcocornietea fruticosae</b>		5	5	4	4	1	5	5	5	4	4	4	2	1	5	5	4	4	4	2	4	4	5	4	4	4	5	5	4	28
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez																														20
<i>Suaeda vera</i> J. F. Gmelin		+	+	+	1	+	+	+	+	1	2	1	+	+	+	2	1	1	+	1	+	+	+	+	+	+	+	+	1	17
<i>Halimione portulacoides</i> (L.) Aellen		1	1	2	1	4	1	2	1	4																				11
<i>Arthrocnemum macrostachyum</i> (Moric.) Moris																														10
<i>Juncus subulatus</i> Forssk.																														7
<i>Aeluropus litoralis</i> (Gouan) Parl.		2				+	1	2	1	+	+	1	3	2	+															7

(Continued)





Table VI. *Arthrocnemo macrostachyi-Halocnematum cruciati* (*Sarcocornietea fruticosae* class, *Halocnemion cruciati* alliance).

(from Sciandrello & Tomaselli 2014, Tab.1, rel. 86–96)												
<b>Arthrocnemo-Halocnematum cruciati</b>												
Relevé number	1	2	3	4	5	6	7	8	9	10	11	
Surface (mq)	50	50	50	50	50	100	50	100	100	100	100	
Coverage(%)	50	50	50	60	90	70	85	80	80	80	90	Presence
<b>Char. Ass</b>												
<i>Halocnemum cruciatum</i> (Forssk.) Tod.	3	2	3	3	1	2	3	4	3	4	4	11
<b>Char. Arthrocnemion glauci</b>												
<i>Arthrocnemum macrostachyum</i> (Moric.) Moris	1	3	1	2	4	3	3	3	4	2	3	11
<b>Char. Sarcocornietea fruticosae</b>												
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez			1	1	1	+	1	+	+	1	+	9
<i>Puccinellia festuciformis</i> (Host) Parl. subsp. <i>convoluta</i> (Hornem.) W.E. Hugues				+			1	1				3
<i>Suaeda vera</i> J. F. Gmelin							+					1
<b>Other species</b>												
<i>Salicornia veneta</i> Pignatti et Lausi				+		+		+	+		+	5
Rel. 1–4, mouth of the Carapelle river, 13.05.2011												
Rel. 5–11, mouth of the Carapelle river, 02.09.2011												

physiognomically characterized by *Sarcocornia alpini* (Figure 8) and is well differentiated by the presence of *Puccinellia festuciformis* (Table V). The association was observed at: Palude di Frattarolo, mouth of the Carapelle river and Saline di Margherita di Savoia.

Recently, at the mouth of the Carapelle river, an hyper-halophilous dwarf-shrub vegetation dominated by *Halocnemum* M. Bieb. was found out and attributed to the association *Arthrocnemo glauci-Halocnematum strobilacei* Oberdorfer 1952 (Sciandrello & Tomaselli 2014). According to the considerations of Biondi et al. (2015), the population has to be attributed to *Halocnemum cruciatum* instead of *H. strobilaceum* and then the vegetation can be attributed to the ***Arthrocnemo macrostachyi-Halocnematum cruciati*** Biondi et al. 2013, association distributed in Sardinia, Sicily, Cyprus, Turkey and north Africa (Biondi et al. 2013). It is an hyper-halophilous vegetation, localized in the inner parts of coastal lagoons and growing on sandy-silty soils subject to prolonged flooding periods. Characteristic species of the association are *Halocnemum cruciatum* and *Arthrocnemum macrostachyum* (Table VI). Within the study area, this vegetation is localized in proximity of the mouth of the Carapelle river, in a rather good conservation status, despite the close contiguity with a highway, towards the inland, and a touristic resort, towards the beach (Figure 9). The ***Puccinellio convolutae-Arthrocnemetum macrostachyi*** grows mainly on

Figure 9. *Arthrocnemo-Halocnematum cruciati*, mouth of the Carapelle river.

clayey soils subject to long periods of submersion. The physiognomy of this plant community is given by the bushes of *Arthrocnemum macrostachyum* (Table VII), whilst *Puccinellia festuciformis* subsp. *convoluta* is characteristic of association (Figure 10). This vegetation finds its optimal conditions even on hypersaline soils (Filigheddu et al. 2000; Cutini et al. 2010). The subassociation ***limonietosum bellidifolii*** is localized in areas subject to less prolonged flooding periods; *Limonium bellidifolium* is a rare halophytic species that differentiates this subassociation (Sciandrello & Tomaselli 2014). The association was observed at the mouths of the

Table VII. *Puccinellio convolutae-Arthrocnemum macrostachyi* (*Sarcocornietea fruticosae* class, *Arthrocnemion macrostachyi* alliance).

		(from Sciandrello & Tomaselli 2014, Tab.1)																																					
<b><i>Puccinellio-Arthrocnemum</i></b>																																							
<b><i>macrostachyi</i></b>																																							
Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28											
Surface (mq)	40	40	50	50	50	50	100	100	100	100	50	100	100	80	100	80	100	100	30	30	40	50	100	100	100	40	100	80											
Coverage (%)	90	100	90	95	100	100	100	100	100	100	100	80	100	100	100	80	100	100	100	95	100	100	90	90	95	90	95	90											
<b>Char. Ass.</b>																																							
<i>Puccinellia festuciformis</i> (Host)	2	3	2	3	1	1	2	3	3	2	3	1	1	1	1	1	1	1	2	1	1	1	2	1	2	1	2	4	1	27									
Parl. subsp. <i>convoluta</i> (Hornem.) W.E. Hugues																																							
<b>Char. Subass.</b>																																							
<i>Limonium bellidifolium</i> (Gouvan) Dumort	1	1	1	1	1	1	1	2																															
<b>Char. Sarcocornietea fruticosae</b>																																							
<i>Arthrocnemum macrostachyum</i> (Moric.) Moris	5	2	4	4	5	5	5	5	5	5	4	4	5	4	5	5	5	5	4	4	5	4	5	5	4	4	5	4	5	28									
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez	1	+	1	1	1	1	1	3	1																														
<i>Halimione portulacoides</i> (L.) Aellen	1	3	1	1	1	+	2	+	1	+	+	+																											
<i>Limonium narbonense</i> Mill. <i>Suaeda vera</i> J.F. Gmelin	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	12									
<i>Triglochin bulbosum</i> L. subsp. <i>barrelieri</i> (Loisel.) Rouy	2	1	2	1	1	2	+	+	1	1	2	+	+	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	7										
<i>Limbarda crithmoides</i> (L.) Du- mort.	1	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	4											
<i>Juncus subulatus</i> Forssk. <i>Elymus elongatus</i> (Host) Rune- mark ssp. <i>elongatus</i>																																							
<i>Limonium virgatum</i> (Willd.) Fourr.																																							
<i>Artemisia caerulea</i> L. <i>Aeluropus litoralis</i> (Gouan) Parl.	1	+																																					
<b>Other species</b>																																							
<i>Salicornia veneta</i> Pignatti et Lausi																																							
<i>Bromus racemosus</i> L. <i>Polypogon monspeliensis</i> (L.) Desf. <i>Parapholis filiformis</i> (Roth) C. E. Hubb.	1	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	7									
<i>Sonchus bulbosus</i> (L.) Kilian & Greuter																																							
<i>Sphenopus divaricatus</i> (Gouan) Rehb.																																							
<i>Juncus maritimus</i> Lam. <i>Sonchus oleraceus</i> L. <i>Galium aparine</i> L. <i>Tripolium pannonicum</i> (Jacq.) Dobroc.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	3									

(Continued)



Table VII. (Continued).

<i>Lolium perenne</i> L.	1	1
<i>Hordeum marinum</i> Huds.		1
Rel. 1–4, mouth of the Candelaro river,		
12.05.2011		
Rel. 5–10, Margherita di Savoia salt pans,	+	
13.05.2011		
Rel. 11–12, San Vito, Vasca Paradiso, Margherita di Savoia salt pans, 13.05.2011		
Rel. 13–16, mouth of the Carapelle river,		
13.05.2011		
Rel. 17, Fimouth of the Carapelle river, Petuso ditch,		
14.05.2011		
Rel. 18, mouth of the Candelaro river,		
14.05.2011		
Rel. 19–21, Margherita di Savoia salt pans,		
01.09.2011		
Rel. 22–27, Almadannata, Margherita di Savoia salt pans,		
02.09.2011		
Rel. 28, Margherita di Savoia salt pans,		
02.09.2011		

Figure 10. *Puccinellio-Arthrocnemetum glauci*.

rivers Carapelle and Candelaro and at the Saline di Margherita di Savoia.

The *Puccinellio festuciformis-Sarcocornietum fruticosae* is localized in areas subject to moderate periods of submersion, usually forming dense communities covering limited areas and adjacent, in the most raised parts, to the *Agropyro scirpei-Inuletum crithmoidis*. This association is characterized by the dominance of *Sarcocornia fruticosa*, which forms dense populations, and is differentiated by *Puccinellia festuciformis* subsp. *convoluta*. This association has been observed by Biondi & Casavecchia (2010) in the area of Capitanata, at the mouths of the rivers Candelaro and Ofanto. *Agropyro elongati-Inuletum crithmoidis* (Table VIII, rel. 1–2) occurs in the most raised parts of the salt marshes, generally not or rarely subject to flooding. Physiognomically, it is characterized by the dominance of *Limbarda crithmoides*, with *Elymus elongatus* ssp. *elongatus* and many other halophytes. This vegetation was observed at the mouth of Carapelle and in Palude Frattarolo. The *Limonio-Artemisietum coerulescentis* has halo-sub-nitrophilous requirements and usually grows in correspondence of the peripheral stations of the salt marshes, on silty-clay soils (Table VIII, rel. 3–4). In favourable conditions, it forms dense communities characterized by the dominance of *Artemisia coerulescens*, that is associated with *Limonium narbonense* and many other halophytes (Pignatti 1966; Kaligarić & Škornić 2007). In the study area, this association was found only in a circumscribed area in the Saline di Margherita di Savoia. *Halimiono-Suaedetum verae* usually occurs in the external parts of salt marshes, rarely subject to flooding (Table VIII, rel. 5–14). This association has halo-sub-nitrophilous requirements, grows on clay-silty soils and forms dense communities dominated by *Suaeda vera* and *Halimione portulacoides*. Observed

Table VIII. Communities of *Inulion crithmoidis* (rel. 1–4) and of *Suaedion verae* (rel. 5–14) (*Sarcocornietea fruticosae* class).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Presence
(from Sciandrello & Tomaselli 2014, Tab.1)															
<i>Agropyro elongati-Inuletum crithmoidis</i> (rel. 1–2)	80	100	30	30	40	100	100	100	100	40	80	100	100	100	
<i>Limonio narbonense-Artemisietum coerulescens</i> (rel. 3–4)	90	100	90	90	80	100	90	100	100	100	90	100	100	100	
<b>Char. Associazione</b>	3	3	3	4	4	3	4	4	1	4	4	4	3	4	4
<i>Limbarda crithmoides</i> (L.) Dumort.															2
<i>Artemisia caerulescens</i> L.															13
<i>Suaeda vera</i> J. F. Gmelin	+		1	1	4	3	4	4	+	4	4	4	1	+	
<b>Char. Sarcocornietea fruticosae</b>															
<i>Halimione portulacoides</i> (L.) Aellen	+	+	1	2	2	+	+	1	5		1	4	5	4	12
<i>Puccinellia festuciformis</i> (Host) Parl. subsp. <i>convoluta</i> (Hornem.) W.E. Hugues		+	+	1	+	+			1		1		1	2	10
<i>Limonium narbonense</i> Mill.	1	2	1	1					+	1	+	+	1	+	9
<i>Arthrocnemum macrostachyum</i> (Moris.) Morris		1	+	1	+			1			+	+			7
<i>Suaeda veneta</i> Pignatti et Lausi	+	1	2	+							1	2	+	+	6
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez					1				1		1	+	+	3	5
<i>Juncus subulatus</i> Forsk.		+							1				+	1	4
<i>Triglochin bulbosum</i> L. subsp. <i>barretieri</i> (Loisel.) Rouy		+									+				2
<i>Limonium bellidifolium</i> (Gouvan) Dumort		+		+							+				2
<i>Halocnemum cruciatum</i> (Forsk.) Tod.											+				1
<i>Aeluropus litoralis</i> (Gouan) Parl.													1		1
<b>Other species</b>															
<i>Hordeum marinum</i> Huds.					1	1	+	1	+						5
<i>Lolium multiflorum</i> Lam.					+	2	1	+	+						5
<i>Melilotus siculus</i> (Turra) All.					+	2	1	1	+						5
<i>Parapholis filiformis</i> (Roth) C. E. Hubb.	2	+			+	+		+	+						4
<i>Melilotus sulcatus</i> Desf.					+	+		+							3
<i>Bromus racemosus</i> L.													+	+	2
<i>Daucus carota</i> L.										3					2
<i>Geranium dissectum</i> L.			1		2	2	1								2
<i>Juncus maritimus</i> Lam.	2	3					+								2
<i>Polygoum monspeliensis</i> (L.) Desf.						+	+								2
<i>Allium arvense</i> Guss.			1												1
<i>Asphodelus ramosus</i> L.															1
<i>Avena barbata</i> Pott ex Link										+					1
<i>Carduus pycnocephalus</i> L.										1					1
<i>Carpobrotus edulis</i> (L.) N.E. Br.										2					1
<i>Ferula communis</i> L.										+					1
<i>Foeniculum vulgare</i> Mill. subsp. <i>piperitum</i> (Ucria) Bég.										+					1
<i>Glebionis coronaria</i> (L.) Spach										+					1
<i>Juncus acutus</i> L.										1					1
<i>Lagurus ovatus</i> L.													1		1
<i>Lotus commutatus</i> Guss.	+														1
<i>Melilotus albus</i> Medik.	+														1

(Continued)





Table IX. Communities of the *Thero-Suaedetum splendidis* class.

<b><i>Salsolo-Suaedetum splendidis</i></b> (rel. 10–13)														
<b><i>Atriplici salinae-Suaedetum spicatae</i></b> (rel. 3–4)														
<b><i>Salsoletum sodae</i></b> (rel. 2)														
<b><i>Suaedo-Salicornietum patulae</i></b> (rel. 8)														
<b><i>Salicornietum venetae</i></b> (rel. 1, 5–7, 9)														
Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	
Surface (mq)	5	5	5	5	4	10	20	10	10	5	5	5	10	
Coverage(%)	70	85	90	90	85	80	90	70	60	50	60	70	95	Presence
<b>Char. Ass.</b>														
<i>Salicornia veneta</i> Pignatti et Lausi	3		1	1	4	4	4	+	3					8
<i>Suaeda spicata</i> (Willd.) Moq.	2		4	5	+		+	1	1					7
<i>Salsola soda</i> L.		4								+	+	+	1	5
<b>Char. Thero-Salicornietea</b>														
<i>Suaeda splendens</i> (Pourr.) Gren. & Godr.		1								3	3	3	5	5
<i>Salicornia patula</i> Duval-Jouve						+		3	+		1	2		5
<b>Trasgr. Sarcocornietea fruticosae</b>														
<i>Sarcocornia perennis</i> (Mill.) A.J. Scott	+	+				+	+	+	+	+	+	+		9
<i>Puccinellia festuciformis</i> (Host) Parl. subsp. <i>convoluta</i> (Hornem.) W.E. Hugues	1		1	+							+	+		5
<i>Aeluropus littoralis</i> (Gouan) Parl.													+	1
<b>Other species</b>														
<i>Spergularia salina</i> J. & C. Presl	2		1	+										4
<i>Crypsis aculeata</i> (L.) Aiton		2									2	1	1	4
<i>Parapholis pycnantha</i> (Hack.) C.E. Hubb.	1		+	1										3
<i>Tripolium pannonicum</i> (Jacq.) Dobrocz.			+	+									+	3
<i>Hordeum marinum</i> Huds.											+	+	+	3
<i>Atriplex prostrata</i> Boucher ex DC. subsp. <i>latifolia</i> (Wahl-enb.) Rauschert			+	1										2
<i>Sphenopus divaricatus</i> (Gouan) Rchb.	+													1
<i>Bolboschoenus maritimus</i> (L.) Palla		+												1
<i>Juncus hybridus</i> Brot.			+											1
<i>Polypogon monspeliensis</i> (L.) Desf.													1	1
Rel. 1–2, Frattarolo swamp, 12.05.2011														
Rel. 3–5, Aloisa, Almadannata, Margherita di Savoia salt pans, 13.05.2011														
Rel. 6–9, Almadannata, Margherita di Savoia salt pans, 02.09.2011														
Rel. 10–13, Frattarolo swamp, 03.09.2011														

*Puccinellio convolutae-Arthrocnemetum macrostachyi*, and the ***Suaedo splendidis-Salicornietum dolichostachyae*** strictly localized at the mouth of the Candelaro river.

As for the communities belonging to the *Thero-Suaedetalia*, ***Atriplici salinae-Suaedetum spicatae*** is a halo-nitrophilous vegetation growing on wet soils rich in nitrates and is well differentiated by *Suaeda spicata* (= *S. maritima*); it has been observed in the area of Saline di Margherita di Savoia (Table IX, rel. 3–4). The ***Salsoletum sodae*** is a termo-

xerophilous association characterized by *Salsola soda* that usually forms almost monospecific communities (Table IX, rel. 2); it grows on halomorphic, well-drained soils rich in nitrates or organic material and was observed in the area of Saline di Margherita di Savoia and of Palude Frattarolo. In this, last area has been observed also the ***Salsolo sodae-Suaedetum splendidis***, halo-subnitrophilous and termophilous vegetation, characterized by *Suaeda splendens* and *Salsola soda* (Table IX, rel. 10–13). At the mouth of the Candelaro river, dense nitrophilous



communities of *Bassia hirsuta* have been found, and referred to the two following associations: *Suaedo maritimae-Bassietum hirsutae* and *Bassia hirsutae-Suaedetum splendentis*, the latter often colonizing abandoned fields after farming, on clayey, salty soils (Biondi & Casavecchia 2010).

**Natura 2000 Habitat:** 1310 “*Salicornia* and other annuals colonizing mud and sand”.

**SAGINETEA MARITIMAE** Westhoff, Van Leeuwen & Adriani 1962

This class is characterized by small therophytic, xerophilous, halophilous and sub-halophilous species of the Atlantic and Mediterranean coasts (Biondi et al. 2014). In Southern Italy, this class is represented by the *Frankenietalia pulverulentae* and the *Crypsidetalia aculeatae* orders. *Frankenietalia* includes the three alliances: *Frankenion pulverulentae*, widespread in salt-marshes and rocky coasts; *Limonium avei*, replacing the previous one in markedly thermo-xerophilous environmental conditions; and *Gaudinio-Podospermion cani*, linked to clayey places of inland salt marshes. *Crypsidetalia aculeatae* includes only the *Crypsidion aculeatae* alliance that groups the therophytic vegetation growing on temporarily inundated substrates. The associations observed in the study area are briefly described below.

*Parapholidetum filiformis* is characterized by the dominance of *Parapholis filiformis* (Table X, rel. 1–3), along with numerous other halophilous and halo-nitrophilous therophytes of the class, and is largely widespread in the coastal wetlands of Apulia (Tomaselli et al. 2011), especially on sand-silty soils subject to short flooding periods (Brullo & Giusso Del Galdo 2003); in the study area, it was found at: Saline di Margherita di Savoia, Palude di Frattarolo and mouth of Candelaro river. The *Hordeo marini-Spergularietum marinae* is the pioneer vegetation of sandy soils with a significative organic component; it is rich in halophilous therophytic species of the *Saginetea maritimae* (Table X, rel. 4–7). In the area of Palude di Frattarolo, it tends to form mosaics with the perennial vegetation of the *Puccinellio-Sarcocornietum alpini* and of the *Halimiono-Suaedetum verae*. The *Sphenopo divaricati-Scorzonoidetum muelleri* is an halo-nitrophilous annual vegetation growing on clayey or clay-silty soils and subject to periodic flooding. It is in catenal contact with the halophilous or sub-halophilous plant communities of the *Juncetea maritimae* or *Salicornietea fruticosae*. *Scorzonoides muelleri* has high cover values, along with several other species belonging to the *Saginetea maritimae* class. It has been observed in the area of the Saline di Margherita di Savoia (Sciandrello & Tomaselli 2014). In the area of the Saline di Margherita di Savoia, along the walkways crossing the salt pans, on soils with a high salt concentration and rich in nitrates, was observed a vegetation linked to markedly



Figure 12. Halo-nitrophilous annual communities (*Sphenopo-Limonietum avei*).

xeric environmental conditions and differentiated by the presence of *Limonium avei* and numerous species of *Saginetea maritimae*, such as *Sphenopus divaricatus*, *Frankenia pulverulenta*, *Spergularia diandra*, *Polypogon maritimus*, *Sagina maritima*, *Plantago coronopus* (Table X, rel. 8–11 and Figure 12). *Limonium avei* is here proposed as characteristic species of the new association *Sphenopo divaricati-Limonietum avei* (Holotypus: Table X, rel.10). *Crypsidetum aculeatae* is a pioneer halo-nitrophilous vegetation of temporarily flooded clay-silty soils. Characterized by *Crypsis aculeata*, it has a fragmented distribution, often forming mosaics with the therophytic plant communities of *Saginetea maritimae* or *Thero-Salicornietea* classes (Table X, rel. 12–17). This association was found in the area of Palude di Frattarolo and of Saline di Margherita di Savoia.

**Natura 2000 Habitat:** 1310 “*Salicornia* and other annuals colonizing mud and sand”.

**TUBERARIETEA GUTTATAE** (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 nom. mut. propos. Rivas-Martínez, Diaz, Fernández-González, Izco, Loidi, Lousa & Penas 2002

The ephemeral sabulicolous plant communities of the Mediterranean region fall within the *Tuberarietea guttatae* class (Rivas Goday 1958). The plant communities identified in the study area belong to the *Cutandietalia maritimae* order and to the association *Sileno coloratae-Vulpietum membranaceae* (Pign. 1953) Géhu & Scoppola 1984. This association, characterized by the dominance of *Vulpia membranacea*, grows in the clearings of the dune psammophilous vegetation, in a thermo-Mediterranean dry bioclimatic belt (Table XI, rel. 1–2). This community, widespread in Apulia (Corbetta et al. 1992; Pirone 2014), is related especially to the degradation processes of the



Table XI. *Sileno coloratae-Vulpietum membranaceae* (*Tuberarietea guttatae*).

<b><i>Sileno coloratae-Vulpietum membranaceae</i></b>			
Relevé number	1	2	
Surface (mq)	50	50	
Coverage(%)	95	90	Presence
<b>Char. Ass.</b>			
<i>Silene colorata</i> Poir.	1	+	2
<b>Char. Alkanno-Maresion</b>			
<i>Vulpia fasciculata</i> (Forssk.) Fritsch	4	4	2
<i>Anisantha rigida</i> (Roth) Hyl.	4	3	2
<i>Medicago littoralis</i> Rohde ex Loisel.	1	+	2
<i>Rostraria litorea</i> (All.) Holub	1	1	2
<i>Omonis diffusa</i> Ten.	2	1	2
<b>Char. Helianthemetea guttati</b>			
<i>Silene conica</i> L.	+	+	2
<i>Trifolium campestre</i> Schreb.	+	1	2
<b>Other species</b>			
<i>Lotus commutatus</i> Guss.	1	+	2
<i>Hypochoeris radicata</i> L.	+	+	2
<i>Pancreatum maritimum</i> L.	+	+	2
<i>Euphorbia terracina</i> L.	+		1
<i>Cerastium semidecandrum</i> L.	1		1
<i>Asparagus maritimus</i> (L.) Mill.	+		1
<i>Artemisia campestris</i> L. subsp. <i>variabilis</i> (Ten.) Greuter	+		1
Rel. 1–2, Mouth of the Candelaro river, 12.05.2011			

psammophilous perennial vegetation of dunes and back-dunes (Minissale & Sciandrello 2015). In the study area, it has been observed near the mouth of the Candelaro river.

**Natura 2000 Habitat:** 2230 “*Malcolmietalia* dune grasslands”.

**NERIO OLEANDRI-TAMARICETEA** Br.-Bl. & O.Bolòs 1958

This class includes dwarf woodlands and scrubs communities growing on river beds and temporary flooded areas with fresh, brackish or saline water. In the Mediterranean region, this class includes the order *Tamaricetalia* and seven alliances (Asensi & Díez-Garretas 2011). The plant communities recorded in the study area are dominated by *Tamarix africana* and were referred to the *Tamaricion africanae* alliance. The *Tamarix* populations seem to be favoured by high salt concentrations in water and by a certain level of anthropic pressure (Salinas et al. 2000). In the study area, this vegetation has been observed in the area of Palude di Frattarolo.

**Natura 2000 Habitat:** 92D0 “Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securion tinctoriae*)”.

## Conclusions

The SCI “Zone Umide della Capitanata” hosts a wide diversity of different vegetation types, most of which of relevant conservation value.

All these phytocoenoses are characterized by specific ecological requirements, and their protection implies the monitoring of numerous ecological factors; at the same time, the maintaining of such communities in a favourable conservation status is fundamental for the functionality of these fragile coastal environments.

Numerous anthropogenic pressures and threats affect the site and compromise its integrity. The three main phenomena that best represent the human impacts are:

- reduction of wetlands (mainly due to previous actions of land reclamation) and habitat fragmentation;
- coastal erosion, especially at the mouth of the Ofanto river (alterations in river ecosystems);
- degradation in quality/quantity of water resources (intensive agriculture)

Among the numerous operations of reclamation realized in the area, the most massive, dating back to the last century, resulted in the loss of over 80,000 ha of wetland. The causes of the coastal erosion are mainly related to the alterations of the flow rates of the Ofanto river and to the presence of touristic structures and port facilities. The dramatic decline of the water resources is related both to the intense agricultural activities (catchment), and to a gradual increase in drought events in the area. Also from the point of view of quality, waters are often rich in pollutants (due to the massive use of pesticides and fertilizers) and/or with high salt values.

The crisis in agriculture has caused various forms of environmental degradation, especially related to the dramatic reduction of wetland areas (habitat reduction/fragmentation) and to the degradation of water resources (habitat alteration). So, it should be essential to develop models for an eco-sustainable agriculture, functional to the conservation of natural environments. Other factors which seriously are compromising the integrity of the site are: soil degradation, lowering and/or pollution of the groundwater, variation in

the salinity of the water bodies due to changes in the hydrological regime, grazing, farming, fires, waste water, infrastructure works, channelling and drainage of watercourses.

In conclusion, among the recommendations considered relevant for the management and the conservation of the site, the following actions are here proposed: the creation of a buffer zone around the marshes; a gradual reduction of the intensive agriculture activities in the surrounding areas and, simultaneously, a conversion to sustainable agriculture practices; maintaining of the ground water levels; monitoring of chemical and physical properties of waters; restoration of part of the wetlands reclaimed; an adequate management of pasture; gradual elimination of the exotic flora.

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