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## Updated and new insights on the coastal halophilous vegetation of southeastern Sicily (Italy)







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### Abstract

An overview of the salt marsh vegetation of southeastern Sicily is here presented. On the basis of a total of 241 relevés, 8 classes and 32 plant communities have been identified, following the Braun-Blanquet phytosociological method. The salt marsh vegetation of southeastern Sicily is represented by aquatic communities of *Ruppiaetea* and *Potamogetonetea*, by helophytic communities of *Phragmito-Magnocaricetea*, by hygrophylous communities of *Juncetea maritimi*, by halophylous communities of *Salicornietea fruticosae*, by annual halo-nitrophylous communities of *Saginetea maritimae*, and finally by halophylous annual communities of *Thero-Suaedetea splendentis*. The plant communities belonging to *Salicornietea fruticosae* and *Juncetea maritimi* classes, were analysed through a numerical analysis (hierarchical clustering). The study also describes two new associations belonging to the *Tamaricion africanae* (*Limbarido crithmoidis-Tamaricetum africanae*) and *Frankenion pulverulentae* (*Brizo minoris-Isolepidetum cernui*) alliances.

Key words: cluster analysis, coastal habitat, *Juncetea maritimi*, phytosociology, salt marshes vegetation, *Salicornietea fruticosae*, syntaxonomy.

### Introduction

Coastal salt marshes are depressions flooded during the rainy season and drying out in spring or early summer. These natural habitats are of great interest, especially for the presence of highly specialized plant communities and, in some cases, due to the presence of rare or endangered plant species. Recently these habitats have been facing increasing human pressure by urban, industrial and agricultural development (Spampinato *et al.*, 2007, 2017; Tomaselli *et al.*, 2012). In Sicily, coastal salt marshes are located mainly in: the western sector of the island, between Trapani and Mazara del Vallo; the eastern sector of the island, in the Hyblaean territory, between Gela and Pachino, and along the coastal strip between Siracusa and Catania. Coastal wetlands and saltmarshes are absent along the northern coast of the island, with the exception of the Tindari lagoons. In Sicily coastal salt marshes have undergone extensive reclamation (De Pietro, 2011; Sciandrello *et al.*, 2015) and, at present, only in the south-east of the island there is still a wetland system of great environmental value (Sciandrello *et al.*, 2014).

Although several phytosociological studies have been carried out on the saltmarsh vegetation of southeastern

Sicily (Frei, 1937; Brullo & Furnari, 1971, 1976; Bartolo *et al.*, 1982; Brullo *et al.*, 2000; Sciandrello, 2007; Minissale & Sciandrello, 2010) surveys using hierarchical classification methods are lacking.

The main objectives of this research were: 1. to analyze the plant communities of the salt marshes using hierarchical classification methods; 2. to update the phytosociological knowledge of the salt marsh vegetation of Sicily in the light of recent reviews and compare it with other Mediterranean territories.

### Study area

The coastal marsh areas of south-eastern Sicily (Fig. 1), locally called “Pantani”, were chosen as representative areas for this study. Due to their remarkable naturalistic value, these coastal wetlands are subjected to various conservation measures, as Natural Reserve, Site of Community Importance (SCI), which since 2017 become Special Area of Conservation (SAC), according to Habitat Directive (43/92/EEC) and Special Protection Area (SPA) according to the Birds Directive (2009/147/EC). They are also Important Bird Areas (IBA) according to the Ramsar Convention (1971) and Important Plant Areas (IPA) according to Blasi *et al.* (2011).

Of all the wetlands distributed along the coast of southeastern Sicily, “Oasi Faunistica di Vendicari” is the only one to be a regional nature reserve, while all the other wet areas are only included in the Natura 2000 network protection system (SPA ITA0900029 “Pantani della Sicilia sud-orientale, Morghella, di Marzamemi, di Punta Pilieri e Vendicari”), except for the wetlands of Pozzallo. The reference SACs of the wetlands are the following: ITA090002 “Vendicari” (1,518 ha); ITA090003 “Pantani della Sicilia sud orientale” (1,603 ha); ITA090004 “Pantano Morghella” (263 ha); ITA090005 “Pantano di Marzamemi” (31 ha); ITA090010 “Isola Correnti, Pantani di Punta Pilieri, Chiusa dell’Alga e Parrino” (147 ha).

The climate is typically Mediterranean. According to climatic data of the neighboring thermo-pluviometric station of Cozzo Spadaro (Portopalo, Siracusa), the mean annual temperature is 18 °C with a maximum average of 25 °C in August and a minimum average of 10.2 °C in January. The mean annual precipitation is 400 mm concentrated in autumn and winter (Zampino et al., 1997). According to the bioclimatic classification proposed by Rivas-Martínez (2004), the study area can be referred to the Mediterranean pluviseasonal oceanic bioclimate, with thermotype lower thermomediterranean and ombrotype lower dry (Bazan et al., 2015).

## Materials and Methods

A total of 241 relevés, of which 189 unpublished and 52 from literature (Brullo, 1988; Minissale & Sciandrello, 2010), were analysed. The study followed the Braun-Blanquet phytosociological approach (Braun-Blanquet, 1964; Westhoff & van der Maarel, 1978) according to fundamental and updated concepts recommended by Dengler et al. (2005, 2008), Biondi (2011), Pott (2011). A multivariate analysis (Linkage method: Flexible Beta, Distance measure: Euclidean) was applied only to relevés from *Salicornietea fruticosae* and

*Juncetea maritimi* classes (153 relevés x 53 species), considering that they represent the two most important and representative classes of the salt marshes of the investigated area and the distinction between the different communities is less evident without statistical support, using the PC-ORD 4.34 software. For multivariate analysis purposes, the cover values were transformed according to the method proposed by van Der Maarel (1979). Taxa nomenclature follows Pignatti (2017-2018), while the syntaxa classification follows Biondi et al. (2014) and Mucina et al. (2016). The names of syntaxa comply with the International Code of Phytosociological Nomenclature (ICPN) (Weber et al., 2000). 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 & Blasi, 2009; Biondi et al., 2012).

## Results and discussion

Overall, 32 coastal plant communities were surveyed, belonging to 8 classes (and six habitats), and including two new associations here described. The dominant coastal vegetation belongs to the *Salicornietea fruticosae* class, with seven communities, and the *Juncetea maritimi* class with six plant communities. The results of the cluster analysis (Fig. 2) applied to the two most significant and complex classes of the saltmarsh vegetation (*Juncetea maritimi* and *Salicornietea fruticosae*) are partially in agreement with the syntaxonomic scheme proposed by Mucina et al. (2016). In fact, the halo-nitrophilous perennial communities of the *Inulion crithmoidis* alliance, traditionally framed in the *Salicornietea fruticosae* class, segregate in the *Juncetea maritimi* class. Nevertheless, whereas Mucina et al. (2016) consider *Inulion crithmoidis* synonym of the *Juncion maritimi* alliance, our results clearly show a division of the *Juncetea maritimi* class into three alliances (Fig. 2) and allow us to re-evaluate the alliance described by Brullo & Furnari (1988): the first groups the halo-nitrophilous plant communities (*Inulion crithmoidis*); the second includes the communities of the sandy soils (*Plantaginion crassifoliae*); the third alliance groups the communities subjected to prolonged flooding (*Juncion maritimi*). The coastal plant communities are reported in the syntaxonomic scheme. Each association is examined from the nomenclatural, floristic, ecological, chorological and syndynamic viewpoint.

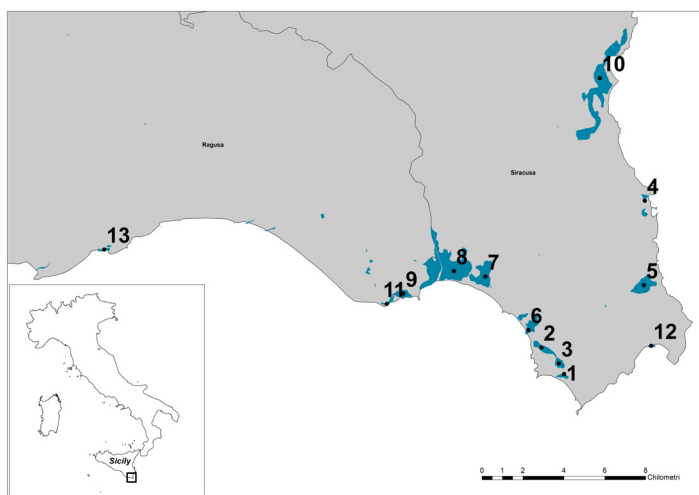


Fig. 1 - Study area. Numbers indicate the salt marshes: 1. Pantano Ponterio, 2. P. Baronello, 3. P. Ciaramiraro, 4. P. Marzamemi, 5. P. Morghella, 6. P. Auruca, 7. P. Cuba, 8. P. Longarini, 9. P. Bruno, 10. P. Vendicari, 11. Gorgo Salato, 12. P. Cannone, 13. P. Pozzallo.

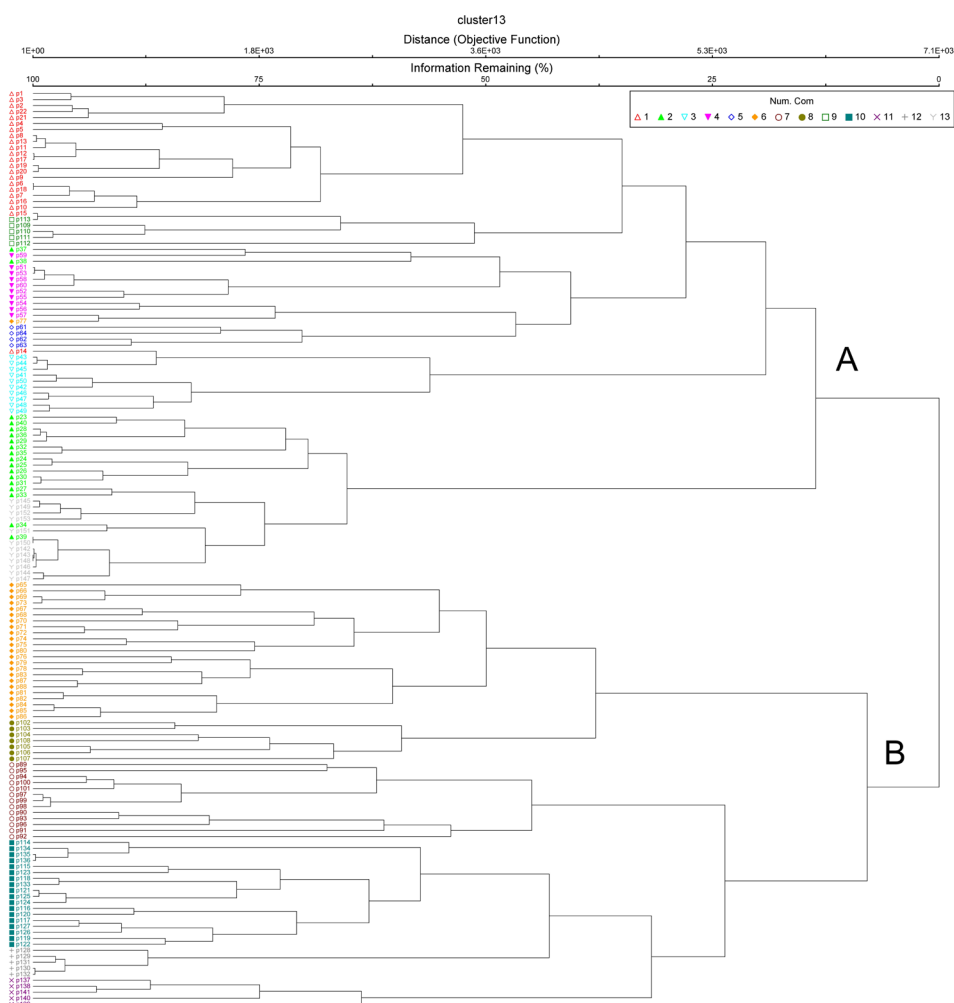


Fig. 2 - Cluster analysis of the *Salicornietea fruticosae* class (A) and *Juncetea maritimi* class (B). Plant communities: 1. *Arthrocaulo meridionalis*-*Juncetum subulati*; 2. *Junco subulati*-*Sarcocornietum alpini*; 3. *Junco subulati*-*Sarcocornietum fruticosae*; 4. *Halimiono portulacoidis*-*Sarcocornietum alpini*; 5. *Halimiono-Suaedetum verae*; 6. *Agropyro scirpei*-*Inuletum crithmoidis*; 7. *Schoeno-Plantagnetum crassifoliae*; 8. *Limonio virgati*-*Juncetum acuti*; 9. *Juncetum subulati*; 10. *Inulo crithmoidis*-*Juncetum maritimi*; 11. *Junco maritimi*-*Spartinetum junceae*; 12. *Junco maritimi*-*Caricetum extensae*; 13. *Aeluropo lagopoidis*-*Sarcocornietum alpini*.

#### ***Aquatic halophilous cormophyte communities***

(*Ruppiaetea maritimae* J. Tx. ex Den Hartog et Segal 1964) Tab. 1

The salt-tolerant plant communities growing in shallow waters of saltmarshes belong to the *Ruppiaetea maritimae* class. The plant communities recorded fall into the *Ruppion maritimae* alliance that includes the halo-hydrophytic communities of brackish water (Tomaselli & Sciandrello, 2017). In salt marshes of southern Sicily, the associations *Enteromorpha intestinalidis*-*Ruppiaetea maritimae* and *Ruppiaetea spiralis* (*Ruppion maritimae*) have been observed. *Enteromorpha intestinalidis*-*Ruppiaetea maritimae* is distributed in brackish, more or less deep waters, and is dominated by *Ruppia maritima*, which sometimes is associated with green algae, such as *Enteromorpha intestinalis* and *Chara* sp. pl. (Sciandrello *et al.*, 2014). In the study area this vegetation is favoured by the presence of waters rich in nitrates originating from the agricul-

tural activities in the surrounding areas. *Ruppiaetea spiralis*, characterized by *Ruppia spiralis* and *Althenia filiformis*, much rare and localized, replaces the *Enteromorpha-Ruppiaetea maritimae* in the brackish marshes with shallow waters normally subject to summer drying, showing a more thermophilous character. Natura 2000 Habitat: 1130 "Estuaries" and 1150\* "Coastal lagoons".

#### ***Aquatic cormophyte communities***

(*Potametea* Klika in Klika & Novak 1941)

This 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 association observed in the study area is *Potametum pectinati*, a submerged vegetation dominated by rooted macrophytes (Bartolo *et al.* 1982). *Potametum pectinati* tolerates waters poor in O<sub>2</sub> and rich in phosphates and nitro-

Tab. 1 - *Enteromorpha intestinalidis-Ruppium maritimum* (rels.1, 6-7), *Ruppium spiralis* (rels.2-5).

Relev. Nr.	1	2	3	4	5	6	7	Presence
Area (m <sup>2</sup> )	4	20	20	10	10	10	10	
Cover (%)	90	90	80	90	100	90	85	
Diagnostic species								
<i>Ruppia cirrhosa</i> (Petagna) Grande	.	5	3	4	5	.	.	4
<i>Enteromorpha intestinalis</i> (L.) Nees	1	+	+	.	.	+	1	5
<i>Ruppia maritima</i>								
<i>Ruppia maritima</i> L.	5	.	.	1	1	4	4	5
Other species								
<i>Althenia filiformis</i> Petit	.	1	1	2	1	.	.	4
<i>Lamprolaminum papulosum</i> (Wallroth) J.	.	.	.	1	+	.	.	2
Groves	.	.	.	.	.	.	.	.
<i>Chara</i> sp.	.	+	1	.	.	.	.	2

gen, from eutrophic to hypertrophic and its presence is an indicator of organic pollution (Brullo & Sciandrello, 2006; Lastrucci et al., 2014). In the study area, this aquatic community is essentially monospecific with high coverage values of *Potamogeton pectinatus*, therefore it was considered useless to propose a phytosociological table. Natura 2000 Habitat: 1150\* "Coastal lagoons".

### Helophytic communities

(*Phragmito-Magnocaricetea* Klika in Klika & Novák 1941) Tab. 2

This class groups the helophytic communities colonizing marshes, fens and fluvial areas, with brackish or fresh, eutrophic or meso-oligotrophic waters. *Phragmito-Magnocaricetea*, in the study area, is represented by the three alliances *Phragmition communis* (including the subhalophilous reed communities), *Magnocaricion* (communities of mesotrophic to dystrophic soils flooded for prolonged periods) and *Scirpion compacti* (that groups the hygrophilous marsh communities of brackish waters). The associations

Tab. 2 - *Scirpo compacti-Juncetum subulati* (rels. 1-7).

Relev. Nr.	1	2	3	4	5	6	7	Presence
Area (m <sup>2</sup> )	40	50	50	8	40	10	20	
Cover (%)	100	100	100	90	100	100	100	
Diagnostic species								
<i>Juncus subulatus</i> Forssk.	1	+	2	+	1	2	3	7
<i>Phragmito-Magocaricetea</i>								
<i>Bolboschoenus maritimus</i> (L.) Palla var. <i>compactus</i>	5	4	4	5	5	5	3	7
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	.	+	+	.	+	.	.	3
Transgressive species from <i>Salicornietea fruticosae</i>								
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez	.	+	+	1	.	.	.	3
<i>Arthrocaulon meridionalis</i> Ramirez, Rufo, Sánchez-Mata & de La Fuente	.	.	+	.	.	2	.	2
<i>Sarcocornia fruticosa</i> (L.) A. J. Scott	.	.	.	.	1	2	2	
<i>Halimione portulacoides</i> (L.) Aellen	.	+	.	.	.	.	.	1
<i>Limonium narbonense</i> Mill.	.	.	.	.	.	1	.	1
Other species								
<i>Limbarda crithmoides</i> (L.) Dumort.	1	.	.	.	.	.	.	1
<i>Polypogon monspeliensis</i> (L.) Desf.	+	.	.	.	.	+	.	2
<i>Juncus maritimus</i> Lam.	.	1	.	.	.	.	.	1
<i>Lythrum junceum</i> Banks & Solander	+	.	.	.	.	.	.	1
<i>Medicago ciliaris</i> (L.) All.	.	.	.	+	.	.	.	1
<i>Cressa cretica</i> L.	.	.	.	.	.	1	.	1

observed in the area are hereafter listed and described. *Phragmitetum communis*, characterized by the dominance of *Phragmites australis*, is widely distributed in the wetlands of central and southern Italy (Minisale & Spampinato, 1986; Maiorca et al., 2002, 2007; Pavone et al., 2007; Tomaselli & Sciandrello, 2017). It is widespread in the whole study area, already reported by Bartolo et al. (1982); in particular, it forms wide and dense stands in many salt marshes of south-eastern Sicily. 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. *Scirpo compacti-Juncetum subulati* (Tab. 2) grows 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*. This sub-halophilous vegetation, that has a wide western Mediterranean distribution (Rivas-Martinez et al., 2001; Brullo & Sciandrello, 2006), covers large areas in some salt marshes of southern Sicily. *Scirpetum compacti*, reported by Bartolo et al. (1982), prefers soils with higher concentrations of salt and more humid in the summer. This halophilous vegetation is characterized by the dominance of *Bolboschoenus maritimus* var. *compactus*. Furthermore, in the study area, the following communities were reported by Bartolo et al. (1982): *Scirpo lacustris-Phragmitetum australis* and *Caricetum hispidae*.

### Sub-halophilous perennial grasslands

(*Juncetea maritimi* Br.-Bl. in Br.-Bl. et al. 1952)

Tabs. 3, 4, 5

The perennial herbaceous vegetation dominated by tall rushes and sedges 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: *Inulion crithmoidis* (communities of halomorphic soils rarely subjected to submersion), *Juncion maritimi* (*Juncus*-dominated communities that develop on soils with a prolonged flooding regime), and *Plantaginion crassifoliae* (*Plantago crassifolia*-dominated communities that develop on sand soils in the margins of lagoons and damp dune-slacks). In the study area, six associations (*Limonio virgati-Juncetum acuti*, *Junco maritimi-Caricetum extensae*, *Limbarido crithmoidis-Juncetum maritimi*, *Junco maritimi-Spartinetum junceae*, *Agropyro scirpei-Inuletum crithmoidis*, *Schoeno-Plantaginietum crassifoliae*) were identified. *Limonio virgati-Juncetum acuti* is distributed in back dune areas, on sand-silty soils rich in salt periodically flooded, and is dominated by *Juncus acutus* and *Limonium virgatum* (Tab. 3). This association is widely widespread along

Tab. 3 - *Schoeno-Plantaginietum crassifoliae* (rels. 1-13), *Limonio virgati-Juncetum acuti* (rels. 14-18, 48, 53).

Cluster Nr.	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	Presence	
Relev. Nr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	48	53		
Area (m <sup>2</sup> )	10	50	50	10	30	50	40	30	50	20	50	20	10	10	50	50	30	30	50	20		
Cover (%)	90	90	95	100	100	100	100	100	70	70	90	80	90	100	90	85	100	100	100	100		
Diagnostic species																						
<i>Plantago crassifolia</i> Forssk.	2	4	2	4	5	4	4	4	4	3	4	4	3	.	.	.	+	.	+	.	15	
<i>Juncus acutus</i> L.	.	3	2	.	3	.	.	3	.	.	.	.	.	4	4	4	5	4	4	4	11	
<i>Juncetea maritimi</i>																						
<i>Limbarda crithmoides</i> (L.) Dumort.	+	2	1	+	1	.	+	2	.	.	.	.	.	2	2	1	2	2	3	3	14	
<i>Schoenus nigricans</i> L.	4	1	4	.	.	2	1	.	1	3	2	1	4	+	1	.	.	.	.	.	12	
<i>Juncus maritimus</i> Lam.	3	.	.	.	.	1	2	1	.	.	.	+	1	.	.	.	+	2	.	1	9	
<i>Carex extensa</i> Good.	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.	.	1	2	.	.	4	
<i>Panicum repens</i> L.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	3	
<i>Spartina versicolor</i> Fabre	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	
Transgressive species from <i>Salicornietea fruticosae</i>																						
<i>Limonium narbonense</i> Mill.	.	2	1	2	1	+	+	1	.	.	.	.	.	+	+	2	2	2	2	1	14	
<i>Limonium virgatum</i> (Willd.) Fourr.	.	.	.	.	.	1	2	+	1	+	1	1	2	+	1	+	1	1	1	.	14	
<i>Elytrigia scirpea</i> (C. Presl.) Holub	.	.	.	2	.	.	+	.	.	.	.	.	.	1	2	1	1	+	.	+	8	
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	3
<i>Juncus subulatus</i> Forssk.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	3
Arthrocaulon meridionalis Ramirez, Rufo, Sánchez-Mata & de La Fuente	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	2	
<i>Halimione portulacoides</i> (L.) Aellen	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	
<i>Aeluropus lagopoides</i> (L.) Trin. ex Thwaites	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	
<i>Suaeda vera</i> J.F. Gmel.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1
Other species																						
<i>Medicago ciliaris</i> (L.) All.	.	.	.	+	.	1	.	1	.	.	.	.	.	.	.	.	.	+	.	.	4	
<i>Daucus carota</i> L. subsp. maritimus (Lam.) Batt.	.	+	+	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	4	
<i>Dittrichia viscosa</i> (L.) Greuter	.	+	+	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	4	
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	.	+	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	3	
<i>Parapholis filiformis</i> (Roth) C. E. Hubb.	.	.	.	.	.	+	.	.	.	.	.	.	.	1	+	.	.	.	.	.	3	
<i>Polygomon monspeliensis</i> (L.) Desf.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	+	3
<i>Sonchus bulbosus</i> (L.) Kilian & Greuter	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	3	
<i>Sporobolus virginicus</i> (L.) Kunth	.	.	.	.	.	.	.	1	1	.	+	.	.	.	.	.	.	.	.	.	3	
<i>Sagina maritima</i> Don	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	3	
<i>Melilotus siculus</i> (Turra) All.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	2
<i>Lotus preslii</i> Ten.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	+	.	2
<i>Centaurium tenuiflorum</i> subsp. acutiflorum (Schott) Zeltner	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
<i>Briza minor</i> L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1
<i>Cressa cretica</i> L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1
<i>Oxalis pes-caprae</i> L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
<i>Suaeda spicata</i> (Willd.) Moq.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1
<i>Asparagus acutifolius</i> L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1
<i>Blackstonia acuminata</i> (W. D. J. Koch & Ziz) Domin	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1
<i>Centaurium spicatum</i> (L.) Fritsch	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1
<i>Atriplex prostrata</i> Boucher ex DC. subsp. latifolia (Wahlenb.) Rauschert	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1
<i>Cynodon dactylon</i> (L.) Pers.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
<i>Piptatherum miliaceum</i> (L.) Coss.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1

the coastal environments of the Italian peninsula, even if it is often subjected to various pressures and disturbance factors determining alterations in its structure and floristic composition (Frondoni & Iberite, 2002; Sciandrello *et al.*, 2014). *Agropyro scirpei-Inuletum crithmoidis* 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 *Thinopyrum elongatum* and many other halophytes (Tab. 5). *Juncus maritimi-Caricetum extensae*, dominated by *Carex extensa* and *Juncus maritimus*, replaces the *Limonio*

*virgati-Juncetum acuti* in areas subject to prolonged flooding periods and loamy soils (Tab. 4). *Limbarda crithmoidis-Juncetum maritimi*, dominated by *Limbarda crithmoides* and *Juncus maritimus*, replaces the *Limonio virgati-Juncetum acuti* in areas subject to prolonged flooding periods and loamy-clayey soils (Tab. 4). *Juncus maritimi-Spartinetum junceae* prefers the upper zone of salt marshes with sandy soils, where it forms a monospecific vegetation characterized by *Spartina versicolor*, often associated with *Juncus maritimus* (Tab. 4) and usually in catenal contact with the psammophilous communities of *Ammophiletea*



Tab. 5 - *Agropyro scirpei-Inuletum crithmoidis* (rels. 58-81).

Cluster Nr.	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	Presence
Relev. Nr.	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	
Area (m <sup>2</sup> )	50	10	5	5	40	50	50	20	50	10	100	20	30	30	30	30	100	100	50	30	20	30	50	50	
Cover (%)	90	100	100	100	100	95	100	95	90	100	100	100	100	100	100	100	100	100	100	100	90	100	90	100	
Diagnostic species																									
Limbarda crithmoides (L.) Dumort.	5	4	4	4	4	4	5	4	4	5	4	4	4	4	4	4	3	4	3	4	3	2	4	4	24
Elytrigia scirpea (C. Presl.) Holub	3	2	2	1	1	+	2	1	2	+	+	2	1	3	1	.	2	2	3	2	2	3	+	1	23
<i>Juncetea maritimi</i>																									
Juncus acutus L.	2	2	.	.	2	.	+	.	1	.	+	.	.	.	.	+	1	2	.	.	1	.	.	.	10
Juncus maritimus Lam.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	2	+	.	1	+	2	.	+	8
Plantago crassifolia Forssk.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.	2
Spartina versicolor Fabre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1
Transgressive species from <i>Salicornietea fruticosae</i>																									
Limonium narbonense Mill.	2	2	.	.	1	.	.	.	+	+	+	2	1	2	1	1	2	2	2	+	+	+	3	2	19
Arthrocaulon meridionalis Ramirez, Rufo, Sánchez-Mata & de La Fuente	+	+	1	.	+	.	.	.	+	.	.	.	.	1	2	1	2	2	+	1	1	1	+	2	16
Halimione portulacoides (L.) Aellen	.	.	.	.	.	.	.	.	1	1	2	2	2	2	.	2	1	2	+	+	1	1	2	14	
Juncus subulatus Forssk.	.	+	.	1	2	1	1	1	.	1	2	.	.	2	.	.	.	1	.	.	.	.	.	.	10
Sarcocornia alpini (Lag.) Rivas Martinez	+	.	2	1	+	+	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	7
Limonium virgatum (Willd.) Fourr.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	.	+	+	.	.	5
Aeluropus lagopoides (L.) Trin. ex Thwaites	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1
Suaeda vera J.F. Gmel.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
Other species																									
Phragmites australis (Cav.) Trin. ex Steud.	.	.	2	.	1	.	.	.	.	2	.	+	.	.	.	.	+	.	.	+	.	+	.	+	8
Medicago ciliaris (L.) All.	+	.	.	.	.	.	.	.	.	+	1	1	+	.	.	+	.	.	.	.	.	.	.	.	6
Polygomon monspeliensis (L.) Desf.	.	.	.	+	+	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Parapholis filiformis (Roth) C. E. Hubb.	1	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Melilotus siculus (Turra) All.	+	.	.	.	.	+	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	4
Sonchus bulbosus (L.) Kilian & Greuter	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	2
Lotus preslii Ten.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	2
Tamarix africana Poir.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	2
Bolboschoenus maritimus (L.) Palla var. compactus	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	2
Briza minor L.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Cressa cretica L.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	2
Lythrum junceum Banks & Solander	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	2
Daucus carota L. subsp. maritimus (Lam.) Batt.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Oxalis pes-caprae L.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1
Salsola soda L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Blackstonia acuminata (W. D. J. Koch & Ziz) Domin	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Centaurium spicatum (L.) Fritsch	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1

Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946 class (*Sciandrello et al.*, 2014, *Tomaselli et al.*, 2011). In the salt marshes of southern Sicily this vegetation is very rare and localized (Pantano Baronello and Pantano Bruno). *Schoeno-Plantaginetum crassifoliae* grows in the outer parts of the salt marshes on sandy-clayey soils, behaving as a transition belt between the halophilous vegetation of *Salicornietea fruticosae* and the psammophilous communities of *Ammophiletea*. It is characterized by the dominance of *Schoenus nigricans* and *Plantago crassifolia* (Tab. 3). This vegetation is very localized and covers small areas in some salt marshes of southern Sicily (Pantano Auruca, P. Longarini, P. Ponterio, Gorgo Salato and Vendicari). Natura 2000 Habitat: 1410 "Mediterranean salt meadows (*Juncetalia maritimi*)".

**Halophylous succulent dwarf shrubs communities** (*Salicornietea fruticosae* Br.-Bl. et Tx. ex A. Bolòs y Vayreda et. O. de Bolòs in A. Bolòs et Vayreda 1950) Tabs. 6, 7, 8

The *Salicornietea fruticosae* class includes halophilous shrub plant communities of both coastal and inland areas, developing on halomorphic soils of salt marshes, estuaries, coastal lagoons (*Sciandrello & Tomaselli*, 2014). This vegetation is characterized by succulent *Chenopodiaceae* with a chamaephytic or nanophanerophytic habitus. In the salt marshes of southern Sicily, seven associations were identified (*Junco subulati-Sarcocornietum alpini*, *Aeluropo lagopoidis-Sarcocornietum alpini*, *Halimiono portulacoidis-Sarcocornietum alpini*, *Juncetum subulati*, *Arthrocaulo meridionalis-Juncetum subulati*, *Junco subulati-Sarcocornietum fruticosae*, *Halimiono-Suaedetum verae*), belonging to the following alliances: *Sarcocornion fruticosae* (halophilous shrub plant communities, subject to periodic flooding and dominated by *Sarcocornia fruticosa* and *Sarcocornia alpini*), *Arthrocnemion glauci* [hyper-halophilous shrub plant communities subject to periodic flooding and dominated by *Arthrocaulon meridionalis* (= *Arthrocnemum macrostachyum*), *Suaedion verae* (halo-nitrophilous shrub communities)]. *Junco sub-*







Tab. 9 - *Salsolium soda* (rels. 1-4, 16-20), *Atriplici salinae-Suaedetum emericum* (rels. 5-11, 23-25, 30-34), *Salicornietum emericum* (rels. 12-13, 21-22), *Cressetum creticae* (rels. 14-15), *Suaedo-Salicornietum patulae* (rels. 26-29, 35-39).

Relev. Nr.	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	29	30	31	32	33	34	35	36	37	38	39	
Suaeda spicata (Willd.) Moq.																																								
Salsola soda L.																																								
Cressa cretica L.																																								
Salicornia emericum Duval-Jouve																																								
<i>Thero-Suaedetum splendidum</i>																																								
Salicornia patula Duval-Jouve																																								
Salicornia dolichostachya Moss																																								
Transgressive species from <i>Salicornietum fruticosae</i>																																								
Arthrocoleum meridionale Ramirez, Rufo, Sánchez-Mata & de La Fuente																																								
Sarcocornia alpina (Lag.) Rivas Martínez																																								
Limbarda erithimoides (L.) Dumort.																																								
Sarcocornia fruticosa (L.) A. J. Scott																																								
Other species																																								
Atriplex prostrata Boucher ex DC. subsp. latifolia (Wahlenb.) Rauschert					1																																			
Phragmites australis (Cav.) Trin. ex Steud.																																								
Spergularia salina J. & C. Presl																																								
Bolboschoenus maritimus (L.) Palla var. compactus																																								
Juncus subulatus Forsk.																																								
Medicago ciliaris (L.) All.																																								
Juncus subulatus Forsk.																																								
Juncus maritimus Lam.																																								
Symphytotrichum squamatum (Spreng.) G.L. Nesom																																								

marshes, rarely subject to flooding. This association has halo-sub-nitrophilous requirements, grows on clay-silty soils and forms dense communities dominated by *Suaeda vera* and *Halimione portulacoides* (Tab. 8). Natura 2000 Habitat: 1420 “Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornietea fruticosi*)”.

**Therophytic succulent plant communities**  
(*Thero-Salicornietea* Tx. in Tx. et Oberd. 1958)  
Tab. 9

This class includes the annual halophilous or halo-nitrophilous vegetation of brackish and salt marshes, with optimum growing season in late summer-autumn (Biondi & Casavecchia, 2010; Biondi et al., 2014, Tomaselli et al., 2020) and is characterized by succulent therophytes belonging to the family *Chenopodiaceae*. The class, according to Biondi et al. (2014), is represented by the two orders: *Thero-Salicornietalia*, typical of areas subject to long flooding periods and including the alliance *Salicornion patulae*, and *Thero-Suaedetalia splendida*, including the halo-subnitrophilous communities of the *Thero-Suaedion splendida* alliance. Five associations have been here identified (*Suaedo-Salicornietum patulae*, *Salicornietum emericum*, *Salsolium soda*, *Atriplici salinae-Suaedetum spicatae*, *Cressetum creticae*), belonging both to the *Thero-Salicornietalia* and *Thero-Suaedetalia splendida* orders. *Suaedo maritima*-*Salicornietum patulae*, develops in the central part of the salt marshes subject to long periods of submersion. It begins developing in early summer when the surfaces are already dried but the soil still remains moist in depth. It is a thermo-xerophilous community characterized by the dominance of *Salicornia patula* that forms scattered populations together with other succulent therophytes, such as *Suaeda spicata*, *Salsola soda*, etc. *Salicornietum emericum*, characterized by the dominance of *Salicornia emericum*, forms more or less dense and almost monospecific plant communities. It differs from the *Suaedo maritima*-*Salicornietum patulae*, for both the dominance of *Salicornia emericum*, and for the ecology, as it is linked to very wet soils, flooded for longer periods and muddy even during the summer period. *Salsolium soda* is a thermo-xerophilous association characterized by *Salsola soda* that usually forms almost monospecific communities; it grows on halomorphic, well drained soils rich in nitrates or organic material (Biondi & Bagella, 2005). *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*). *Cressetum creticae* is a halo-subnitrophilous and termophilous vegetation type, characterized by *Cressa cretica*, often



silty soils subject to short flooding periods (Brullo & Giusso, 2003). *Brizo minoris-Isolepidetum cernui* is an annual spring vegetation type growing on sandy or clayey-silty soils and subject to periodic flooding. It is in catenal contact with the sub-halophilous plant communities of the *Inulo-Juncetum maritimi* or *Juncetum maritimi-Caricetum extensae* (*Juncetea maritimi*). This halo-nitrophilous vegetation is characterized by the dominance of *Isolepis cernua*, a small plant belonging to the *Cyperaceae* family, which grows together with several sub-halo-nitrophilous species of *Saginetea maritimae*, such as *Juncus hybridus*, *J. ambiguus*, *J. foliosus*, *Blackstonia acuminata*, *Polypogon monspeliensis*, *Plantago coronopus*, *Parapholis filiformis*, *Briza minor* ect. For its floristic peculiarity, this community is here proposed as a new association, named *Brizo minoris-Isolepidetum cernui* ass. nova (*Holotypus*: rel. 7, Tab. 10 this paper). For its floristic set *Brizo minoris-Isolepidetum cernui* shows some relations with the *Isolepido-Saginetum maritimae*, association described by Brullo (1988) for Vendicari, found within the communities belonging to *Schoeno-Plantaginetum crassifoliae*. It is characterized by less hygrophilous species, such as *Sagina maritima*, *Parapholis filiformis*, *P. incurva*. Natura 2000 Habitat: 1310 “Salicornia and other annuals colonizing mud and sand”.

**Dwarf woodlands, scrubs permanent communities** (*Nerio-Tamaricetea* Br.-Bl. & O. Bolós 1958) Tab. 11

The class includes the halophilous vegetation characterized by *Tamarix* species of the intermittent/permanent water courses and coastal wetlands. This vegetation is typical of the thermo-Mediterranean thermotype, occa-

sionally occurring in the meso-Mediterranean thermotype (Brullo & Spampinato, 1997; Biondi et al., 2014).

Traditionally, one order (*Tamaricetalia*) and four alliances have been distinguished in the Mediterranean region (Asensi & Diez-Garretas, 2011): *Tamaricion africanae* Br.-Bl. & O. Bolós 1958 (fresh water and brackish waters), *Tamaricion boveano-canariensis* (brackish water), *Imperato cylindricae-Saccharion ravennae* Br.-Bl. & O. Bolós 1958 (communities of tall grasses) and *Rubo ulmifolii-Nerion oleandri* Bolós 1985 (oleander or chaste tree communities developing on stony and sandy streambeds). The plant communities recorded in the saltmarshes of southeastern Sicily are dominated by *Tamarix africana* and were referred to the *Tamaricion africanae* alliance, that groups communities developing on water courses and coastal wetlands (Brullo & Sciandrello, 2006). This halophilous woody vegetation develops along the edges of salt marshes, subjected to long periods of submersion and characterized by mainly silty soils. Physiognomically, it is characterized by *Tamarix africana* and some halophilous species of the *Salicornietea fruticosae*, such as *Elytrigia scirpea*, *Sarcocornia alpini*, *Arthrocaulon meridionalis*, *Halimione portulacoides*, ect. *Limbarido crithmoides* is here identified as diagnostic halophilous species of a new association, with the name *Limbarido crithmoidis-Tamaricetum africanae* ass. nova (*Holotypus*: rel. 4, Tab. 11 this paper). It is in catenal contact with the halophilous vegetation of the *Salicornietea fruticosae* or sub-halophilous plant communities of the *Juncetea maritimi*. Natura 2000 Habitat: 92D0 “Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)”.

Tab. 11 - *Limbarido crithmoidis-Tamaricetum africanae* ass. nova

Relev. Nr.	1	2	3	4*	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Presence	
Area (m <sup>2</sup> )	10	20	40	50	50	50	50	50	20	20	20	20	20	20	20	20	20	20		
Cover (%)	90	95	95	80	90	90	90	90	100	100	100	100	80	80	100	80	80	85		
<b>Diagnostic species</b>																				
<i>Limbarido crithmoides</i> (L.) Dumort.	3	2	1	2	1	2	1	+	2	1	1	+	+	+	+	2	1	+	18	
<b><i>Nerio-Tamaricetea</i></b>																				
<i>Tamarix africana</i> Poir.	4	3	5	4	5	5	4	4	3	4	4	4	3	4	4	3	3	3	18	
<i>Tamarix gallica</i> L.	.	.	.	+	.	1	.	2	.	.	+	+	+	.	.	.	.	.	6	
<b>Transgressive species from <i>Salicornietea fruticosae</i></b>																				
<i>Sarcocornia alpini</i> (Lag.) Rivas Martinez	1	+	.	1	+	.	.	+	.	.	.	.	1	.	+	+	1	2	10	
<i>Halimione portulacoides</i> (L.) Aellen	.	.	.	1	.	+	.	1	+	2	3	2	3	.	.	.	.	.	8	
<i>Elytrigia scirpea</i> (C. Presl.) Holub	+	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	6	
<i>Arthrocaulon meridionalis</i> Ramirez, Rufo, Sánchez-Mata & de La Fuente	2	.	.	+	.	.	.	2	.	.	.	.	.	.	+	.	.	+	6	
<i>Juncus subulatus</i> Forssk.	.	.	1	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	3	
<b>Other species</b>																				
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	.	1	+	.	.	1	+	.	.	.	.	.	.	1	.	.	.	.	5	
<i>Atriplex prostrata</i> Boucher ex DC. subsp. <i>latifolia</i> (Wahlenb.) Rauschert	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	5	
<i>Centaurea sphaerocephala</i> L.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	3	
<i>Juncus maritimus</i> Lam.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	2	
<i>Carex extensa</i> Good.	.	.	.	.	.	2	+	.	.	.	.	.	.	.	.	.	.	.	2	
<i>Spartina versicolor</i> Fabre	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1	
<i>Sonchus bulbosus</i> (L.) Kilian & Greuter	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	
<i>Arundo donax</i> L.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	
<i>Bolboschoenus maritimus</i> (L.) Palla	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	
<i>Cynodon dactylon</i> (L.) Pers.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	
<i>Imperata cylindrica</i> (L.) Rausch.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	
<i>Parapholis filiformis</i> (Roth) C. E. Hubb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	
<i>Suaeda spicata</i> (Willd.) Moq.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	

## Conclusion

The study of the plant communities with the phytosociological method is basic for detecting and assessing the habitats of conservation interest in line with the objectives of the European Habitats Directive 92/43/EEC (Biondi *et al.*, 2012; European Commission, 2013; Gigante *et al.*, 2016; Angiolini *et al.*, 2017; Tomaselli *et al.*, 2017). The present study allowed us to identify six habitats well-typified in terms of their floristic composition and structure [1130 “Estuaries”, 1150\* “Coastal lagoons”, 1410 “Mediterranean salt meadows (*Juncetalia maritimi*)”, 1420 “Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornietea fruticosi*)”, 1310 “Salicornia and other annuals colonizing mud and sand”, 92D0 “Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)”].

In addition, the study reports two new associations for Sicily: the first one is *Brizo minoris-Isolepidetum cernui* (*Saginetea maritimae*), the second one *Limbarido crithmoidis-Tamaricetum africanae* (*Nerio-Tamaricetea*). We also reported, for the first time in Sicily, both the *Juncus maritimi-Caricetum extensae*, hemicriptophytic grassland dominated by *Juncus maritimus* and *Carex extensa*, widespread in Corsica, Sardinia and Apulia (Biondi, 1992; Géhu & Biondi, 1995; Sciandrello & Tomaselli, 2014) and the *Scirpo compacti-Juncetum subulati*, described by Géhu *et al.* (1992) for the wetland of Camargue, south of Arles (France), and known also from Corsica, Sardinia, the Adriatic coast (Géhu & Biondi, 1994, 1996; Filigheddu *et al.*, 2000, Sciandrello & Tomaselli, 2014) and Calabria (Maiorca *et al.*, 2007).

From a phytosociological point of view, the salt marsh communities of Sicily show a remarkable autonomy, as evidenced by several vicariant taxa, such as *Arthrocaulon meridionalis*, *Sarcocornia alpini*, *Aeluropus lagopoides*, *Elytrigia scirpea*, *Halocnemum cruciatum*, *Limonium pachynense*, and *Triglochin bulbosa* subsp. *barrelieri* (Bacchetta *et al.*, 2012; de La Fuente *et al.*, 2013; Biondi *et al.*, 2013; Sciandrello & Tomaselli, 2014; Ramírez *et al.*, 2019). The floristic composition analysis of the Sicilian halophilous vegetation highlights, in fact, phylogeographic differences between the central Mediterranean area, with a xeric climate, and the northern Mediterranean, influenced by a temperate climate (Sciandrello *et al.*, 2014). Furthermore, our study confirms the disappearance of some syntaxa, recorded in the past for the salt marshes of south-eastern Sicily and no longer found to date, due to reclamation activities started in the years 1970-80 to recover surfaces for agriculture, mainly vineyards and then greenhouse crops. Some examples are the *Soncho-Cladietum marisci* reported by Bartolo *et al.* (1982) for Pantano Arezzi (Marina di Marza), which formed dense populations in the central part of the salt marsh, and *Halopeplidetum amplexicaulis*, reported by Brullo & Furnari (1976) for Pantano Ciaramiraro and P. Longarini. Together with these plant communities, some diagnostic and rare species have disappeared in saltmarshes of southeastern Sicily, such as *Halopeplis amplexicaulis* (Vahl) Ces., a very rare halophilous annual species in Sicily, and *Linum maritimum*, species known only for Pantano Arezzi. In conclusion, this alarming scenery highlights how important are the activities of habitat monitoring, in order to preserve plant communities and rare and threatened species.

## Syntaxonomic scheme

RUPPIETEA MARITIMAE J. Tx. ex Den Hartog et Segal 1964

*RUPPIETALIA* J. Tx. ex Den Hartog et Segal 1964

**Ruppion maritimae** Br.-Bl. ex Westhoff in Bennema *et al.* 1943

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

*Ruppium spiralis* Hocquette 1927 corr. Iversen 1934

POTAMOGETONETEA Klika in Klika et Novak 1941

*POTAMOGETONETALIA* Koch 1926

**Potamogetonion** Libbert 1931

*Potametum pectinati* Cartensen 1955

PHRAGMITO-MAGNOCARICETEA Klika in Klika & Novák 1941

*PHRAGMITETALIA* Koch 1926

**Phragmition communis** Koch 1926

*Phragmitetum communis* (W. Koch 1926) Schmale 1939

*Scirpo lacustris-Phragmitetum australis* Koch 1926

*MAGNOCARICETALIA PIGNATTI* 1954

**Magnocaricion elatae** Koch 1926

*Caricetum hispidae* Brullo & Ronsisvalle 1975

*SCIRPETALIA COMPACTI* Heijný in Holub, Heijný, Moravec et Neuhäusl 1967 corr. Rivas-Martínez, Costa, Castroviejo et E. Valdés 1980

**Scirpion compacti** Dahl & Hadač 1941 corr. Rivas-Martínez et al. 1980

*Scirpetum compacti* Van Langendonck 1931 corr. Bueno et F. Prieto in Bueno 1997

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

JUNCETEA MARITIMI Br.-Bl. in Br.-Bl. et al. 1952

*JUNCETALIA MARITIMI* Br.Bl. ex Horvatic 1934

**Inulion crithmoidis** Brullo et Furnari 1988

*Limonio virgati-Juncetum acuti* Brullo et Di Martino ex Brullo et Furnari 1976

*Agropyro scirpei-Inuletum crithmoidis* Brullo in Brullo et al. 1988

**Juncion maritimi** Br.Bl. ex Horvatic 1934

*Junco maritimi-Caricetum extensae* Géhu 1976

*Junco maritimi-Spartinetum junceae* O. de Bolòs 1962 (nom. inv. prop. Filigheddu, Farris et Biondi 2000)

*Limbaro crithmoidis-Juncetum maritimi* Brullo in Brullo et al. 1988

**Plantaginion crassifoliae** Br.-Bl. in Br.-Bl. et al. 1952

*Schoeno-Plantaginetum crassifoliae* Br.-Bl. in Br.-Bl., Roussine et Negre 1952

SALICORNIETEA FRUTICOSAE Br.-Bl. et Tx. ex A. Bolòs y Vayreda et. O. de Bolòs in A. Bolòs et Vayreda 1950

*SALICORNIETALIA FRUTICOSAE* Br.-Bl. 1933

**Salicornion fruticosae** Br.-Bl. 1933

*Junco subulati-Sarcocornietum alpini* Brullo et Sciandrello in Giusso et al. 2008

*Aeluropo lagopoidis-Sarcocornietum alpini* Brullo in Brullo et al. 1988 corr. Barbagallo et al. 1990

*Junco subulati-Sarcocornietum fruticosae* Brullo 1988

**Arthrocnemion glauci** Rivas-Mart. et Costa M. 1984

*Arthrocaulo meridionalis-Juncetum subulati* Brullo et Furnari 1976 nom. corr. *hoc loco*

*Juncetum subulati* Caniglia, Chiesura, Curti, Lorenzoni, Marchiori, Razzara, Tornadore 1984

**Suaedion brevifoliae** Br.-Bl. et O. de Bolòs 1958 (= *Suaedion verae* Brullo et Furnari 1988)

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

*Halimiono portulacoidis-Sarcocornietum alpini* Rivas-Martínez et Costa 1984

THERO-SUAEDETEA SPLENDENTIS Rivas-Martínez 1972

*THERO-SALICORNIETALIA* Tüxen in Tüxen et Oberdorfer ex Géhu et Géhu-Franck 1984

**Salicornion patulae** Géhu et Géhu-Franck ex Rivas-Martínez 1990

*Salicornietum emerici* O. Bolòs 1962 ex Brullo et Furnari 1976

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

*THERO-SUAEDETALIA SPLENDENTIS* Br.-Bl. et O. Bolòs 1958

**Thero-Suaedion splendentis** Br.-Bl. in Br.-Bl., Roussine et Nègre 1952

*Salsoletum sodae* Pignatti 1953

*Atriplici salinae-Suaedetum spicatae* O. Bolòs et Vigo 1984 corr. Rivas-Martínez, T.E. Díaz, Fernández-González, Izco, Loidi, Lousã et Penas 2002

*Cressetum creticae* Brullo & Furnari 1976

SAGINETEA MARITIMAE Westhoff, Van Leeuwen et Adriani 1962

*FRANKENIETALIA PULVERULENTAE* Rivas-Mart. ex Castroviejo et Porta 1976

**Frankenion pulverulentae** Rivas-Mart. ex Castroviejo et Porta 1976

*Parapholido-Frankenietum pulverulentae* Rivas-Martínez ex Castroviejo et Porta 1976

*Isolepido-Saginetum maritimae* Brullo 1988

*Brizo minoris-Isolepidetum cernui* ass. nova

*Parapholidetum filiformis* Brullo, Scelsi et Siracusa 1994

*Polypogonetum subspathacei* Gamisans 1992

NERIO-TAMARICETEA Br.-Bl. et O. Bolòs 1958

*TAMARICETALIA AFRICANAE* Br.-Bl. et O. Bolòs 1958

*Tamaricion africanae* Br.-Bl. et O. Bolòs 1958

*Limbarido crithmoidis-Tamaricetum africanae* ass. nova

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- Appendix I: Localities, data and authors of the relevés**
- Tab. 1 - *Enteromorpha intestinalidis-Ruppia maritima* (rels. 1, 6-7) and *Ruppia spiralis* (rels. 2-5); in brackets the authors of the relevés: Rel. 1, Pantano Morghella, 21.10.2011 (Sciandrello); Rels. 2-3, Vendicari, 29.04.2011 (Minissale & Sciandrello); Rels. 4-5, Pantano Morghella, 29.04.2011 (Minissale & Sciandrello); Rels. 6-7, Pantano Morghella, 4.4.2019 (Giusso & Sciandrello).
- Tab. 2 - *Scirpo compacti-Juncetum subulati* (rels. 1-7); in brackets the authors of the relevés: Rel. 1, Pantano Ponterio, 31.05.2012 (Sciandrello); Rel. 2, Pantano Baronello, 08.12.2011 (Sciandrello); Rel. 3, Pantano Ciaramiraro, 30.09.2011 (Sciandrello); Rel. 4, Pantano Cuba, 07.11.2011 (Sciandrello); Rel. 5, P. Marzamemi, 30.09.2011 (Sciandrello); Rel. 6, P. Cuba, 08.12.2011 (Sciandrello); Rel. 7, P. Auruca, 08.12.2011 (Sciandrello).
- Tab. 3 - *Schoeno-Plantaginietum crassifoliae* (Rels. 1-13); *Limonio virgati-Juncetum acuti* (Rels. 14-18, 48, 53); in brackets the authors of the relevés: Rel. 1, Pantano Ponterio, 06.12.2011 (Sciandrello); Rels. 2-3, Pantano Ponterio, 14.03.2011 (Sciandrello); Rel. 4, Pantano Auruca, 21.10.2011 (Sciandrello); Rel. 5, Pantano Auruca, 15.03.2012 (Sciandrello); Rel. 6, Pantano Vendicari, 20.12.2011 (Sciandrello); Rel. 7, Pantano Vendicari, 03.02.2010 (Sciandrello); Rel. 8, Gorgo Salato, 20.12.2011 (Sciandrello); Rels. 9-13, Pantano Vendicari (Minissale & Sciandrello, 2010, Tab. 7, Rels. 8-12); Rel. 14, Pantano Ponterio, 06.12.2011 (Sciandrello); Rels. 15-16, Pantano Ponterio, 31.05.2012 (Sciandrello); Rels. 17-18, Pantano Auruca, 21.10.2011 (Sciandrello); Rel. 48, Pantano Cannone (Portopalo), 21.02.2019 (Giusso, Minissale & Sciandrello); Rel. 53, Pantano Ponterio, 4.9.2013 (Sciandrello).
- Tab. 4 - *Limbarido crithmoidis-Juncetum maritimi* (Rels. 24-37, 49-52); *Junco maritimi-Caricetum extensae* (Rels. 43-47); *Junco maritimi-Spartinetum junceae* (Rels. 38-42); in brackets the authors of the relevés: Rel. 24, Pantano Ponterio, 31.05.2012 (Sciandrello); Rel. 25, Pantano Baronello, 08.12.2011 (Sciandrello); Rel. 26, Pantano Bruno, 07.11.2011 (Sciandrello); Rel. 27, Pantano Vendicari, 20.12.2011 (Sciandrello); Rel. 28, Pantano Vendicari (Costa Eoro), 14.01.2011 (Minissale & Sciandrello); Rel. 29, Pantano Vendicari, 03.02.2010 (Sciandrello); Rel. 30, Gorgo Salato, 20.12.2011 (Sciandrello); Rels. 31-37, Pantano Vendicari (Minissale & Sciandrello, 2010, Tab.7, Rels. 1-7); Rel. 38, Pantano Baronello, 08.12.2011 (Sciandrello); Rels. 39-40, Pantano Bruno, 07.11.2011 (Sciandrello); Rel. 41, Gorgo Salato, 20.12.2011 (Sciandrello); Rel. 42, Pantano Ciaramiraro, 27.09.2012 (Sciandrello); Rels. 43-47, Pantano Pozzallo, 11.04.2019 (Minissale & Sciandrello); Rel. 49, Pantano Cannone (Portopalo), 21.02.2019 (Giusso, Minissale & Sciandrello); Rels. 50-52, Pantano Ponterio, 4.9.2013 (Sciandrello).
- Tab. 5 - *Agropyro scirpei-Inuletum crithmoidis* (Rels. 58-81); in brackets the authors of the relevés: Rel. 58, Pantano Ponterio, 30.09.2011 (Sciandrello); Rel. 59, retroduna (Pantano Ponterio), 06.12.2011 (Sciandrello); Rels. 60-61, Pantano Ponterio, 14.03.2012 (Sciandrello); Rel. 62, Pantano Ponterio, 31.05.2012 (Sciandrello); Rel. 63, Pantano Ponterio, 31.05.2012 (Sciandrello); Rels. 64-66, Pantano Ponterio, 31.05.2012 (Sciandrello); Rels. 67-68, Pantano Baronello, 08.12.2011 (Sciandrello); Rel. 69, Pantano Morghella, 21.10.2011 (Sciandrello); Rel. 70,

Pantano Morghella, 29.04.2011 (Minissale & Sciandrello); Rels. 71-72, Pantano Longarini, 07.11.2011 (Sciandrello); Rel. 73, Gorgo Salato, 20.12.2011 (Sciandrello); Rels. 74-81, Pantano Vendicari (Minissale & Sciandrello, 2010, Tab.6, Rels. 16-23).

Tab. 6 - *Arthrocaulo meridionalis-Juncetum subulati* (Rels. 1-20, 82-83); *Juncetum subulati* (Rels. 58-62); in brackets the authors of the relevés: Rel. 1, Pantano Ponterio, 06.12.2011 (Sciandrello); Rels. 2-3, Pantano Ponterio, 31.05.2012 (Sciandrello); Rel. 4, Pantano Ciaramiraro, 30.09.2011 (Sciandrello); Rel. 5, Pantano Longarini, 07.11.2011 (Sciandrello); Rel. 6, Pantano Vendicari, 20.12.2011 (Sciandrello); Rel. 7, Pantano Vendicari (Costa Elero), 14.01.2011 (Minissale & Sciandrello); Rels. 8-10, Pantano Vendicari, 03.02.2010 (Sciandrello); Rel. 11, Pantano Vendicari, 08.10.2008 (Sciandrello); Rels. 12-20, Pantano Vendicari (Minissale & Sciandrello, 2010, Tab.6, Rels. 1-9); Rels. 82-83, Pantano Ponterio, 4.9.2013 (Sciandrello). Rels. 58-59, Pantano Ponterio, 31.05.2012 (Sciandrello); Rel. 60, Pantano Marzamemi, 21.10.2011 (Sciandrello); Rel. 61, Pantano Auruca, 21.10.2011 (Sciandrello); Rel. 62, Pantano Vendicari, 20.12.2011 (Sciandrello).

Tab. 7 - *Junco subulati-Sarcocornietum alpini* (Rels. 21-38), *Aeluropo lagopoidis-Sarcocornietum alpini* (Rels. 63-74); in brackets the authors of the relevés: Rel. 21, Pantano Ponterio, 30.09.2011 (Sciandrello); Rel. 22, Pantano Ponterio, 14.03.2012 (Sciandrello); Rels. 23-24, Pantano Ponterio, 31.05.2012 (Sciandrello); Rels. 25-26, Pantano Baronello, 30.09.2011 (Sciandrello); Rels. 27-28, Pantano Marzamemi, 21.10.2011 (Sciandrello); Rels. 29-31, Pantano Morghella, 29.04.2011 (Minissale & Sciandrello); Rel. 32, Pantano Auruca, 21.10.2011 (Sciandrello); Rel. 33, Pantano Cuba, 07.11.2011 (Sciandrello); Rel. 34, Pantano Longarini, 07.11.2011 (Sciandrello); Rel. 35, Vendicari (Costa Elero), 14.01.2011 (Minissale & Sciandrello); Rels. 36-38, Pantano Vendicari (Minissale & Sciandrello, 2010, Tab.6, Rels. 10-12); Rel. 63, Pantano Gorgo Salato, 06.09.2003 (Sciandrello), Rel. 64, Pantano Bruno, 06.09.2003 (Sciandrello), Rels. 65-67, Pantano Longarini, 06.09.2003 (Sciandrello), Rel. 68, Pantano Cuba, 07.10.2003 (Sciandrello), Rels. 69-70, Pantano Grande Roveto 07.10.2003 (Sciandrello), Rels. 71-72, Pantano Baronello, 07.10.2003 (Sciandrello), Rels. 73-74, Pantano Morghella, 07.10.2003 (Sciandrello).

Tab. 8 - *Junco subulati-Sarcocornietum fruticosae* (Rels. 39-43, 84-88), *Halimiono portulacoidis-Sarcocornietum alpini* (Rels. 44-53), *Halimiono-Suaedetum verae* (Rels. 54-57); in brackets the authors of the relevés: Rels. 39-40, Pantano Baronello, 08.12.2011 (Sciandrello); Rels. 41-43, Pantano Vendicari (Minissale & Sciandrello, 2010, Tab.6, Rels. 13-15); Rel. 44, Pantano Baronello, 30.09.2011 (Sciandrello); Rels. 45-46, Pantano Marzamemi, 21.10.2011 (Sciandrello); Rels. 47-48, Pantano Morghella, 21.10.2011 (Sciandrello); Rels. 49-50,

Pantano Morghella, 29.04.2011 (Minissale & Sciandrello); Rel. 51, Vendicari, 20.12.2011 (Sciandrello); Rels. 52-53, Vendicari (Costa Elero), 14.01.2011 (Minissale & Sciandrello); Rel. 54, Pantano Ponterio, 31.05.2012 (Sciandrello); Rel. 55, Pantano Ciaramiraro, 30.09.2011 (Sciandrello); Rels. 56-57, Pantano Longarini, 07.11.2011 (Sciandrello); Rels. 84-88, Pantano Baronello, 4.9.2013 (Sciandrello).

Tab. 9 - *Salsoletum sodae* (Rels. 1-4, 16-20), *Atriplici salinae-Suaedetum spicatae* (Rels. 5-11, 23-25, 30-34), *Salicornietum emerici* (Rels. 12-13, 21-22), *Cressetum creticae* (Rels. 14-15), *Suaedo-Salicornietum patulae* (Rels. 26-29, 35-39); in brackets the authors of the relevés: Rels. 1-2, Pantano Ponterio, 22.05.2012 (Sciandrello); Rel. 3, Pantano Ponterio, 31.05.2012 (Sciandrello); Rel. 4, Pantano Morghella, 21.10.2011 (Sciandrello); Rels. 5-6, Pantano Ponterio, 31.05.2012 (Sciandrello); Rel. 7, Pantano Vendicari, 20.12.2011 (Sciandrello); Rel. 8, Pantano Grande, Vendicari (Minissale & Sciandrello 2010, Tab. 5, Rel.3); Rels. 9-10, Pantano Roveto, Vendicari (Minissale & Sciandrello 2010, Tab.5, Rels. 4-5); Rel. 11, Pantano Baronello, 27.09.2012 (Sciandrello); Rel. 12, Pantano Roveto, Vendicari (Minissale & Sciandrello 2010, Tab.5, Rel. 1); Rel. 13, Pantano Grande, Vendicari (Minissale & Sciandrello 2010, Tab.5, Rel.2); Rels. 14-15, Pantano Baronello, 27.09.2012 (Sciandrello); Rels. 16-25, Pantano Ponterio, 23.09.2013 (Sciandrello); Rels. 26-34, Pantano Morghella, 24.09.2013 (Sciandrello); Rels. 35-39, Pantano Morghella, 11.11.2013 (Sciandrello).

Tab. 10 - *Brizo minoris-Isolepidetum cernui* (Rels. 1-9, 17-20), *Parapholidetum filiformis* (Rels. 10-16), *Polypogonetum subsphatacei* (Rels. 21-22), *Parapholido incurvae-Frankenietum pulverulentae* (Rels. 23-27), *Isolepido-Saginetum maritimae* (Rels. 28-32); in brackets the authors of the relevés: Rels. 1-5, Pantano Ponterio, 22.05.2012 (Sciandrello & Spampinato); Rels. 6-7, Pantano Ponterio, 31.05.2011 (Sciandrello); Rels. 8-16, Pantano Ponterio, 31.05.2011 (Sciandrello); Rels. 17-20, Pantano Pozzallo, 11.04.2019 (Minissale & Sciandrello); Rels. 21-22, Vendicari (Cittadella), (Minissale & Sciandrello 2010, Tab. 10, Rel. 1-2); Rels. 23-27, Vendicari (1-3) and Pantano Ciaramiraro (4-5) (Brullo 1988, Tab. 1, Rels. 1-5); Rels. 28-32 Pantano Sichilli, Vendicari (Brullo 1988, Tab. 2, Rels. 1-5).

Tab. 11 - *Limbarido crithmoidis-Tamaricetum africanae* ass. nova (Rels. 1-18); in brackets the authors of the relevés: Rel. 1, Pantano Ponterio, 06.12.2011 (Sciandrello & Spampinato); Rels. 2-3, Pantano Ponterio, 15.03.2012 (Spampinato & Sciandrello); Rels. 4-5, Pantano Ponterio, 27.09.2012 (Sciandrello); Rels. 6-7, Pantano Ciaramiraro, 27.09.2012 (Sciandrello); Rels. 8, Pantano Longarini, 27.09.2012 (Sciandrello); Rels. 9-13, Pantano Morghella, 4.11.2013 (Sciandrello); Rels. 15-18, Pantano Ponterio, 4.11.2013 (Sciandrello).