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Title: Therophytic halophilous vegetation classification in South-Eastern Italy

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Running head: Therophytic halophilous vegetation in South-Eastern Italy

Abstract

Halophilous, sub-halophilous and halo-nitrophilous annual plant communities belonging to the *Thero-Salicornietea* and *Saginetea maritimae* classes have been analyzed in South-Eastern Italy. Even if numerous contributions have been provided on these vegetation types, at diverse scales of observation, the different and sometimes contrasting syntaxonomic treatments adopted by different Authors, as well as the phytogeographical interpretations, have led to uncertainty about their proper classification and nomenclature. In the present contribution a data-set of 391 relevés (230 from literature and 161 original data) was first subjected to some basic statistics and then analyzed through flexible beta clustering. CH index was used to determine the best partition, and the phi coefficient for the identification of diagnostic species. Indirect gradient analysis was performed by DCA ordination. Results were interpreted from a syntaxonomic point of view.

As regards *Thero-Salicornietea*, halophilous communities are well separated from the halo-nitrophilous ones in the two orders *Thero-Salicornietalia* and *Thero-Suaedetalia splendentis*. Within *Thero-Salicornietalia,* a new alliance, *Salicornion venetae*, including the tetraploid *Salicornia* vegetation typically growing in long flooded sites of the Adriatic region is here proposed. As for *Saginetea maritimae,* two main groups well separate: rocky coasts, sandy soils (*Saginetalia maritiimae*, with the E-Mediterranean alliance *Sileno sedoidis-Catapodion balearici*) and salt marshes, clayey-silty soils (*Frankenietalia pulverulentae,* here with the two alliances *Frankenion pulverulentae* and *Limonion avei*).

Key words: halophilous vegetation, *Thero-Salicornietea, Saginetea maritimae,* vegetation classification, syntaxonomy, coastal vegetation, South-Eastern Italy, Mediterranean area.

Taxonomic references: Pignatti (2017-2019); Bartolucci et al. (2018). For Salicornia and Suaeda, two keystone genera for the communities of Thero-Salicornietea class, although taking into account the recent work of Kadereit et al (2012), we referred to Iberite (2017, in Pignatti) and to Brullo & Guarino (2017, in Pignatti), respectively. Also for the genus Hornungia, we referred to Pignatti (2017).

Synaxonomic references: Rivas-Martinez et al (2001); de Foucault et Bioret (2010); Biondi et al. (2014); Mucina et al. (2016).

Abbreviations: EEC = European Economic Community; CH = Calinski-Harabasz; DCA = Detrended Correspondence Analysis; ICPN = International Code of Phytosociological Nomenclature

Introduction

Therophytic halophilous vegetation characterizes extremely specialized wet habitats, extensively distributed in coastal and also in inland areas. These habitats have a great conservation value, determined by the presence of highly specialized and rare species but, at the same time, are threatened by numerous anthropogenic pressures such as, among others, changes in water management, agriculture intensification, urbanization. For this reason, they have been included in the Annex I of the 92/43/EEC Directive, identified by the habitat type code 1310, 'Salicornia and other annuals colonizing mud and sand'. Strictly complying with the Interpretation Manual (European Commission 2013), only the communities "colonising periodically inundated muds and sands of marine or interior salt marshes" can be referred habitat 1310; these communities fall within the phytosociological classes *Thero-Salicornietea, Saginetea maritimae, Crypsietea aculeatae*.

The class *Thero-Salicornietea*, with Eurasian distribution, includes pioneer coastal or continental vegetation growing in maritime and inland salt marshes, occupying those sites with the highest salt concentration, generally positioned in the first-line belt of the flooding zonation, on raw (mineral) soils, from sandy to loamy or clay depending on sedimentation conditions, in large part poor in nutrients, temporarily flooded and drying out in summer. The phenological optimum is late summer to autumn. This vegetation is formed of annual succulent halophytes belonging to the *Chenopodiaceae*; in particular, the dominant species belong to *Salicornia* and *Suaeda,* rather complicated genera from the taxonomical point of view, presenting numerous microspecies whose correct identification is essential for the syntaxonomy of *Thero-Salicornietea* communities (Rivas-Martinez & Herrera 1996; Loidi et al. 1999; Mucina et al. 2016). This vegetation is characterized by low species richness and monospecificity is quite frequent; moreover, many of these species have wide ecological range and high morphological variability.

Originally framed in a single class along with the perennial communities (Br.-Bl. 1933; Br.-Bl 1952), this vegetation was recognized as authonomous *Therosalicornietea* class by Pignatti (1953a), with one order and one alliance (*Therosalicornietalia*, *Therosalicornion*), including both halophilous and halonitrophilous vegetation. This framework, with various alternating nomenclatural interpretations, has been maintained by many authors, (e.g. Tüxen & Oberdorfer 1958; Br.-Bl. & O. de Bolòs 1958; Kaligarič & Škornik 2006; Stancic et al. 2008; Mucina et al. 2016) even if many others (e.g. Brullo & Furnari 1976; Géhu & Géhu-Franck 1984; Géhu et al. 1984; Poldini et al 1999; Rivas-Martinez et al. 2001; Biondi et al. 2014; etc) separates the halophytic *Salicornia* vegetation (*Thero-Salicornietalia*) from the halo-nitrophilous communities (*Thero-Suaedetalia* Br.-Bl. & Bolòs 1958; *Thero-Suaedion* Br-Bl 1931), arranging these last syntaxa either in the *Thero-Salicornietea* or in the *Cakiletea maritimae* Tx & Preis 1950 (ord. *Euphorbietalia peplis* Tx 1950; Géhu & Géhu-Franck 1984).

The class *Saginetea maritimae*, with Atlantic-Mediterranean (up to Syria) and Macaronesian distribution, groups terophytic, salt tolerant, sub-nitrophilous vegetation formed by species of small size, with winter-spring cycle. It tolerates short temporary flooding in winter and long arid period during the rest of the year, on halomorphic, loamy to sandy, soils that are extremely variable in terms of salinity and water availability, with alternating periods of salt concentration and humidity. These communities usually cover small surfaces, forming mosaic with perennial communities of classes *Crithmo-Limonietea, Juncetea maritimi, Salicornietea fruticosae, Helichryso-Crucianelletea maritimae* (Westhoff et al. 1962; Tüxen & Westhoff 1963; Castroviejo & Porta 1976; Rivas-Martinez & Costa 1976; Brullo 1988; de Foucault & Bioret 2010; Mucina et al. 2016).

The *Saginetea maritimae* class was described by Westhoff, Van Leeuwen & Adriani (1962), for the annual, halo-tolerant communities of the European Atlantic coasts, with one order (*Saginetalia maritimae*) and one alliance (*Saginion maritimae*), and then extended by Tüxen & Westhoff (1963) to the Mediterranean. Rivas-Martínez (Rivas-Martínez & Costa 1976, Castroviejo & Porta 1976) created the class *Frankenietea pulverulentae* (with one single order, *Frankenietalia pulverulentae*, and one alliance, *Frankenion pulverulentae*) for the Mediterranean communities but, as evidenced by numerous authors, there are no so many differences between the Mediterranean and the Atlantic to justify a separation at the class level (Rivas-Martínez et al. 2001; Brullo et al. 2002; de Foucault & Bioret 2010; Biondi et al. 2014). Therefore, only one class is unanimously recognized, the *Saginetea maritimae*, with two orders: *Saginetalia maritimae* Westhoff, Leeuwen & Adriani 1962, that extends from the Atlantic coasts to the Mediterranean basin and relates to temperate and Mediterranean macrobioclimates; and *Frankenietalia pulverulentae* Rivas-Mart ex Castroviejo & Porta 1976, with Mediterranean and Macaronesia distribution and related to Mediterranean macrobioclimate. Some Authors give a more ecological-edaphic-phytogeographic distinction (*Saginetalia maritimae* on sandy substrates of Atlantic dune complexes or Mediterranean and

Atlantic cliffs; *Frankenietalia pulverulentae* on sandy loamy substrates, Mediterranean coastal lagoons or salt marshes; de Foucault & Bioret 2010; Biondi et al. 2014; Mucina et al. 2016).
There is an extensive literature regarding the therophytic halophilous vegetation of the Italian peninsula and its islands, where numerous associations have been recorded and described (Pignatti 1953b; Brullo & Furnari 1976; Brullo 1988; Poldini et al. 1999; Brullo & Siracusa 2000; Biondi et al. 2001; Brullo & Giusso 2003; Brullo et al. 1994; Biondi & Pesaresi 2004; etc.). In this contribution we focus on the South-Eastern part of the Italian peninsula, that is characterized by its large coastal extent and by the presence of a large variety of environments and vegetation types and, even if numerous contributions have been produced on the coastal vegetation of this area (Corbetta et al. 1989; Biondi et al. 2006; Biondi 2007; Biondi & Casavecchia 2010; Sciandrello & Tomaselli 2014; Tomaselli et al. 2011; Tomaselli & Sciandrello 2017; Tomaselli & Terzi 2019, etc.), only sparse and discontinuous information deals with this vegetation and in particular with the *Saginetea* class. Moreover, considering the different and sometimes contrasting syntaxonomic treatments adopted from time to time by different Authors, we thought it appropriate to analyze the issue as a whole, on the basis of numerical analyses, in order to achieve to a framework, as clear and comprehensive as possible, for this study area.

Materials and methods

The South-Eastern part of the Italian peninsula corresponds to Apulia and part of Basilicata Regions (Fig. 1). This area is characterized by a wide coastal extent, nearly 950 km long, with alternating rocky and sandy shores and with numerous wetlands and salt marshes.

#Fig. 1 approximately here#

Literature data on vegetation of coastal areas, wetlands and salt marshes in SE-Italy was examined (Corbetta 1970; Géhu et al. 1984; Brullo 1988; Corbetta et al. 1989; Brullo & Giusso del Galdo 2003; Corbetta et al. 2006; Tomaselli et al. 2008; Biondi & Casavecchia 2010; Tomaselli et al. 2011; Silletti 2012; Sciandrello et al. 2015; Tomaselli & Sciandrello 2017; Veronico et al. 2017) and phytosociological relevès on therophytic halophilous and halo-nitrophilous vegetation were selected and organized in a data-set. In addition, original vegetation data were sampled in the field on a period between 2007 and 2018, according to the phytosociological approach (Braun-Blanquet 1964, Westhoff & van der Maarel 1978), and to fundamental and updated concepts suggested by Dengler et al. (2005) and Biondi (2011). Finally, a matrix of 391 (objects) relevés x 195 (variables) species was obtained, including 230 relevés from literature and the 161 original relevés. Original relevés, as well as references of literature data, are reported in electronic Supplements (S1, S2 and S3).

Some simple basic statistics were calculated: number of species per relevè, matrix density, species frequency. Furthermore, a correlation analysis, between area of relevès and number of species per relevè, was made (not considering the literature data lacking of this information).

For the identification of outliers, on the basis of area of relevès and number of species per relevè, the three sigma test was applied and 11 relevés were thus removed from the matrix (3 of *Saginetea* and 8 of *Thero-Salicornietea*, that is those relevés with n. species > 20 and surface > 46 sqm). Then, in order to visualize the general data structure and to detect the presence of other outliers, the matrix was subjected to different agglomerative methods based on cluster analysis, by using different combinations of distance measures and group linkage methods, on both presence/absence values and cover values (transformed according to the method proposed by van der Maarel (1979)), all performed with Syntax 2000 (Podani 2001). Species with frequency lower than 2% were removed from the dataset and, finally, a matrix of 376 x 121 was obtained. After separating the two groups of *Thero-Salicornietea* (188x37) and *Saginetea* (188x69), further analyses were carried out separately on each dataset.

For the definition of plant communities within each dataset, hierarchical clustering was performed by using flexible beta linkage, with the Bray-Curtis coefficient, according to Tichý et al. (2010). Beta was set at −0.25 so that flexible beta clustering became a space-conserving method (McCune & Grace 2002). To identify the best partition, with the optimal number of clusters, we resorted to the CH Index (Calinski & Harabasz, 1974), that expresses the ratio between-cluster variance and the overall within-cluster variance; well-defined clustering solutions yield high values of CH index. Moreover, the "Optimclass 1" method (P < 10-6) was used (OptimClass 1 searches the partition with the maximum number of faithful species across all clusters; Tichý et al. 2010) and the function "Crispness of Classification" was applied to each partition of the data set ("Crispness of Classification" expresses the 'separation power' of the species; the higher the average separation power, the better the clusters can be distinguished by the diagnostic species, and then, the better the classification; Botta-Dukát et al. 2005; Tichy & Holt 2006). Diagnostic species of the vegetation units (partitions) were determined through the calculation of their fidelity (phi coefficient), based on cover data with the size of all groups standardized to equal size; non-significant values of phi at

P = 0,005 were excluded based on Fisher's exact test (Tichy & Chytry 2006); species with phi > 0.3 were considered as diagnostic and species with phi > 0.4 as higly diagnostic. Then, the syntaxonomic identification of the obtained partitions was carried out on the basis of the analysis of their diagnostic species, using Author's own expert knowledge and literature.

For the ordination analyses the DCA was performed, taking into account the bioclimatic variables at 30s resolution from WorldClim (Fick & Hijmans, 2017).

Hierarchical clustering and ordination analysis were run by PCOrd version 6.0 (McCune & Mefford 2010). CH Index was performed by MATLAB™software. Optimclass and Crispness of Classification, as well as the determination of diagnostic species were performed by software JUICE (Tichý 2002). QGis software (https://www.qgis.org) was used for the interpolation of the bioclimatic variables and the surveyed plant communities.

The nomenclatural decisions were taken according to the 3rd edition of the International Code of Phytosociological Nomenclature (ICPN, Weber et al. 2000).

Results

On the basis of the basic statistics implemented on the initial matrix (391x195), the average number of species per relevé is 7.9 (min 1 and max 21) with median 6 and standard deviation 4.01. The area of relevés is extremely variable, ranging from 0.1 to 100 sqm (average 10.3), with median 10 and standard deviation 11.58. The matrix shows a low data density (2944 cells with values vs 73299 empty cells). The average frequency of the species is low, with a value of 3.86 (median 1.53). However, the low species richness is a typical feature of this type of vegetation, especially in *Thero-Salicornietea*.

The correlation analysis between relevé area and number of species provided a p value 0.65 and R^2 0.002, indicating no significance and therefore no correlation number of species-surface area (Fig 2).

#Fig. 2 approximately here#

In Fig. 3 two dendrograms, resulting from the cluster analysis of the *Thero-Salicornietea* and *Saginetea* data sets respectively, are showed.

#Fig. 3 approximately here#

#Fig. 4 approximately here#

In the *Thero-Salicornietea* dendrogram (Fig. 3a), a cluster B consisting of 23 relevés all referring to *Salicornia veneta* and *S. dolichostachya* (*S. procumbens* group) communities, clearly separates from the main cluster (A). Cluster A divides into A1 (including all the relevés with dominant *Salicornia patula* (*S. perennans* group)) and A2, that is a large cluster including the remaining part of the relevés. Both CH index (Fig. 4a) and Crispness of Classificaton indicate 8 as best number of partitions. Thus, the dendrogram was pruned at eight partitions, even if we decided to further separate cluster 8 in two sub-clusters, 8a and 8b, that refer, respectively, to *Salicornia veneta* and *S. dolichostachya* (Fig. 3a). Optimclass (Supplement S4), indicates the higher number of faithful species between 12 and 21 partitions. However, it should be considered that in the list of the faithful species are included many species belonging to other syntaxa, such as *Sarcocornietea* or *Juncetea*, which very frequently form mosaics with therophytic communities. As a result, the real number of diagnostic species is much lower than the one resulting from the analysis and probably the Optimclass results may be biased. Table 1 displays the synoptic fidelity table at 3 goups (the three main clusters; distrimination at the level of orders-alliances). In Table 2 the synoptic frequency table at 9 groups (plant community level) is reported, while the synoptic phydelity table at 9 groups is in Supplement S5.

#Table 1 approximately here#

#Table 2 approximately here#

As for Saginetea, two main clusters clearly separates, A and B (Fig. 3b), indicating two main ecological contexts related, in broad terms, to cliff and rocky coast (A) and to coastal salt marshes (B). Both CH Index (Fig. 4b) and Crispness of Classification curves indicate 2 as best number of partitions. Obviously, this value cannot be used for the identification of the best number of partitions for the definition of the single plant communities. The OptimClass curve (Supplement S4) indicates high amounts of faithful species between 9 and 14 partitions for the clustering method used in our analysis. On the basis of literature and expert knowledge, the classification with 11 clusters was identified as the most ecologically meaningful and the dendrogram was pruned at 11 partitions (Fig. 3b). The groups thus identified correspond to the surveyed associations, quite autonomous from a floristic and ecological point of view. Tab. 3 displays the synoptic fidelity table at 2 goups (the two main clusters; distrimination at the level of orders). In Tab. 4 the the synoptic frequency table at 11 groups (plant community level) is reported, while the synoptic phydelity table at 11 groups is in Supplement S6.

#Table 3 approximately here#

#Table 4 approximately here#

The complete list of diagnostic, constant and dominant species for *Thero-Salicornietea* and *Saginetea maritimae* is in Supplementary material S7 and S8, respectively.

Figures 5 and 6 show the ordination obtained by DCA for the *Thero-Salicornietea* and the *Saginetea* communities, respectively. As for *Thero-Salicornietea* (Fig. 5), the highest data dispersion is obtained with the axes 2 and 3, with a main gradient of precipitation (soil moisture) on axis 2 and soil salinity (soil nitrates) on axis 3. In the case of *Saginetea* (Fig. 6) the highest data dispersion results with the axes 1 and 2, with main gradient of precipitation (soil moisture) and granulometry on axis 1 and soil salinity (soil nitrates) on axis 2, with a strong correspondence with the cluster analysis results.

#Fig. 5 approximately here#

#Fig. 6 approximately here#

Discussion

As regards the numerical analysis, the low number of species that characterizes large part of these communities, often doesn't allow the identification of large groups of true diagnostic species; therefore, a clear discrimination between communities is often difficult to achieve. Moreover, many of these species are characterized by wide ecological range and, for these reasons, in some cases, it may appear that many species associate with each other casually and the concept of fidelity, in these cases, may appear accidental. These features sometimes make the interpretation of statistical analysis results a complex issue.

Thero-Salicornietea

A crucial issue concerning the syntaxonomy of the class *Thero-Salicornietea* is the taxonomic identity of the *Salicornia* species. The complexity of the genus *Salicornia* in Europe has produced many reversals alternating partitions within the genus, leading in turn to a fair deal of confusion, at both taxonomic and syntaxonomic level. Traditionally, two series have been identified, diploid and tetraploid, each of them with numerous species and micro-species. The revision proposed by Kadereit et al. (2012) has deeply transformed the taxonomy of the genus, reducing the Mediterranean species to only three entities: *S. procumbens* subsp. *procumbens* (tetraploid, distributed along Mediterranean and Atlantic coasts and including *S. emerici*, *S. veneta* and *S. dolichostachya*); *S. perennans* subsp. *perennans* (diploid, with Mediterranean and Eurasian distribution, including *S. patula*); *S. europaea subsp. europaea* (diploid, western Mediterranean); as regards the Italian peninsula, only the two first taxa, *S. procumbens* subsp. *procumbens* and *S. perennans* subsp. *perennans* are recognized. Nevertheless, the existence of numerous microtaxons morphologically quite well differentiated, traditionally used in phytosociology and, above all, each of them characterized by particular ecological conditions, would encourage it to maintain their use in phytosociology. For this reason we refer to the classification proposed by Iberite (2017, in Pignatti) who recognize the presence, for the Italian peninsula, of the diploid *S. patula* and of the tetraploid *S. emerici*, *S. veneta* and *S. dolichostachya.*

Among the complex nomenclatural issues concerning this class and its subordinate syntaxonomic ranks, one of the crucial points deals with the separation of the halophilous communities from the halo-nitrophilous ones. As outlined in Introduction, numerous and contrasting points of view have alternative risen in the last sixty years. In the recent contribution on the classification of the European vegetation, Mucina et al. (2016) gather together the pioneer vegetation of annual succulent halophytes in the class *Thero-Salicornietea* Tx. in Tx. & Oberd. 1958 and report, for the Mediterranean area, the only one order *Therosalicornietalia* Pignatti 1952 (considered by these Authors synonym of, among others, *Thero-Salicornietalia* Tx. ex Géhu & Géhu-Franck 1984 and *Thero-Suaedetalia* Br.-Bl. & O. de Bolòs 1958) and the only one alliance *Therosalicornion* Br.-Bl. 1933 (considered synonim of, among others, *Salicornion patulae* Géhu & Géhu-Franck 1984 and *Salicornion emerici* Géhu et Géhu-Franck 1984). The opportunity of separating the halophilous from the halo-nitrophilous types in different high syntaxa has been taken into consideration by numerous Authors. Rivas Martinez et al (2001), in the syntaxonomical checklist of the Iberian Peninsula, propose two separate orders: *Thero-Salicornietalia* Tx. in Tx. & Oberd. 1958 ex Géhu & Géhu-Frank 1984 (littoral and inland halophytic communities) and *Thero-Suaedetalia* Br.-Bl. & O. de Bolòs 1958 (littoral and inland halo-nitorphilous communities). This separation has been reproposed by numerous Authors for Mediterranean countries (e.g. Brullo et al. 2002; Bardat et al. 2004; Biondi & Casavecchia 2010; Biondi et al. 2014). The numerical analyses carried out in this study clearly separate the merely halophilous aspects, characterized by different species of diploid (Fig. 3a, cluster A1; Table 1, column 1) and tetraploid *Salicornia* (Fig. 3a, cluster B; Table 1, column 2), from the halo-nitrophilous ones (Fig. 3a, cluster A2; Table 1, column 3), well differentiated by halo-nitrophilous and subnitrophilous species such as *Soda inermis, Suaeda splendens, Spirobassia* *hirsuta*. For this reason, in this contribution we prefer to keep them separated; in this framework, the *Therosalicornietalia* Pignatti 1953, conceived by its Author as order including the whole pioneer halophilous vegetation, should be considered *nomen ambiguum* as pointed out by Rivas-Martinez et al. (2001), who separate the halophilous *Salicornia* vegetation (*Thero-Salicornietalia* Tx. in Tx. & Oberd. 1958 ex Géhu & Géhu-Franck 1984) from the halo-nitrophilous communities (*Thero-Suadetalia splendentis* Br.-Bl. & O. de Bolòs 1958). Within the *Thero-Salicornietalia*, the *Therosalicornion* described by Br.-Bl. 1933 and grouping both *Salicornia* and the *Suaeda* communities, cannot be considered a valid syntaxon. The marked separation between diploid and tetraploid *Salicornia* communities lead us to propose a new alliance, the *Salicornion venetae,* including the tetraploid *Salicornia* vegetation typically growing in long flooded sites and that well differentiates from the *Salicornion patulae* (diploid *Salicornia* vegetation in periodically flooded sites in Mediterranean area). As character species of this new alliance *Salicornia veneta, S. dolychostachya* and *Suaeda splendens* can be identified (holotypus: Salicornietum venetae Pignatti 1966). The *Salicornion venetae* can be considered as a geographic, North- Mediterranean (Adriatic) vicariant of the *Salicornion emerici* (tetraploid *Salicornia* vegetation, in long flooded sites, in W-Mediterranean and Thermo-Atlantic area), described by Géhu & Géhu-Franck (1984). The halo-nitrophilous vegetation, characterized by *Suaeda* sp. pl., *Spirobassia hirsuta, Soda inermis* etc, falls into the *Thero-Suaedion splendentis* Br.-Bl. in Br.-Bl. et al. 1952 and it should no longer be considered *nomen superfluum* (Mucina et al. 2016).

At the level of plant communities, 9 syntaxa have been recognized, described below.

The Salicornia sp. vegetation _(Thero-Salicornietalia)_

Salicornia veneta **and** ***S. dolichostachya*** **group (*****Salicornion venetae*****).** Table 2, columns 8 and 9

This group includes tetraploid *Salicornia* species: *S. veneta* and *S. dolichostachya*, included in *S. procumbens* subsp. *procumbens* by Kadereit et al. (2012). The presence of *S. emerici* vs *S. veneta* in the south Adriatic remains controversial (Biondi & Casavecchia 2010; Iberite & Iamonico 2016). As regards the ecology, the species belonging to this group usually live in depressions that are flooded for most of the summer season. Among the various associations recognized for the Adriatic (*Salicornietum emerici, Salicornietum venetae, Suaedo splendentis-Salicornietum venetae; Suaedo splendentis-Salicornietum dolichostachyae*; Gehu et al. 1984; Biondi & Casavecchia 2010;

Veronico et al. 2017), only the *Salicornietum venetae* Pignatti 1966 and the *Suaedo splendentis-Salicornietum dolichostachyae* Biondi & Casavecchia 2010 are here recognized.

***Salicornia patula* group (*Salicornion patulae*)**. Table 2, column 1

Salicornia patula forms plant communities that develop in more elevated positions respect to the tetraploids *Salicornia* vegetation and on saltier substrates, flooded for shorter time. The association is the *Suaedo maritimae-Salicornietum patulae* Brullo & Furnari ex Géhu & Géhu-Franck 1984. The original name of the association was based on *Suaeda maritima* (L) Dumort, taxon widely distributed in the Atlantic coasts of Europe and north America and replaced, in Central-Western Mediterranean, by *Suaeda spicata* (Willd.)Moq (Pedrol & Castroviejo 1990, Pignatti 2017, Tomaselli & Sciandrello 2017, Brullo et al. 2019). Thus, the correct name is *Suaedo spicatae-Salicornietum patulae* Brullo & Furnari ex Géhu & Géhu-Franck 1984 corr. Alcaraz, Ríos, De la Torre, Delgado & Inocencio 1998. The three relevés of the *Suaedo splendentis-Salicornietum patulae* Biondi & Casavecchia 2010 mix with the others of *Suaedo-Salicornietum patulae*, segregating at 32 groups that, in the present analysis, is not to be considered significant.

The halo-nitrophilous vegetation *(Thero-Suaedetalia - Thero-Suaedion)*

***Spirobassia hirsuta* group.** Table 2, column 2

Spirobassia hirsuta forms dense nitrophilous communities often localized at the edges of lagoons, often in contact with the *Salicornietum patulae*, in locations where dead and decaying organic material (e.g. *Ruppia* sp.pl. or algae) periodically settles forming variable amounts of deposits. The associaton is the *Suaedo maritimae-Bassietum hirsutae* Braun-Blanquet 1928, whose name should be amended, for the reasons mentioned in the above section, and according to the art. 43 (ICPN), in *Suaedo spicatae-Bassietum hirsutae*.

***Suaeda spicata* group.** Table 2, column 3

Suaeda spicata (Willd.)Moq., as mentioned above, has Mediterranean distribution, vicariant of the Atlantic *S. maritima.* It is halo-nitrophilous species, preferring soils with a significant organic component, rather humid in the summertime (Brullo et al. 2019), and is generally favoured by natural disturbances (e.g. grazing, field abandonment). This vegetation can be referred to the *Suaedetum spicatae* Pignatti 1953 corr. Brullo et al. (2019) (=*Atriplici salinae-Suaedetum spicatae*

O. Bolòs & Vigo 1984 corr. Rivas-Martinez et al. 2001), and may be considered as the Mediterranean vicariant of the *Suaedetum maritimae* (von Soó 1927) Wendelberger 1943.

***Suaeda splendens* group.** Table 2, column 4

Suaeda splendens forms halo-subnitrophilous and termophilous vegetation, often colonizing abandoned fields after farming, usually on clayey, salty soils (Biondi & Casavecchia 2010). The communities here analyzed can be referred to the *Bassio hirsutae-Suaedetum splendentis* Biondi & Casavecchia 2010.

***Soda inermis* group.** Table 2, column 7

Halo-nitrophilous and termophilous vegetation, growing on soils rich in organic content and forming floristically very poor communities dominated by *Soda inermis* (= *Salsola soda*). Among the diagnostic species, *Atriplex tatarica* is a typical species of disturbed habitats. These communities can be referred to the *Salsoletum sodae* Pignatti 1953.

***Sporobolus aculeatus* group.** Table 2, column 5

Sporobolus aculeatus (= *Crypsis aculeata* (L.) Aiton) grows on salinizated and temporary flooded soils, forming paucispecific communities dominated by this prostrate small graminoid. Similar communities, described in other parts of the Italian peninsula, have been referred to the *Crypsidetum aculeatae* (Bojko 1932 nom.nud.) Wenzl 1934 (Corbetta et al. 1989; Biondi et al. 1992; Frondoni & Iberite 2002), and framed in the *Crypsidion aculeatae* Pignatti 1954, *Crypsidetalia aculeatae* Vicherek 1973 and in the *Saginetea maritimae* class (also according to the Prodromus of the Italian Vegetation, Biondi et al 2014). Nevertheless, both *Crypsidetalia aculeatae* and *Cypero-Spergularion salinae* Slavnić 1948 (= *Crypsidion aculeatae* Pignatti 1954) refer to periodically flooded saline habitats of subcontinental Central and Eastern Europe (Mucina et al 2016). Then we believe that the Mediterranean communities, and in particular those analysed in this contribution, cannot be referred to this association. Biondi & Bagella (2005) describe a *Salicornio patulae-Crypsidetum aculeatae,* framed in the *Salicornion patulae,* to be considered a transition between the *Crypsidetum aculeatae* and the *Suaedo-Salicornietum patulae.* As mentioned above, the *Sporobolus aculeatus* relevés segregate with the *Therosalicornietalia* vegetation in all the clustering analyses applied to the whole data-set. Nevertheless, no diagnostic species have been identified to recognize a precise association. Thus, we here refer to *Sporobolus* *aculeatus* community, within the *Thero-Suaedion splendentis*, pending further investigations on a wider range of study.

***Halopeplis amplexicaulis* group.** Table 2, column 6

Halopeplis amplexicaulis is S-Mediterranean species of semi-arid zones, very rare and localized in the study area, where it finds a chorologic limit. This species colonizes the innermost band of the haloseries, far from the sea, characterized by very high salt concentration and a long period of summer drought (Estrelles et al. 2018). This vegetation has been referred to the *Halopeplidetum amplexicaulis* Burollet 1927 (Silletti 2012), association with a south-Mediterranean distribution (Rivas-Martinez 1990; Brullo et al. 2002) and is here framed within the *Microcnemion coralloidis* Rivas Martínez 1984 alliance (Rivas-Martinez 1990; Rivas Martínez et al. 2001).

Saginetea maritimae

As pointed out in Introduction, the class *Saginetea maritimae* includes two orders, well defined from bio-geographic and bio-climatic point of view, the Atlantic-Mediterranean *Saginetalia maritimae* (temperate to Mediterranean macrobioclimates) and the strictly Mediterranean *Frankenietalia pulverulentae*. Mucina et al. (2016) underline also the edaphic nature: sandy soils for *Saginetalia* and clayey-silty soils for *Frankenietalia*. This distinction had been previously noticed by Géhu (1987) and by de Foucault & Bioret (2010), who differentiated the spring communities on sandy substrates of the Atlantic sandy coast complexes or of the Mediterranean and Atlantic cliffs (*Saginetalia*), and the late spring or early-summer communities which preferentially develop at the edges of Mediterranean salt marshes, on sandy loamy substrates (*Frankenietalia*).

Within the *Saginetalia*, a single alliance has been recognized for long time, the *Saginion maritimae*. In a revision of the class *Saginetea maritimae* at the European level (de Foucault & Bioret 2010) the Authors describe a new alliance, the *Sileno sedoidis–Catapodion loliacei,* including the thermophilous therophytic communities with central-eastern Mediterranean distribution (E-Mediterranean optimum). This framework has been followed in the prodrome of Italian vegetation (Biondi et al. 2014), where this syntaxon is referred as halophytic vegetation with *Silene sedoides* and *Parapholis incurva* forming very small-scale populations on sandy or loamy-sandy shallow soils, mainly in rocky coast environments (corrosion basins). Mucina et al. (2016) reduce the extent of the alliance to Southern Aegean and Cypriotic territories, but we believe that the distribution area is the original one proposed by the Authors. However, the name must be correct (art. 43 of ICPN) in *Sileno sedoidis–Catapodion balearici* since, according to Brullo et al. 2003, *C. marinum* (= *C. loliaceum*) has Atlantic distribution, while in the Mediterranean territories it is replaced by *C. balearicum* and *C. pauciflorum*. Thus, *C. balearicum*, instead of *C. loliaceum*, has to be recognized among the diagnostic species of the alliance (as evidenced also in Biondi et al. 2014). Mucina et al (2016) identify a central-eastern Mediterranean group of alliances of the *Saginetalia maritimae*, that includes the *Junco ranarii-Plantaginion commutatae* Horvatić 1934 for the Adriatic area. The presence of *Juncus ranarius* as diagnostic species would circumscribe the distribution of this alliance to the north-eastern Adriatic. However, pending further investigation, the communities under investication shoudn't be attributable to this syntaxon.

Within the *Frankenietalia*, numerous alliances have been recognized by different Authors: *Frankenion pulverulentae* Rivas-Mart. ex Castroviejo & Porta 1976 (temporarily flooded depressions, with wide Mediterranean distribution), *Hordeion marini* Ladero et al. 1984 (halo-nitrophilous communities; nevertheless it is not floristically well differentiated, and is considered syn of *Frankenion pulverulentae* by several Authors, e.g. Brullo & Giusso 2003 and Mucina et al. 2016), *Polypogonion subspathacei* Gamisans 1990 (circumscribed to Corsica and Sardinia, but considered syn. of *Frankenion* by some authors, e.g. Brullo & Giusso 2003), *Gaudinio-Podospermion cani* Brullo & Siracusa 2000 (including clayey-gully inland environments of central-Mediterranean), *Limonion avei* Brullo 1988 (typical of thermo-xeric bioclimate, central Mediterranean). As regards this last alliance, Mucina et al. (2016) consider the *Limonion avei* as syn. of *Pholiuro-Spergularion* Pignatti 1952 but, as already pointed out by Guarino & Pasta (2017), the Pholiuro-Spergularion is included, in the same paper, among the synonyms of *Junco ranarii-Plantaginion commutatae*.

As already pointed out in Results, the cluster analysis of the *Saginetea* data set clearly separates two main clusters, A and B (Fig. 3b), representing two ecologically well differentiated contexts. Looking at the synoptic phidelity table at two groups, the first one includes the diagnostic species referring to *Saginetalia maritimae* and *Sileno-Catapodion* (Table 3, col. 1), while the second one includes those of *Frankenietalia* and *Frankenion pulverulentae* (Table 3, col. 2). In the 11-column synoptic table (Table 4), the first four columns (cluster A in Fig. 3b) fall into the *Sileno sedoidis-Catapodion loliacei* that is typical vegetation of the cliffs. Columns 7 and 9-11 (cluster B in Fig. 3b) are well framed in the *Frankenion pulverulentae,* being typical of areas temporarily flooded at the edge of coastal lagoons. Column 8 refers to *Limonion avei.*

At the level of plant communities, 11 syntaxa have been recognized, described below.

Rocky coasts (*Sileno-catapodion*)

***Silene sedoides* group.** Table 4, columns 1 and 2

This group includes thero-halophytic vegetation of cliffs and rocky coasts, characterized by the dominance of *Silene sedoides* (Steno-Mediterranean distribution, with eastern gravitation) on thin, sandy to coarse-sandy soils, exposed to the sea spray and occasionally to sea waves (*Parapholido incurvae-Silenetum sedoidis* Gehu et al. 1990) or on in more sheltered stands (*Sileno sedoidis-Hymelobetum revelieri* Brullo & Giusso 2003). The *Parapholido incurvae-Silenetum sedoidis* has central-eastern Mediterranean distribution, from France to Cyprus (Géhu et al. 1990, 1992b), while the *Sileno sedoidis-Hymelobetum revelieri* is circumscribed to the Apulia region (Brullo & Giusso 2003). Both the associations form mosaics with the *Crithmo-Staticetea* communities. The *Parapholido incurvae-Silenetum sedoidis* is the nomenclatural typus of the *Sileno sedoidis-Catapodion balearici*.

***Parapholis incurva* and *Plantago coronopus* group.** Table 4, column 3

This cluster has no true diagnostic species. *Catapodium balearicum* and *Plantago coronopus* are constant species, *Parapholis incurva* is both constant and dominant. These species are shared (as constant or diagnostic) with other communities of the *Sileno sedoidis-Catapodion balearici.* On the basis of floristic composition, structure and ecology, it is possible to refer this community to the *Parapholido incurvae-Catapodietum balearici* Rivas-Martínez et al. 1990 corr. Brullo & Giusso 2003, widely distributed from SW Iberian peninsula and Balearic islands to Italy, on both rocky and sandy seashores, in disturbed areas usually subject to trampling (Rivas-Martinez et al. 1990; Brullo & Giusso 2003).

***Anthemis peregrina* group.** Table 4, column 4

Anthemis peregrina (= *Anthemis tomentosa*) has East Mediterranean distribution and characterizes various associations, framed in different high syntaxa (e.g *Alkanno-Malcolmion*, *Tuberarietea*; *Euphorbion peplidis, Cakiletea maritimae*) but always on sandy soils and in coastal areas (Géhu et al. 1992a; Tomaselli et al. 2011). The communities surveyed in the study area can be referred to the *Phleo cesii-Anthemidetum tomentosae* nom. corr. hoc loco (= *Rostrario-Anthemidetum tomentosae* Tomaselli, Di Pietro & Sciandrello 2011 in Biologia 66 (6): 1038-2011; taxonomic correction: *Phleum arenarium* L. subsp. *caesium* H.Scholz has been misidentificated with *Rostraria litorea* (All.) Holub; art. 43 and art 10 of ICPN.) that is thero-halophytic communities of rocky coasts, characterized by the dominance of *Anthemis peregrina*, often in catenal contact with the *Parapholido incurvae-Silenetum sedoidis*.

Salt marshes (*Frankenion pulverulentae*)

***Hordeum marinum* group.** Table 4, columns 5 and 6

This group refers to sub-nitrophilous, therophytic, termophilous communities dominated by annual halo-tolerant to halophilous graminoids (*Hordeum marinum, Hainardia cylindrica*) widespread in Mediterranean salt marshes, on clay or sandy-clay soils, in disturbed sites subject to grazing or also abandoned fields (fallow lands). The *Hordeum marinum* communities develop in disturbed, brackish wet areas often in mosaic with *Sarcocornietea* vegetation, and can be referred to the *Spergulario salinae-Hordeetum marini* Biondi Filigheddu & Farris 2001 (= *Hordeo maritimi-Spergularietum marinae* Guarino, Minissale & Sciandrello 2008, syntax syn.), widespread in Sardinia (Biondi et al. 2001), southern Italy and Sicily (Guarino et al. 2008; Veronico et al. 2017). *Hainardia cylindrica* is sub-nitrophilous, halotolerant and stress-tolerant species, growing in badland inland areas (Biondi & Pesaresi 2004) or in coastal lagoon environments. Here we introduce a new association, the *Hordeo marini-Hainardetum cylindricae* (holotypus rel. n. 3, Table 5), dominated by *Hainardia cylindrica* along with *Hordeum marinum* and having, as diagnostic species, *Polypogon monspeliensis* and *Spergularia salina*. These communities are often in contact with the *Spergulario salinae-Hordeetum marini,* respect to which occupy positions subject to more intense disturb-nitrification. Date, site of the relevés in Tab. 5 are in Appendix A1.

#Table 5 approximately here#

***Isolepis cernua* and *Juncus hybridus* group.** Table 4, column 7

Isolepis cernua, diagnostic of the *Isoeto-Nanojuncetea* class, indicates less xerophytic and halomorphic requirements respect to the other communities of the alliance. This hygrophilous vegetation can be referred to the *Isolepido-Saginetum maritimae* Brullo 1988, growing on sandy-silty soils periodically flooded during the winter, and forming mosaic with the perennial halo-hygrophilous formations of the *Juncetalia maritimae* (Apulia, Sicily, Sardinia; Brullo & Giusso 2003).

***Frankenia pulverulenta* group.** Table 4, column 9

Halo-nitrophilous communities dominated by *Frankenia pulverulenta,* that usually develop on periodically flooded, silty soils at the edges of coastal lagoons and salt pans, in very xeric environments. This vegetation can be attributed to the *Parapholido incurvae-Frankenietum pulverulentae*, association with central-western Mediterranean distribution.

***Scorzoneroides muelleri* group.** Table 4, column 10

Scorzoneroides muelleri is a rare species with southern Mediterranean distribution, usually growing on clayey or clay-silty soils subject to periodic flooding, in semi-arid disturbed areas. These communities (*Sphenopo divaricati-Scorzoneroidetum* muelleri) are in catenal contact with the halophilous or sub-halophilous vegetation of the *Juncetea maritimae* or *Salicornietea fruticosae* classes (Sciandrello et al. 2015; Tomaselli & Sciandrello 2017).

Parapholis filiformis group. Table 4, column 11

Parapholis filiformis forms spring ephemeral grasslands with high cover values, on wet clay or sandy-clay soils, flooded in winter for very short period an dried in summer (even if maintaining some constant humidity under the ground surface), with moderate salinity and some nitrification. The *Parapholidetum filiformis* Brullo et al. 1994 usually forms mosaics with *Juncetea* or *Sarcocornietea* communities (especially *Inulion crithmoidis* and *Suaedion breviflorae*). It is characterized by less salty and more moist soils than those of other communities of *Frankenion.* It has central and southern Italy distribution (Frondoni & Iberite 2002; Brullo & Giusso 2003; Biondi & Bagella 2005; Tomaselli et al. 2011; Tomaselli & Sciandrello 2017).

Salt marshes (*Limonion avei*)

***Limonium avei* group.** Table 4, column 6

Extremely localized in the study area, in very dry environments at the edge of salt pans, the *Limonium avei* communities (*Sphenopo divaricati-Limonietum avei*) fall within the *Limonion avei*, alliance of the *Frankenietalia* circumscribed to the most arid territories of the central-eastern Mediterranean.

Conclusions

The present study contributes to provide a comprehensive framework for the classification of the therophytic halophilous vegetation in South–Eastern Italy. For both *Thero-Salicornietea* and *Saginetea maritimae* classes, an updated syntaxonomic scheme is provided, on the basis of the literature but also in the light of the results of numerical classification. A new alliance, the *Salicornion venetae* (*Thero-Salicornietalia*), is here proposed.

Nevertheless, some outstanding issues remain, in particular the proper syntaxonomical classification of *Sporobolus aculeatus* communities in Mediterranean territories, whose solution requires further investigations on a wider range of analysis.

An additional issue regards the attribution of the surveyed plant communities to habitat 1310 'Salicornia and other annuals colonizing mud and sand' (Annex I of the 92/43/EEC Directive). In fact, strictly complying with the Interpretation Manual (European Commission 2013; Biondi et al 2009), only those colonising salt marshe environments can be referred to this habitat. This means that *Thero-Salicornietea* communities all refer to habitat 1310 and instead, as regards the *Saginetea maritimae,* only *Frankenion pulverulentae* and *Limonion avei* can be considered as habitat, while *Sileno sedoidis-Catapodion balearici* should be excluded. Nevertheless, considering the presence of specialized and rare species, the often very limited extent and also the numerous pressures affecting the *Sileno-Catapodion* communities, they should be included in habitat 1310 as well.

Syntaxonomic scheme

Thero-Salicornietea Tx. in Tx. & Oberd. 1958

Thero-Salicornietalia Tx. in Tx. & Oberd. 1958 ex Géhu & Géhu-Franck 1984

Salicornion patulae Géhu & Géhu-Franck 1984

Suaedo spicatae-Salicornietum patulae Brullo & Furnari ex Géhu & Géhu-Franck 1984 corr. Alcaraz, Ríos, De la Torre, Delgado & Inocencio 1998

Salicornion venetae all nova hoc loco

Salicornietum venetae Pignatti 1966

Suaedo splendentis-Salicornietum dolichostachyae Biondi & Casavecchia 2010

Thero-Suaedetalia splendentis Br.-Bl. & O. de Bolòs 1958

Thero-Suaedion splendentis Br.-Bl. in Br.-Bl. & al. 1952

Suaedo spicatae-Bassietum hirsutae Braun-Blanquet 1928 corr. hoc loco

Suaedetum spicatae Pignatti 1953 corr. Brullo & al 2019

Bassio hirsutae-Suaedetum splendentis Biondi & Casavecchia 2010

Salsoletum sodae Pignatti 1953

Sporobolus aculeatus comm.

Microcnemion coralloidis Rivas-Mart. & Géhu in Rivas-Mart. 1984

Halopeplidetum amplexicaulis Burollet 1927

Saginetea maritimae Westhoff, Van Leeuwen & Adriani 1962

Saginetalia maritimae Westhoff, Van Leeuwen & Adriani 1962

Sileno sedoidis-Catapodion balearici de Foucault & Bioret 2010 nom. corr. hoc loco

Sileno sedoidis-Hymelobetum revelieri Brullo & Giusso 2003

Parapholido incurvae-Silenetum sedoidis Géhu et al. 1990

Parapholido incurvae-Catapodietum balearici Rivas-Martínez et al. 1990 corr. Brullo & Giusso 2003

Phleo cesii-Anthemidetum tomentosae Tomaselli, Di Pietro & Sciandrello 2011, nom. corr. hoc loco

Frankenietalia pulverulentae Rivas-Martínez ex Castroviejo & Porta 1976

Frankenion pulverulentae Rivas-Martínez ex Castroviejo & Porta 1976

Parapholido incurvae-Frankenietum pulverulentae Rivas Martinez ex Castroviejo & Porta 1976

Spergulario salinae-Hordeetum marini Biondi Filigheddu & Farris 2001

Hordeo marini-Hainardetum cylindricae ass. nova hoc loco

Isolepido-Saginetum maritimae Brullo 1988

Sphenopo divaricati-Scorzoneroidetum muelleri Sciandrello, Silletti & Tomaselli 2015

Parapholidetum filiformis Brullo, Scelsi & Siracusa 1994

Limonion avei Brullo 1988

Sphenopo divaricati-Limonietum avei Tomaselli & Sciandrello 2017

Author contribution

V.T. planned the research and led the field sampling, the statistical analyses and the writing. All other authors participated in the field sampling, contributed to the writing and critically revised the manuscript. In particular, G.V. created the data-base and revised taxonomic nomenclature, S.S. performed the ordination analysis and L.F. contributed to planning and performing the analyses and to the interpretation of the results.

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Appendix I

Date, site of relevés in Tab. 5 (Hordeo marini-Hainardetum cylindricae) - 1-2: 20/05/2015, Saline Punta della Contessa (BR); 3-6: 11/06/2013, S. Floriano (BAT); 7-8: 24/06/2014, Saline Punta della Contessa (BR); 9-10: 05/06/2014, S. Floriano (BAT). Sporadic species – Rel. 1: Filago pygmaea (+); rel. 3: Soda inermis (1); Rel. 7: Trigonella sicula (+); Rel. 8: Suaeda maritima (1), Cynodon dactylon (1).

Tab. 1

Percentage synoptic table with fidelity (Phi coeff.)			
cluster	1	2	3
n of relevés	41	23	124
Atriplex tatarica	---	---	44.7
Galatella pannonica subsp. pannonica	---	---	18.2
Halimione portulacoides	---	20.9	---
Hordeum marinum	---	---	20.9
Puccinellia festuciformis subsp. lagascana	---	44	---
Salicornia dolichostachya	---	47.5	---
Salicornia fruticosa	31.9	---	---
Salicornia patula	73.6	---	---
Salicornia veneta	---	87.7	---
Soda inermis	---	---	55.2
Spirobassia hirsuta	---	---	52.6
Sporobolus aculeatus	---	---	22.6
Suaeda spicata	---	---	20.3
Suaeda splendens	---	---	29.6

Tab. 1 - Synoptic fidelity table for the Thero-Salicornietea at 3 goups, discriminating at the level of orders/alliances. 1: Salicornion patulae and 2: Salicornion venetae (Thero-Salicornietalia); 3: Thero-Suaedion (Thero-Suaedetalia splendentis).

Tab. 2

Percentage synoptic table									
cluster	1	2	3	4	5	6	7	8	9
n of relevès	41	49	11	24	11	4	25	16	7
Char. and Diff. associations									
Sporobolus aculeatus	2	0	0	13	100	0	4	0	0
Therosalicornietea, Thero-Suaedetalia splendentis and Thero-Suaedion splendentis									
Soda inermis	7	39	27	25	70	33	100	0	0
Suaeda spicata	61	100	100	0	30	0	40	19	0
Spirobassia hirsuta	22	100	0	46	0	0	64	0	0
Suaeda splendens	7	0	0	100	40	0	0	0	0
Thero-Salicornietalia and Salicornion patulae									
Salicornia patula	100	51	64	29	40	0	4	13	0
Salicornion venetae									
Salicornia veneta	2	0	0	4	0	0	0	100	0
Salicornia dolichostachya	0	0	0	0	0	0	0	0	100
Microcnemion coralloidis									
Halopeplis amplexicaulis	0	0	0	0	0	100	0	0	0

Tab. 2 - Synoptic frequency table for the Thero-Salicornietea at 9 goups, discriminating at the level of plant communities: 1 - *Salicornia patula* comm. (*Suaedo spicatae-Salicornietum patulae*); 2 – *Spirobassia hirsuta* comm. (*Suaedo spicate-Bassietum hirsutae*); 3 – *Suaeda spicata* comm. (*Suaedetum spicatae*); 4 – *Suaeda splendens* comm. (*Bassio hirsutae-Suaedetum splendentis*); 5 – *Sporobolus aculeatus* (= *Crypsis aculeata*) comm.; 6 – *Halopeplis amplexicaulis* comm. (*Halopeplidetum amplexicaulis*); 7 – *Soda inermis* (= *Salsola soda*) comm. (*Salsoletum sodae*); 8 – *Salicornia veneta* comm. (*Salicornietum venetae*); 9 – *Salicornia dolichostachya* comm. (*Suaedo splendentis-Salicornietum dolychostachyae*).

Tab. 3

Percentage synoptic table with fidelity (Phi coeff.)		
cluster	1	2
n of relevés	84	104
Anacyclus clavatus	---	30.7
Anthemis peregrina	65.1	---
Bellis annua	---	22.5
Beta vulgaris subsp. maritima	30.2	---
Bromus racemosus ssp. racemosus	---	24.7
Catapodium balearicum	80.4	---
Catapodium pauciflorum	61.4	---
Centaurium erythraea ssp. erythraea	---	28.9
Crithmum maritimum	32.4	---
Cynodon dactylon	16.1	---
Frankenia hirsuta	58.7	---
Frankenia pulverulenta	---	20.5
Hainardia cylindrica	---	30.8
Hordeum marinum	---	63.7
Hornungia procumbens subsp. revelierei	30.2	---
Isolepis cernua	---	21.3
Juncus hybridus	---	41.8
Lagurus ovatus subsp. ovatus	25.4	---
Limonium avei	---	17.2
Limonium japigicum	42.8	---
Limonium narbonense	---	28.9
Limonium virgatum	55	---
Lolium rigidum subsp. rigidum	---	42.6
Lotus cytisoides	44.7	---
Lysimachia arvensis subsp. arvensis	---	35.3
Medicago littoralis	49.5	---
Moraea sisyrinchium	39.8	---
Parapholis filiformis	---	34.4
Parapholis incurva subsp. incurva	24.3	---
Phleum arenarium subsp. caesium	35.3	---
Plantago coronopus	28.9	---
Polypogon maritimus subsp. maritimus	---	23.6
Polypogon monspeliensis	---	38.6
Puccinellia festuciformis subsp. lagascana	---	49.5
Reichardia picroides	52.5	---
Scorzoneroides muelleri	---	45
Silene sedoides ssp. sedoides	49.4	---
Soda inermis	---	24.7
Spergularia marina	---	28.3
Spergularia media	---	31.7
Sphenopus divaricatus ssp. divaricatus	---	53.3
Suaeda vera	---	48.8
Trifolium scabrum	25.9	---
Trigonella sicula	---	52.5
Trigonella sulcata	---	24.7
Valantia muralis	27.7	---

Tab. 3 - Synoptic fidelity table for the Saginetea maritimae at 3 goups, discriminating at the level of orders/alliances: 1: Sileno sedoidis-Catapodion balearici (Saginetalia maritimae); 2: Frankenion pulverulentae (Frankenietalia pulverulentae).

Tab. 4

Percentage synoptic table											
cluster	1	2	3	4	5	6	7	8	9	10	11
n of relevès	8	19	27	30	19	10	9	6	6	18	20
Char. and Diff. associations											
Hornungia procumbens subsp. revelierei	100	32	0	0	0	0	0	0	0	0	0
Anthemis peregrina	0	47	41	100	0	0	0	0	0	0	0
Phleum arenarium subsp. caesium	0	0	19	63	0	0	0	0	0	0	15
Hainardia cylindrica	0	0	0	0	32	100	0	0	0	0	10
Hordeum marinum	0	0	0	0	100	100	44	83	0	65	0
Isolepis cernua	0	0	0	0	0	0	100	0	0	0	0
Scorzoneroides muelleri	0	0	0	0	5	0	0	0	0	100	0
Saginetea maritimae and Saginetalia maritimae											
Parapholis incurva subsp. incurva	100	89	100	53	68	30	67	100	100	59	35
Plantago coronopus	75	95	96	53	37	30	78	100	33	65	30
Sagina maritima	50	26	22	13	11	0	44	100	0	0	15
Spergularia marina	0	0	26	0	63	70	33	0	100	0	20
Centaurium tenuiflorum s.l.	0	11	0	17	11	20	22	0	0	0	25
Sileno sedoidis-Catapodion balearici											
Silene sedoides ssp. sedoides	100	100	4	17	0	0	0	0	0	0	0
Catapodium balearicum	100	53	67	100	0	0	0	0	0	0	0
Catapodium pauciflorum	0	53	41	83	0	0	0	0	0	0	0
Frankenietalia pulverulentae and Frankenion pulverulentae											
Frankenia pulverulenta subsp. pulverulenta	0	0	7	0	0	0	0	100	100	6	0
Sphenopus divaricatus subsp. divaricatus	0	0	0	0	42	10	0	100	100	68	10
Polypogon maritimus subsp. maritimus	0	0	0	0	16	0	0	33	0	0	30
Polypogon monspeliensis	0	0	0	0	32	70	22	0	0	18	30
Juncus hybridus	0	0	0	0	26	20	100	0	0	12	55
Parapholis filiformis	0	0	0	0	0	20	0	0	0	0	100
Limonion avei											
Limonium avei	0	0	0	0	0	0	0	100	0	0	0

Synoptic frequency table for the Sagineea maritimae at 11 goups, discriminating at the level of plant communities: 1 and 2 - *Silene sedoidis* communities (1 - *Sileno sedoidis-Hymenolobetum revelieri*; 2 - *Parapholido incurvae-Silenetum sedoidis*); 3 – *Parapholis incurva* comm. (*Parapholido incurvae-Catapodietum balearici*); 4 – *Anthemis peregrina* (= *A. tomentosa*) comm. (*Phleo cesii-Anthemidetum tomentosae*); 5 – *Hordeum maritimum* comm. (*Spergulario salinae-Hordeetum marini*); 6 – *Haynardia cylindrica* comm. (*Hordeo marini-Hainardetum cylindricae*); 7 – *Isolepis cernua* comm. (*Isolepido-Saginetum maritimae*); 8 – *Limonium avei* comm. (*Sphenopo divaricati-Limonietum avei*); 9 – *Frankenia pulverulenta* comm. (*Parapholido incurvae-Frankenietum pulverulentae*); 10 – *Scorzoneroides muelleri* comm. (*Sphenopo divaricati-Scorzoneroidetum muelleri*); 11 – *Parapholis filiformis* comm. (*Parapholidetum filiformis*)

Tab. 5

relevé number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
surface (sqm)	8	10	30	10	10	20	12	6	10	10
cover (%)	70	85	85	90	90	90	100	95	90	85
Char. and Diff. Association										
Hainardia cylindrica	4	5	5	5	5	5	3	2	+	1
Hordeum marinum	2	1	1	3	2	3	5	4	5	5
Saginetea maritimae and Saginetalia maritimae										
Spergularia marina	.	+	2	.	+	.	2	1	2	1
Parapholis incurva subsp. incurva	.	.	2	.	.	.	.	.	2	1
Plantago coronopus	1	2	.	.	.	.	.	.	1	.
Centaurium tenuiflorum s.l.	1	+	.	.	.	.	.	.	.	.
Frankenietalia pulverulentae and Frankenion pulverulentae										
Polypogon monspeliensis	.	.	+	1	+	+	+	.	+	1
Parapholis filiformis	.	.	.	.	.	.	+	1	.	.
Juncus hybridus	.	.	.	.	.	.	1	+	.	.
Sphenopus divaricatus subsp. divaricatus	.	.	1	.	.	.	.	.	.	.
Other species										
Puccinellia festuciformis subsp. lagascana	.	.	1	1	+	1	.	+	+	1
Lolium rigidum subsp. rigidum	.	.	+	+	.	+	.	.	.	+
Beta vulgaris subsp. Maritima	+	+	.	.	.	.	1	1	.	.
Atriplex prostrata	.	.	.	.	+	+	+	+	.	.
Trigonella sulcata	.	.	.	.	.	.	+	.	+	1
Anacyclus clavatus	1	1	.	.	.	.	.	.	.	.
Helminthotheca echioides	.	.	.	.	.	.	+	.	.	+
Phalaris paradoxa	.	.	.	.	.	.	+	.	+	.
Suaeda vera	.	.	+	.	.	.	.	.	+	+

Tab. 5: Hordeo maritimi-Haynardietum cylindricae, ass. nova hoc loco.

Fig. 1

a b

Fig. 1 – Study area with the location of sites where phytosociological relevés have been performed; a) Thero-Salicornietea; b) Saginetea maritimae.

Fig. 2

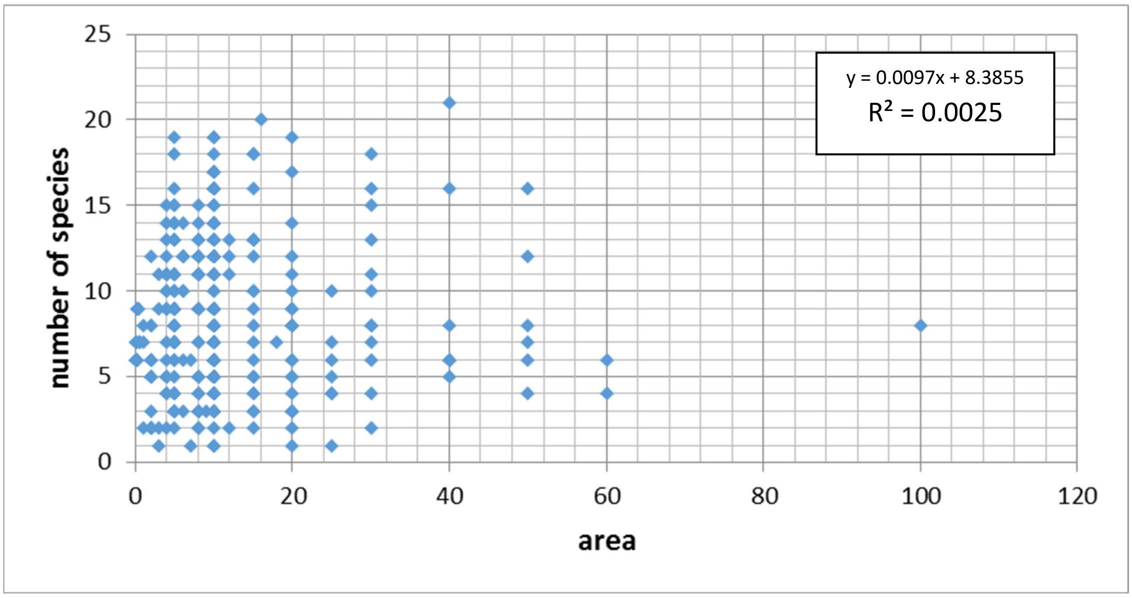


Fig. 2 – Graphic resulting from the correlation analysis between relevé area and number of species per relevé.

Fig 3a

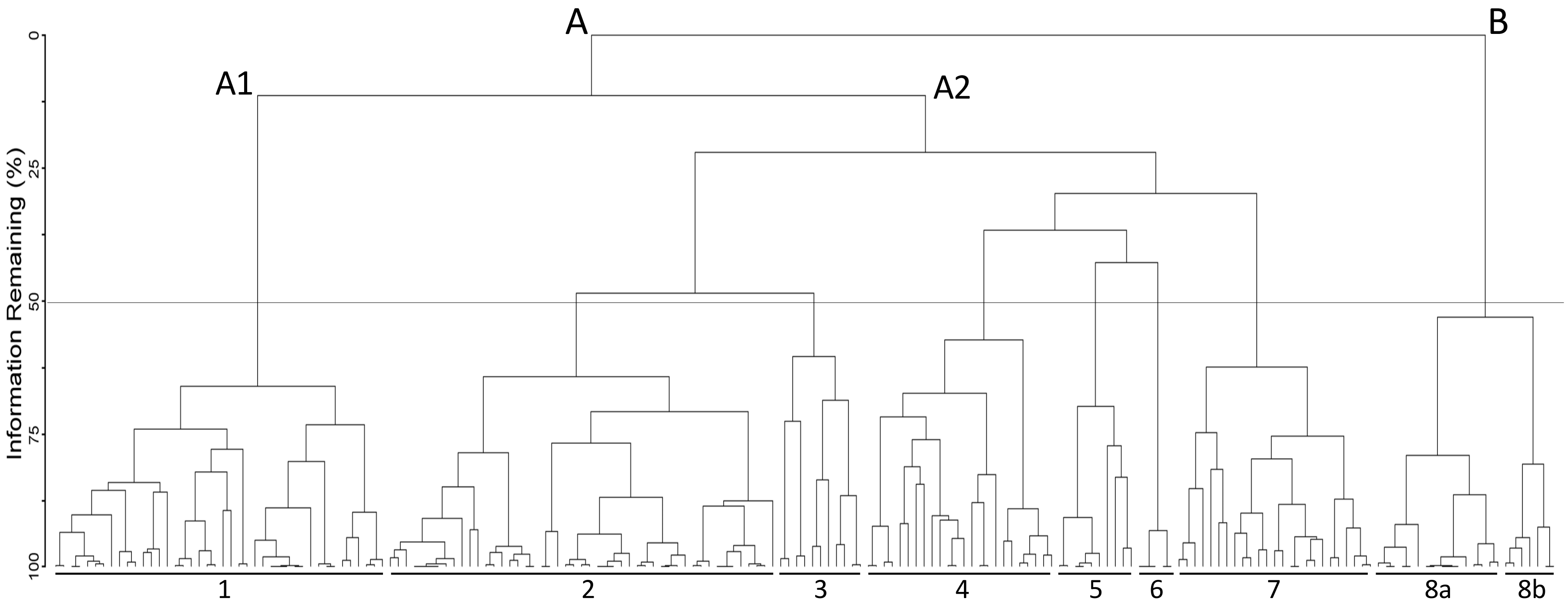


Fig. 3a - Dendrogram from the cluster analysis (Bray Curtis, Fexible Beta) of the *Thero-Salicornietea* data-set: 1 - *Salicornia patula* comm. (*Suaedo spicatae-Salicornietum patulae*); 2 – *Spirobassia hirsuta* comm. (*Suaedo spicate-Bassietum hirsutae*); 3 – *Suaeda spicata* comm. (*Suaedetum spicatae*); 4 – *Suaeda splendens* comm. (*Bassio hirsutae-Suaedetum splendentis*); 5 – *Sporobolus aculeatus* (= *Crypsis aculeata*) comm.; 6 – *Halopeplis amplexicaulis* comm. (*Halopeplidetum amplexicaulis*); 7 – *Soda inermis* (= *Salsola soda*) comm. (*Salsoletum sodae*); 8a – *Salicornia veneta* comm. (*Salicornietum venetae*); 8b – *Salicornia dolichostachya* comm. (*Suaedo splendentis-Salicornietum dolychostachyae*).

Fig 3b

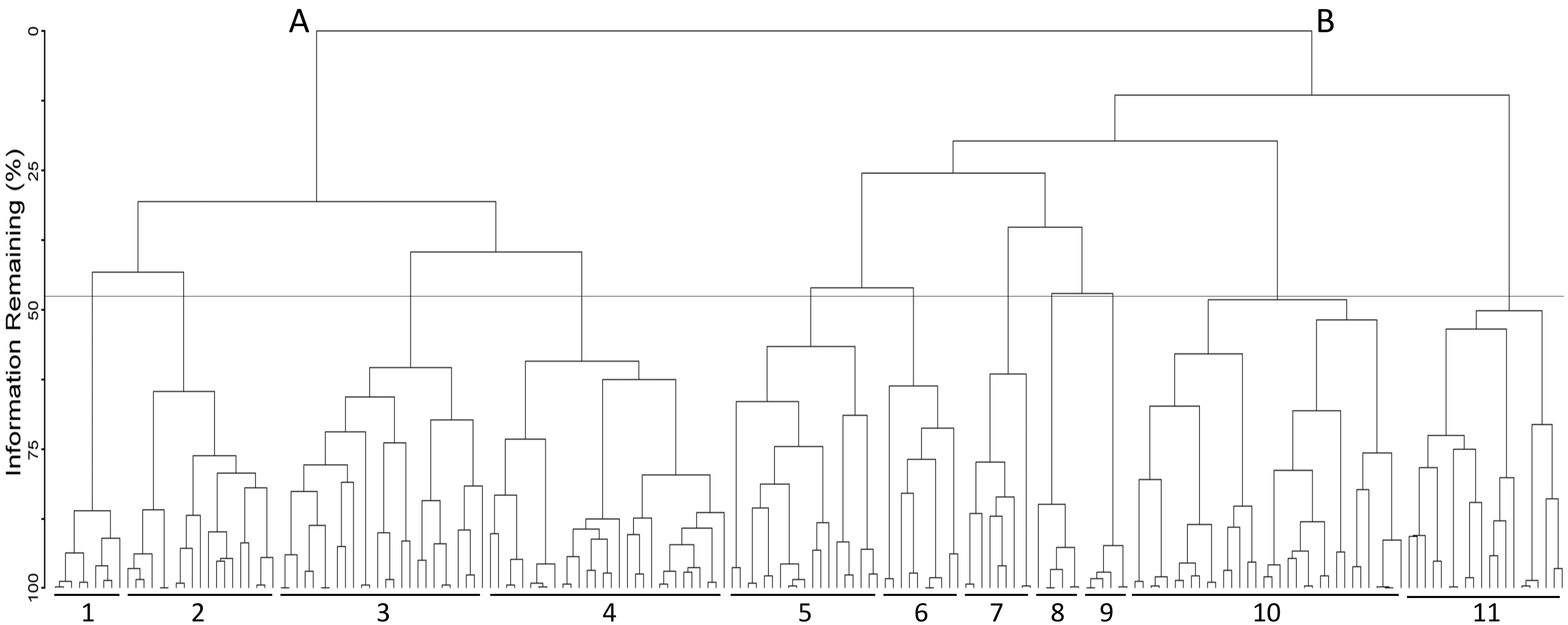
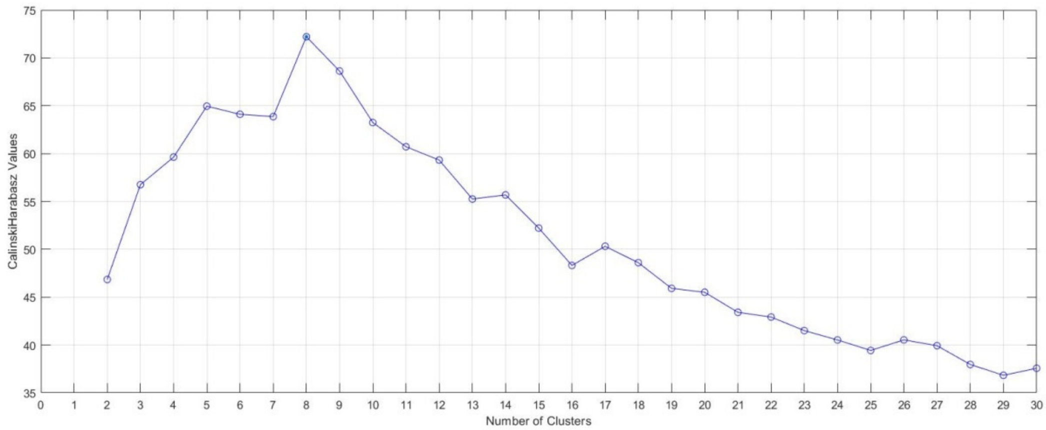


Fig. 3b - Dendrogram from the cluster analysis (Bray Curtis, Fexible Beta) of the *Saginetea* data-set: 1 and 2 - *Silene sedoidis* communities (1 - *Sileno sedoidis-Hymenolobetum revelieri*; 2 - *Parapholido incurvae-Silenetum sedoidis*); 3 – *Parapholis incurva* comm. (*Parapholido incurvae-Catapodietum balearici*); 4 – *Anthemis peregrina* (= *A. tomentosa*) comm. (*Phleo cesii-Anthemidetum tomentosae*); 5 – *Hordeum maritimum* comm. (*Spergulario salinae-Hordeetum marini*); 6 – *Haynardia cylindrica* comm. (*Hordeo marini-Hainardetum cylindricae*); 7 – *Isolepis cernua* comm. (*Isolepido-Saginetum maritimae*); 8 – *Limonium avei* comm. (*Sphenopo divaricati-Limonietum avei*); 9 – *Frankenia pulverulenta* comm. (*Parapholido incurvae-Frankenietum pulverulentae*); 10 – *Scorzoneroides muelleri* comm. (*Sphenopo divaricati-Scorzoneroidetum muelleri*); 11 – *Parapholis filiformis* comm. (*Parapholidetum filiformis*).

Fig 4

a



b

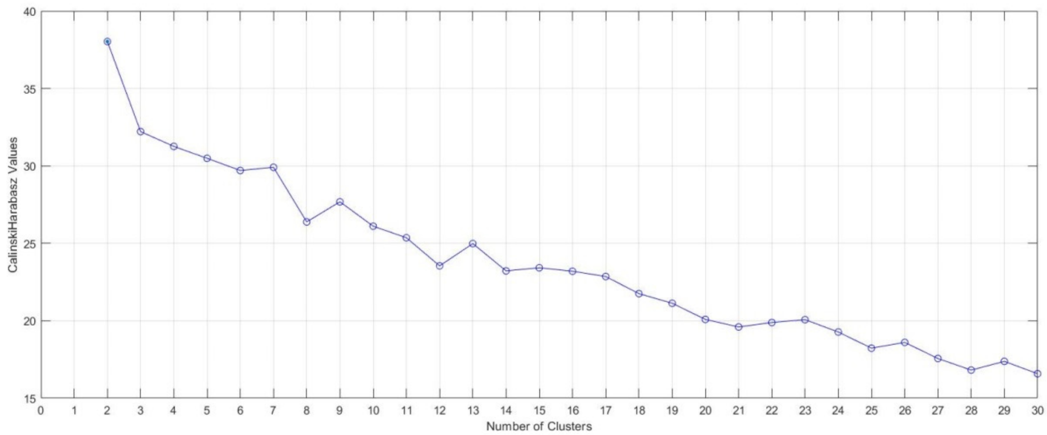
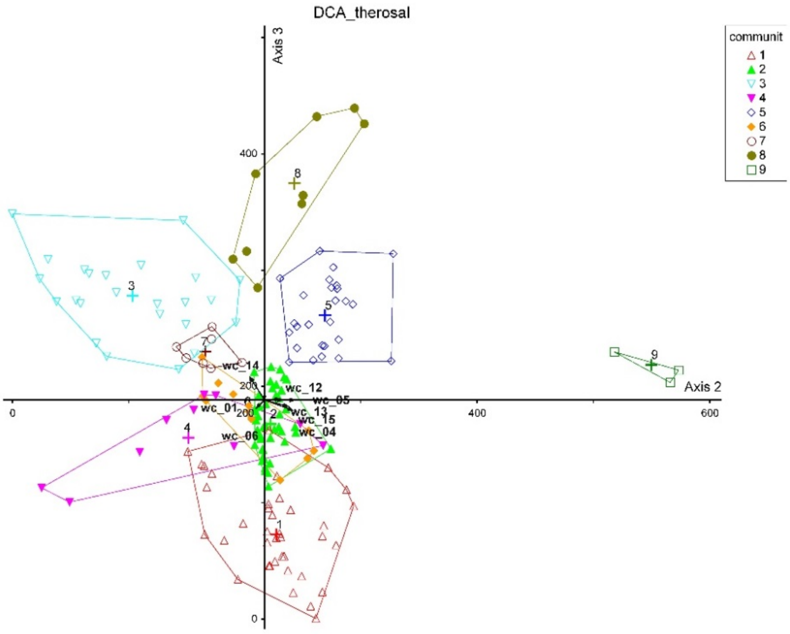


Fig. 4 - CH Index, expressing the ratio between-cluster variance and the overall within-cluster variance, computed for *Thero-Salicornietea* (a) and *Saginetea maritimae* (b) data-sets.

Fig 5

a



b

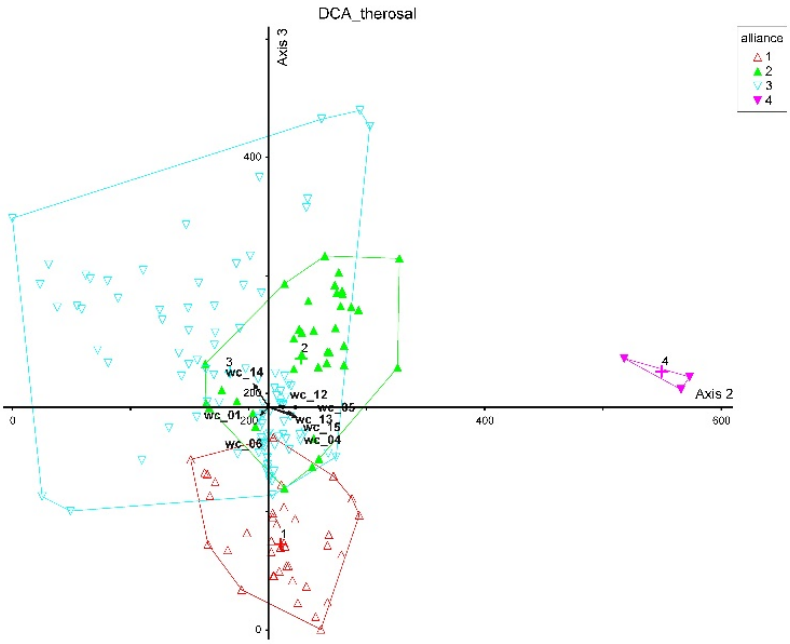


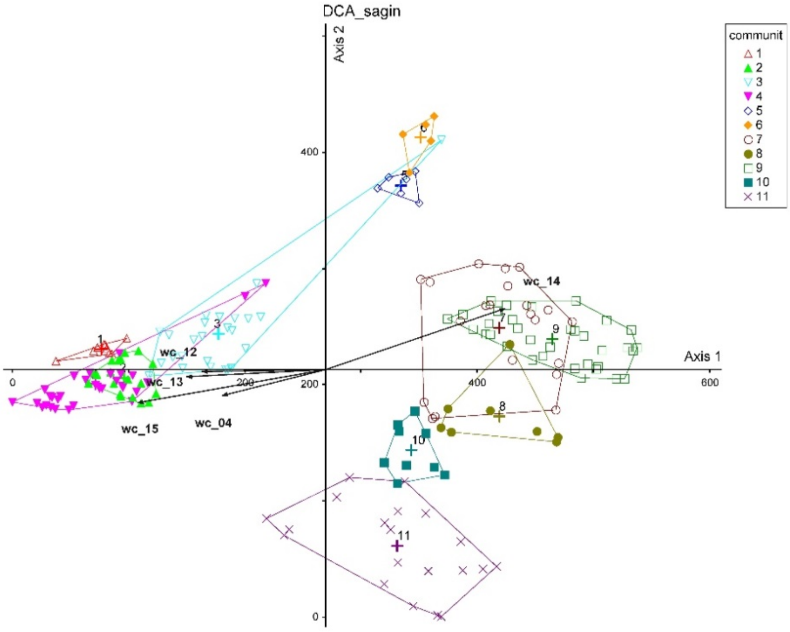
Fig. 5: DCA ordination of *Thero-Salicornietea* relevés, 2D (axis 2-3). Results allow to highlight main gradients of precipitation (soil moisture) and soil salinity (soil nitrates) on axes 2 and 3. The different communities (a) and alliances (b) result quite well separated.

(a) - 1: *Suaedo spicatae-Salicornietum patulae*; 2: *Suaedo spicatae-Bassietum hirsutae*; 3: *Suaedetum spicatae*; 4: *Salsoletum sodae*; 5: *Salicornietum venetae*; 6: *Suaedo splendentis-Salicornietum dolychostachyae*; 7: *Bassio-Suaedetum splendentis*; 8: *Sporobolus aculeatus* comm.; 9: *Halopeplidetum amplexicaulis*.

(b) – 1: *Salicornion patulae*; 2: *Salicornion venetae*; 3: *Thero-Suaedion splendentis*; 4: *Microcnemion coralloidis*

Fig 6

a



b

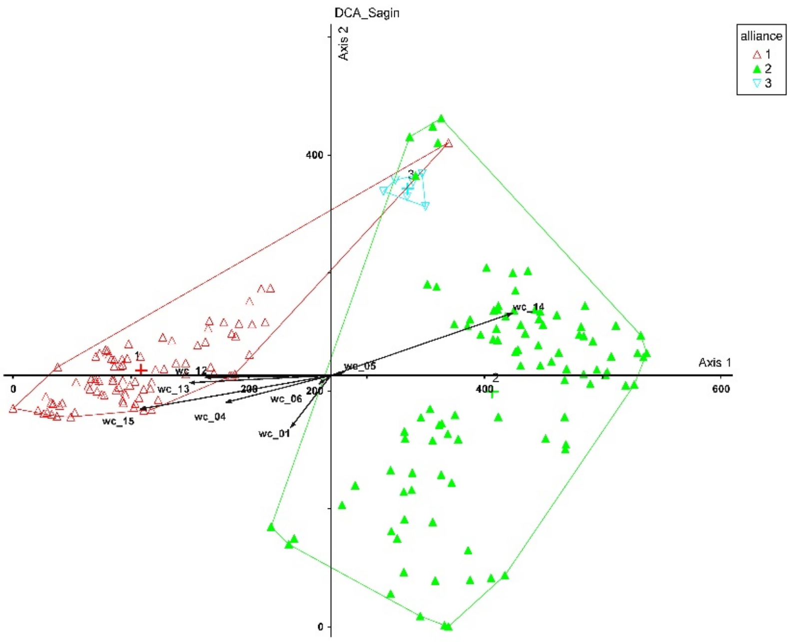


Fig. 6: DCA ordination of *Saginetea maritimae* relevés, 2D (axis 1-2). Results allow to highlight main gradients of precipitation (soil moisture) and granulometry on axis 1 and of soil salinity (soil nitrates) on axis 2. The different communities (a) and alliances (b) result quite well separated.

(a) - 1: *Sileno sedoidis-Hymenolobetum revelieri*; 2: *Parapholido incurvae-Silenetum sedoidis*; 3: *Parapholido incurvae-Catapodietum balearici*; 4: *Phleo cesii-Anthemidetum tomentosae*; 5: *Sphenopo divaricati-Limonietum avei*; 6: *Parapholido incurvae-Frankenietum pulverulentae*; 7: *Spergulario salinae-Hordeetum marini*; 8: *Hordeo marini-Hainardetum cylindricae*; 9: *Sphenopo divaricati-Scorzoneroidetum muelleri*; 10: *Isolepido-Saginetum maritimae*; 11: *Parapholidetum filiformis*.

(b) – 1: *Sileno-Catapodion balearici*; 2: *Frankenion pulverulentae*; 3: *Limonion avei*.

On the positive side of axis 1 the salt marshes communities included in *Frankenion pulverulentae* and *Limonion avei* alliances clearly segregate, while the rocky coasts communities of the *Sileno sedoidis-Catapodion balearici* are located on the negative side. Along the axis 2, the most halophilous communities of salt marshes (*Sphenopo divaricati-Limonietum avei* and *Parapholido incurvae-Frankenietum pulverulentae*) segregate on the positive side, and the sub-halophylous of moist soils (*Isolepido-Saginetum maritimae, Parapholidetum filiformis*) on the negative side.