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Phytosociological analysis in Sardinian Mediterranean temporary wet habitats

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Abstract
The aims of this research were to contribute to the knowledge of the Mediterranean temporary wet habitats vegetation and to investigate the spatial distribution and the temporal successions of plant communities under different hydrological regimes in North Western Sardinia. The vegetation was sampled in temporary wet habitats located in large depressions (temporary ponds), in small depressions in patchwork with the vegetation dominated by *Myrtus communis* (waterlogged soils) and in rocky outcrops (rock pools). Three belts were recognized in temporary ponds: a central belt, an intermediate belt, and an outer belt. Overall 11 associations and subassociations were identified, within 4 syntaxonomic classes: *Potametea, Isoeto-Nanojuncetea, Isoeto-Littorelletea* and *Phragmito-Magnocaricetea*. Four new associations have been described: *Isoeto tigulianae-Callitrichetum brutiae, Romuleo requienii-Isoetetum histricis, Apio crassipedis-Elatinetum macropodae,* and *Lythro hyssopifoliae-Crassuletum vaillantii.* Moreover, within the *Preslion cervinae* alliance of the *Isoeto-Nanojuncetea* class, a new Tyrrhenian suballiance *Apienion crassipedis*, has been established, for which the typical association is the *Apio crassipedis-Isoetetum tigulianae* Biondi & Bagella 2005 corr. hoc loco. Aquatic vegetation was found in the central and intermediate belt of the temporary ponds and within the rock pools. Late winter–spring amphibious communities were present in almost all temporary wet habitats. Summer plant communities were found exclusively in the central belt of temporary ponds.

Key words: *Apienion crassipedis*, biogeography, hydrological regimes, *Isoeto-Nanojuncetea*, rock pools, temporary ponds, waterlogged soils.

Riassunto
Con questa ricerca si è voluto dare un contributo alla conoscenza della vegetazione che caratterizza gli habitat temporaneamente inondati del Mediterraneo e, in particolare, alla sua distribuzione spaziale e alla sua dinamica temporale in diverse condizioni di inondazione. Le analisi sono state effettuate nella Sardegna Nord occidentale in tre diverse tipologie di habitat umidi: ampie depressioni (stagni temporanei), piccole depressioni a mosaico con la vegetazione arbustiva a dominanza di *Myrtus communis* e cavità rocciose. Solo all'interno degli stagni temporanei è stata riconosciuta una zonizzazione della vegetazione, determinata dalla presenza di tre fasce concentriche: una centrale, una intermedia e una esterna. Le analisi fitosociologiche hanno consentito di individuare 11 associazioni e subassociazioni riferibili a quattro classi: *Potametea, Isoeto-Nanojuncetea, Isoeto-Littorelletea* e *Phragmito-Magnocaricetea*. Sono state riconosciute e descritte 4 nuove associazioni: *Isoeto tigulianae-Callitrichetum brutiae, Romuleo requienii-Isoetetum histricis, Apio crassipedis-Elatinetum macropodae* e *Lythro hyssopifoliae-Crassuletum vaillantii* e una nuova suballeanza a distribuzione tirrenica del *Preslion cervinae*, indicata come *Apienion crassipedis* per la quale è stata indicata come associazione tipo *Apio crassipedis-Isoetetum tigulianae* Biondi & Bagella 2005 corr. hoc loco. La vegetazione acquatica è stata rinvenuta nella fascia centrale e in quella intermedia degli stagni temporanei e all'interno delle cavità rocciose. La vegetazione anfibia tardo invernale-primaverile è stata invece rinvenuta in tutte le tipologie di habitat indagati. Infine la vegetazione anfibia a fenologia estiva è stata rinvenuta esclusivamente nella fascia centrale degli stagni.

Parole chiave: *Apienion crassipedis*, biogeografia, *Isoeto-Nanojuncetea*, regime idrologico, stagni temporanei.

Introduction

Temporary wet habitats (TWHs) are shallow wetlands, characterized by alternating phases of drought and flooding and by a very self-contained hydrology. They occur in endoreic depressions that are submerged for sufficiently long periods of time to allow the development of hydromorphic soils, aquatic or semi-aquatic vegetation, and specific animal communities. However, they dry out for a sufficiently long duration to exclude more widespread plant and animal communities, characteristic of permanent wetlands (Grillas, 2004).

The high spatial-time variability of plant and animal communities in TWHs, mostly depends on their hydrological regime (e.g. water-depth dynamics and flooding period), morphology, and size (Fernández-Aláez *et al.*, 1999; Collinson *et al.*, 1995; Oertli *et al.*, 2002; Williams, 2005; Deil, 2005).

From a syntaxonomic point of view, the vegetation that characterizes these habitats is referable not only to the class *Isoeto-Nanojuncetea* Br.-Bl. & Tüxen ex Westhoff, Dijk, & Passchier 1946, which includes pioneer annual and dwarf perennial ephemeral isoetid communities growing on periodically flooded bare soils, but also to the classes (a) *Isoeto-Littorelletea* (Br.-Bl. & Vlieger in Vlieger, 1937), which includes dwarf helophyte amphibious oligotrophic communities on shores of dystrophic lakes, nutrient-poor standing/slow-flooding water, and (b) *Charetea fragilis* Fukarek ex Krausch 1964, which includes *Charophyte* pioneer communities growing on subaquatic barren soils of pools, lakes, and shallow water courses (Rivas-Martínez *et al*., 2002). Furthermore, communities belonging to other classes, such as *Potametea* Klika in Klika & Novák 1941, *Phragmito-Magnocaricetea* Klika in Klika & Novák 1941, *Molinio-Arrhenatheretea* Tüxen 1937 and *Helianthemetea guttati* (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 em. Rivas-Martínez 1978, could be present in a temporal succession at the same sites (Bagella *et al.*, 2007).

Mediterranean temporary wet habitats are considered to be habitats of Community Interest (European Commission, 1992) and are included in the "standing water group". Following Bagella *et al*. (2007), *Isoetion* communities have to be assigned to the habitat 3170*-Mediterranean temporary ponds; *Preslion cervinae*, *Cicendio-Solenopsion laurentiae* and *Agrostion salmanticae* communities have to be assigned to habitat 3120-Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean with *Isoetes* spp.; *Cyperetalia fusci* and *Littorelletea uniflorae* communities to habitat 3130-Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *Isoeto-Nanojuncetea*.

The aims of this research were: i) to characterize the hydrological regimes (water depth and flooding duration) in different kinds of Mediterranean temporary wet habitats; ii) to contribute to the phytosociological knowledge, both biogeographical and ecological aspects, of the Mediterranean temporary wet habitats vegetation and iii) to investigate the spatial distribution and the temporal successions of plant communities under different hydrological regimes.

Fig. 1 – Location of the study area

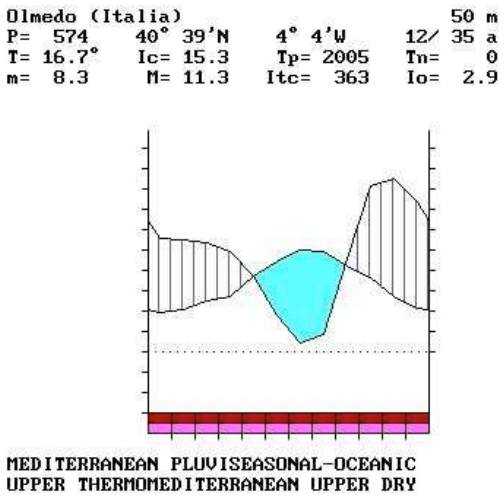

Fig. 2 – Thermopluviometric diagram for the study area

Materials and Methods

The study area, the tableland of Monte Rosso – Monte Miale Ispina (200 m a.s.l.), is located in North-Western Sardinia, in the municipality of Olmedo, province of Sassari, Sardinia (Fig. 1). This tableland, of impermeable ignimbritic rocks of the Oligo-Miocene (Barca *et al*., 1996), is 430 ha, of which temporary wet habitats occupy 12 ha. Annual mean temperature is 16.7°C and annual rainfall is 573.6 mm (average for the years 1988-99 and 1965-99, respectively). According to the classification by Rivas-Martìnez *et al.* (2002), the area is included in the thermo-Mediterranean phytoclimatic belt (Fig. 2).

The plant landscape is characterized by the neutro-acidophilic cork-oak series, *Violo dehnhardtii-Querco suberis myrtetosum communis* sigmetum (Bacchetta *et al*., 2004), typical of hydromorphic soils with a clay texture and slow drainage. Land use until 20 years ago was mainly based on traditional livestock activities. Subsequently, a strong reduction of the stocking rate occurred, leading to the current total abandoning of the territory.

Regular surveys of vegetation were carried out every month, beginning from March, according to the method of the sigmatist school of Zürich-Montpellier (Braun-Blanquet, 1951), until the vegetation was completely withered. The vegetation was sampled in the temporary wet habitats (TWHs) located in large depressions (temporary ponds = TPs), in small depressions in patchwork with the vegetation dominated by *Myrtus communis* (waterlogged soils = WSs), and in rocky outcrops (rock pools = RPs) (Fig. 3). Following the zonation scheme proposed for Moroccan ponds (Rhazi *et al.*, 2006), which is based on water depth at the beginning of the season, morphology of the pond and kind of vegetation present, three belts were recognized in the TPs: a central belt (CB), an intermediate belt (IB), and an outer belt (OB). Water depth was monitored monthly throughout the year in the RPs, in the WSs and in the 3 belts of the TPs.

Phytosociological data were converted according

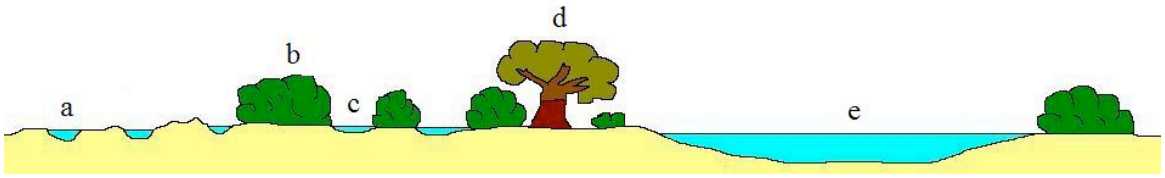

Fig. 3 – Plant landscape of the study area (a = rock pools; b = *Myrtus communis* maquis; c = water logged soils; d = *Violo dehnhardtii-Quercetum suberis myrtetosum*; e = temporary pond).

to the ordinal scale proposed by Van der Maarel (1979). A matrix of similarities between each pair of samples was then calculated using the Bray–Curtis similarity coefficient on untransformed data (Bray & Curtis, 1957). Cluster analysis was used to produce a dendrogram of the surveys with the algorithm of medium linkage (Anderson & Underwood, 1997). Plant communities were identified as homogeneous groups in the dendrogram of the surveys. Formal significance tests for differences between groups were conducted using the one-way analysis of similarities (ANOSIM) permutation/randomization test (Clarke & Warwick, 2001). The phytosociological tables were arranged on the basis of the statistical analysis.

The nomenclature follows Ferrarini *et al.* (1986) for the Pteridophytes and Tutin *et al.* (1964–1980, 1993) and Pignatti (1982) for the Spermatophytes. Life forms were classified according to Raunkiaer (1934), by using types and abbreviations reported by Pignatti (1982). Weighted life form spectra were calculated for each plant community, in addition to the richness and evenness values (Shannon & Weaver, 1949).

For the syntaxonomy were followed the standards contained in the third edition of the International Code of Phytosociological Nomenclature (Weber *et al.*, 2000).

Results

Hydrological regimes

In the TPs, the maximum water depth was reached in February in each belt. Differences in depth between the CB and the IB was 6-11 cm and between IB and OB was 4-12 cm. The flooding period was 8 months in CB, 7 months in IB, and 2 months in OB (Fig. 4).

In the WSs, the flooding period was from January to April, with a maximum water depth of 5 cm in February. RPs were filled in February and completely dry in March.

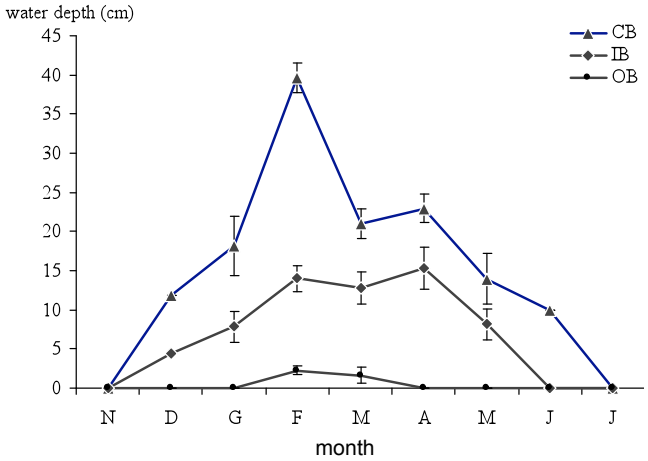

Fig. 4 – Water-depth trend (± sd).

Vegetation

Overall, 111 surveys were carried out and 82 taxa recorded. In the dendrogram (Fig. 5), two main clusters were identified: cluster A included late winter–spring vegetation; cluster B included summer vegetation. Within cluster A, sub-cluster a1 included aquatic vegetation, and sub-cluster a2 included amphibious vegetation. On the whole, 11 plant communities were identified (Fig. 5). Differences between the communities were significant by the ANOSIM test (Global R = 0.944; significance level of sample statistic = 0.001; $0.001<p<0.029$).

Late winter–spring vegetation

Aquatic vegetation

Aquatic vegetation includes communities of the *Isoeto-Littorelletea, Potametea,* and *Phragmito-Magnocaricetea* classes and *Preslion cervinae* alliance of the *Isoeto-Nanojuncetea* class.

ELEOCHARO PALUSTRIS-JUNCETUM HETERO-PHYLLI Paradis & Pozzo di Borgo 2005 (Table 1)

The plant communities referable to this association, originally described in Corse (Paradis & Pozzo di Borgo, 2005) and here indicated for the first time in Sardinia, were located in the CBs of the TPs during

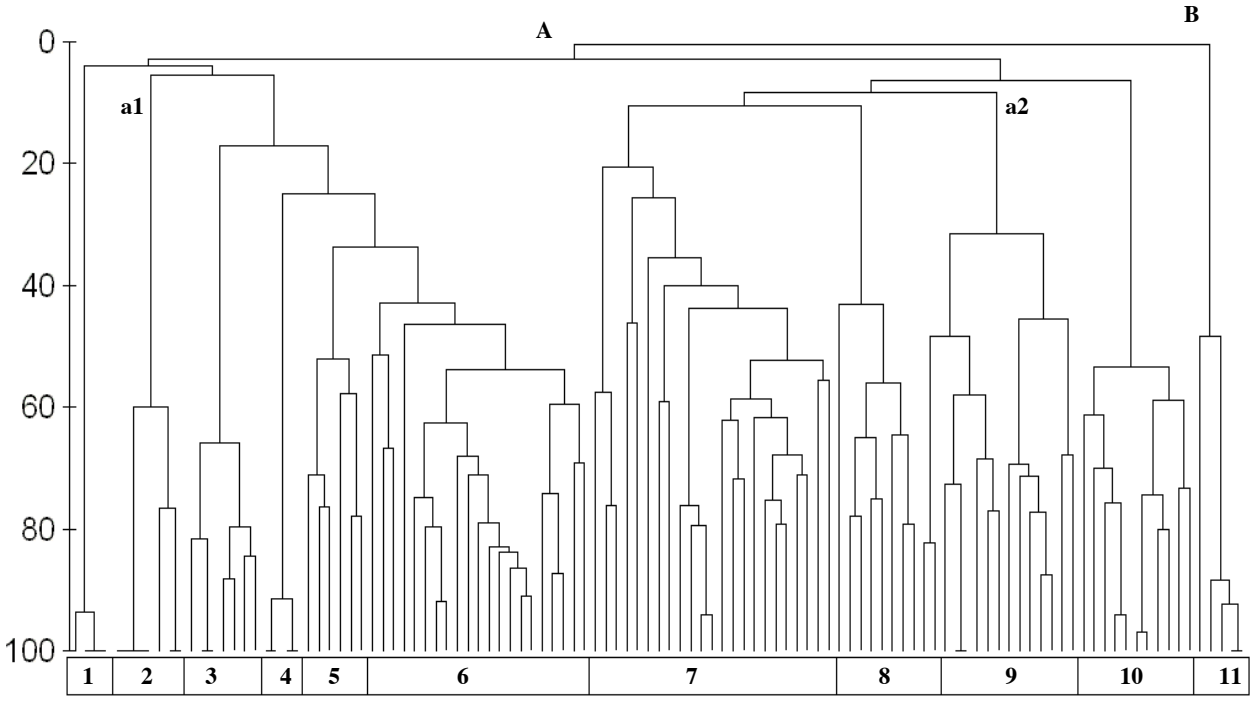

Fig. 5 – Dendrogram of the surveys (1 = *Eleocharo palustris-Juncetum heterophylli*; 2 = *Callitrichetum stagnalis*; 3 = *Baldellio ranunculoidis-Eleocharitetum palustris*; 4 = *Apio crassipedis-Elatinetum macropodae*; 5 = *Isoeto tigulianae-Callitrichetum brutiae*; 6 = *Apio crassipedis-Isoetetum tigulianae*; 7 = *Romuleo requienii-Isoetetum histricis*; 8 = *Bellido annuae-Cicendietum filiformis* subass. *solenopsidetosum laurentiae*; 9 = *Anthoxantho aristati-Agrostietum salmanticae*; 10 = *Lythro hyssopifoliae-Crassuletum vaillantii*; 11 = *Mentho pulegii-Exaculetum pusilli* subass. *eryngetosum barrelieri*).

flooding and had their maximum development in April-May. Hydrophytes (e.g. *Juncus heterophyllus*, *Baldellia ranunculoides*, *Myriophyllum verticillatum,* and *Ranunculus baudotii*) made up 62% of the cover (Fig. 6). Richness was very low (10 taxa), and evenness was also low (1.8), because of the strong dominance of *Juncus heterophyllus.*

CALLITRICHETUM STAGNALIS Segal 1965 (Table 2)

The plant communities referable to this association, present in several sites in Sardinia, e.g. La Maddalena (Biondi & Bagella, 2005), were located in the IB of the TPs, on shallow soils, (rel. 5, 6, 7 in Table 2), where they had their maximum development in March-April and in the RPs (rel. 1, 2, 3, 4 in Table 2), where they were well developed in February and remained so until the end of March.

Hydrophytes (Fig. 6; e.g. *Callitriche stagnalis* and *Ranunculus baudotii*) strongly dominant, representing 84% of the cover. Therefore, evenness and richness were very low (1.5 and 14, respectively).

Tab. 1 - *Eleocharo palustris-Juncetum heterophylli* Paradis & Pozzo di Borgo 2005

	Rel. no.	1	2	3	4	P
	TWH	TP	TP	TP	TP	r
	Coverage (%)	100	100	100	100	e
	Area (m^2)	4	4	4	4	s.
	Charact. taxa of the ass.					
I	Juncus heterophyllus Desf.	5.5	5.5	5.5	5.5	4
He	Eleocharis palustris (L.) R. & S.	1.1	1.1	+	1.1	4
	Charact. taxa of the upper units					
I	Baldellia ranunculoides (L.) Parl.	1.2	1.1	1.1	1.1	4
	Other taxa					
H	Oenanthe fistulosa L.	2.2	3.3	3.3	3.3	4
I	Myriophyllum verticillatum L.	1.1	1.1	+	1.1	4
G	Glyceria spicata Guss.	+	+	+	+	4
H	Lotus uliginosus Sckuhr	+	.	+	.	2
H	Mentha pulegium L.	+	.	+	.	2
I	Ranunculus baudotii Godron	+	.	+	.	2

BALDELLIO RANUNCULOIDIS-ELEOCHARITETUM PALUSTRIS Biondi & Bagella 2005 (Table 3)

This association, which has been described in the La Maddalena archipelago (Biondi & Bagella, 2005), included communities that developed in April-June, in both CBs of the TPs. They were dominated by the only helophyte discovered in the area, *Eleocharis palustris,* and included 21 taxa with an evenness value of 2.6.

Tab. 2 - *Callitrichetum stagnalis* Segal 1965

	Rel. no.	1	2	3	4	5	6	7	P
	TWH	RP	RP	RP	RP	TP	TP	TP	r
	Coverage (%)	100	100	100	100	90	90	90	e
	Area (m^2)	1	2	1	1	1	2	2	s.
	Charact. taxa of the ass.								
I	Callitriche stagnalis Scop.	5.5	5.5	5.5	5.5	3.4	4.4	4.4	7
	Charact. taxa of the upper units								
I	Ranunculus baudotii Godron	.	.	.	.	1.1	2.2	2.2	3
	Other taxa								
T	Ranunculus ophioglossifolius Vill.	.	.	.	.	2.3	1.2	1.2	3
T	Crassula vaillantii (Willd.) Roth	+	+	+	.	.	.	.	3
T	Trifolium resupinatum L.	+	+	+	.	.	.	.	3
T	Bellis annua L.	+	+	.	.	.	.	.	2
G	Isoetes histrix Bory	.	+	.	+	.	.	.	2
T	Silene laeta (Aiton) Godron	+	.	.	+	.	.	.	2
T	Lythrum hyssopifolia L.	.	+	+	.	.	.	.	2
T	Plantago coronopus L. subsp. commutata (Guss.) Pilger	.	+	+	.	.	.	.	2
	Accidental taxa	1	0	1	0	2	0	0	

Tab. 3 - *Baldellio ranunculoidis-Eleocharitetum palustris* Biondi & Bagella 2005

	Rel. no.	1	2	3	4	5	6	P
	TWH	TP	TP	TP	TP	TP	TP	r
	Coverage (%)	100	100	100	100	100	100	e
	Area (m²)	20	7	20	10	6	10	s.
	Charact. taxa of the ass.							
He	Eleocharis palustris (L.) R. & S.	4.4	3.3	4.4	4.4	3.3	3.3	6
I	Baldellia ranunculoides (L.) Parl.	.	.	.	1.1	2.2	2.2	3
	Charact. taxa of the upper units							
G	Glyceria spicata Guss.	3.3	4.4	1.1	1.1	.	.	4
H	Oenanthe fistulosa L.	+	.	.	3.3	.	1.2	3
	Other taxa							
I	Isoetes tiguliana Gennari	2.2	2.2	3.3	1.2	1.2	1.2	6
H	Apium crassipes (Koch) Rchb. fil.	+	1.2	2.2	3.3	3.3	1.2	6
H	Lotus uliginosus Sckuhr	+	+	+	.	+	r	5
T	Polypogon maritimus Willd.	1.1	.	1.1	+	.	+	4
T	Ranunculus ophioglossifolius Vill.	+	1.2	1.1	.	.	.	3
H	Mentha pulegium L.	.	.	.	+	1.2	+	3
T	Trifolium michelianum Savi	1.1	+.2	+	.	.	.	3
H	Alopecurus bulbosus Gouan	+	+	+	.	.	.	3
T	Myosotis sicula Guss.	+	+	+	.	.	.	3
T	Illecebrum verticillatum L.	+	.	+	r	.	.	3
H	Rumex pulcher L.	.	.	.	.	1.2	+	2
T	Agrostis salmantica (Lag.) Kunth	+	.	+	.	.	.	2
I	Juncus heterophyllus Desf.	.	.	.	+	.	+.2	2
	Accidental taxa	1	1	0	2	0	0	

APIO CRASSIPEDIS-ELATINETUM MACROPODAE ass. nova hoc loco (holotypus rel. no. 2, Table 4)

The communities dominated by *Elatine macropoda* were present in the IB of the TPs from March, when water depth was 10–15 cm. They could be considered hydrophytic communities, hydrophytes covering 74% (Fig. 6), and surviving until June on waterlogged areas. The proposal of a new association is based on the fact that these communities present floristic and ecological characteristics different from those of *Elatinetum macropodae* Br.-Bl. (1931) 1935 communities. Furthermore because they occur in long-submerged depressions they have to be considered as belonging to the *Preslion cervinae* alliance instead of the *Isoetion* alliance.

Richness and evenness showed low values: 8 and 1.8, respectively.

ISOETO TIGULIANAE-CALLITRICHETUM BRUTIAE ass. nova hoc loco (holotypus rel. no. 1, Table 5)

isoetetosum tigulianae subass. nova hoc loco (holotypus rel. no. 1, Table 5)

myriophylletosum verticillati subass. nova hoc loco (holotypus rel. no. 6, Table 5)

The communities dominated by *Callitriche brutia* are proposed to be referred to this new association of the *Preslion cervinae* alliance. *Callitriche brutia* geographical distribution includes Western and Southern Europe, eastwards to Italy (Tutin *et. al*., 1964-80). Two associations in which this species was dominant were already described: *Myriophyllo alterniflori-Callitrichetum brutiae* Cirujano, Pascual & Velayos 1986 for the Iberian peninsula (Cirujano *et al.*, 1986) and *Ranunculo-Callitrichetum brutiae* Brullo & Minissale 1998 for Sicily (Brullo *et al*., 1987, Brullo & Minissale, 1998). The new association proposed is differentiated by the presence of *Isoetes tiguliana* and *Apium crassipes*.

Two subassociations were recognized: *isoetetosum*

Tab. 4 – *Apio crassipedis-Elatinetum macropodae* ass. nova (holotypus rel. no. 2)

	Rel. no.	1	2*	3	4	P
	TWH	TP	TP	TP	TP	r
	Coverage (%)	90	90	90	90	e
	Area (m^2)	1	1	1	1	s.
	Charact. and diff. taxa of the ass. and of the suball. *Apienion crassipedis*					
I	Elatine macropoda Guss.	5.5	4.5	4.5	4.5	4
I	Isoetes tiguliana Gennari	2.2	3.2	2.2	2.2	4
H	Apium crassipes (Koch) Rchb. fil.	+.2	1.1	+.2	+.2	4
T	Antinoria insularis Parl.	.	1.2	+	+	3
	Charact. taxa of the upper units					
T	Juncus pygmaeus Richard	1.2	1.1	1.1	1.2	4
T	Ranunculus ophioglossifolius Vill.	+	+	1.1	+	4
T	Lythrum borysthenicum (Schrank) Litv.	+	+	1.1	.	3
T	Crassula vaillantii (Willd.) Roth	+	+	.	+	3

Tab. 5 – *Isoeto tigulianae – Callitrichetum brutiae* ass. nova (holotypus rel. no. 1)
isoetetosum tigulianae subass. nova rel. 1-3 (holotypus rel. no. 1)
myriophylletosum verticillati subass. nova rel. 4-7 (holotypus rel. no. 6)

	Rel. no.	1*	2	3	4	6	5	7	P
	TWH	TP	TP	TP	TP	TP	TP	TP	r
	Coverage (%)	90	100	100	100	100	100	100	e
	Area (m^2)	4	1	1	2	2	2	4	s.
	Charact. and diff. taxa of the ass. and the upper units								
I	Callitriche brutia Petagna	4.4	5.5	5.5	4.4	5.5	4.4	5.5	7
I	Isoetes tiguliana Gennari	3.3	1.2	1.2	1.1	.	2.2	1.1	6
H	Apium crassipes (Koch) Rchb. fil.	.	+	+	.	+	+	+	5
	Diff. taxa of the subass. *myriophylletosum verticillati*								
I	Myriophyllum verticillatum L.	.	.	.	3.3	3.3	3.3	2.2	4
I	Ranunculus baudotii Godron	+	.	.	+	.	2.2	1.1	4
	Other taxa								
G	Glyceria spicata Guss.	+	.	.	+	+	+	+	5

tigulianae, which represents the typical aspects of the association (rel. 1-3 in Table 5), and *myriophylletosum verticillati* (rel. 4-7 in Table 5), present in deepest water, which represents a transition toward the class *Potametea.*

The communities belonging to this association were located in the CB and IB of the TPs in March-April and were composed nearly exclusively by hydrophytes (Fig. 6), e.g. *Callitriche brutia*, *Myriophyllum verticillatum*, *Isoetes tiguliana*, and *Ranunculus baudotii*. Diversity was low both in terms of richness (6 taxa) and evenness (1.5).

APIO CRASSIPEDIS-ISOETETUM TIGULIANAE Biondi & Bagella 2005 corr. hoc loco (Table 6)

The communities placed in this association, which was also described in the La Maddalena archipelago (Biondi & Bagella, 2005), developed mostly in the IBs of the TPs from March to May. They survived until the substratum was waterlogged and represented a transition between the aquatic and amphibious vegetation, with 3 codominant life forms (Fig. 6): hemicryptophytes 34%, hydrophytes+helophytes 34%, and therophytes 30%. An increase in the richness and evenness values (34 and 2.7, respectively) was recorded with respect to the communities dominated by hydrophytes+helophytes.

Amphibious vegetation

Amphibious vegetation includes the communities of *Isoetion, Cicendio-Solenopsion laurentiae,* according to Brullo & Minissale (1998), and *Agrostion salmanticae* alliances.

ROMULEO REQUIENII-ISOETETUM HISTRICIS ass. nova hoc loco (holotypus rel. no. 13, Table 7)

The ephemeral dwarf communities dominated by *Isoetes histrix,* were referred to this new association of the *Isoetion* alliance. With respect to the other communities dominated by *Isoetes histrix*, e.g. *Junco capitati-Isoetetum hystricis* Br.-Bl. 1936, the differential species is the Tyrrhenian endemic *Romulea requienii*.

These communities develope in the OB of the TPs and in the WSs very early in the season (March-April). The dominant life forms were therophytes (52%): e.g. *Lythrum hyssopifolia*, *Juncus hybridus* and *J. pygmaeus;* and geophytes (39%): e.g. *Ophioglossum lusitanicum*, *Romulea requienii,* and *R. ligustica* (Fig. 6). The level of diversity was the highest in comparison to all the other plant communities present in the TWHs studied in the area (richness: 49 and evenness: 3.3).

BELLIDO ANNUAE-CICENDIETUM FILIFORMIS De Foucault 1988
solenopsidetosum laurentiae Paradis & Pozzo di Borgo 2005 (Table 8)

Communities dominated by therophytes, which provided 85% of the cover (Fig. 6), were referred to this subassociation, reported in Corsica by Paradis & Pozzo di Borgo (2005), and described here for the first time in Sardinia.

They develop in April-May in the OB of the TPs and in the WSs, and are rich in species characteristic of the class *Isoeto-Nanojuncetea* (e.g. *Cicendia filiformis*,

Tab. 6 - *Apio crassipedis-Isoetetum tigulianae* Biondi & Bagella 2005 corr. hoc loco

	Rel. no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	P
	TWH	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	r
	Coverage (%)	100	90	100	100	100	100	100	90	90	100	100	100	100	100	100	100	100	100	100	100	100	e
	Area (m^2)	2	2	2	2	2	2	4	4	1	2	2	2	2	4	4	4	4	4	1	4	2	s.
	Charact. and diff taxa of the ass. and of the suball. *Apienion crassipedis*																						
I	Isoetes tiguliana Gennari	4.5	1.1	4.4	4.4	3.4	4.4	4.4	3.3	4.4	3.4	5.5	4.4	5.5	4.4	5.5	3.4	4.4	3.3	2.2	4.4	4.5	21
H	Apium crassipes (Koch) Rchb. fil.	+.2	+	+	+.2	2.3	+.2	+	+	1.1	2.3	3.3	1.2	1.2	2.2	2.2	2.3	4.4	5.5	5.5	2.2	3.3	21
T	Ranunculus ophioglossifolius Vill.	1.2	2.2	1.2	+.2	3.3	3.3	3.3	3.3	2.2	3.4	2.3	3.3	1.2	2.3	2.3	2.3	1.1	+	r	+	1.2	21
	Charact. taxa of the upper units																						
H	Ranunculus cordiger Viv. subsp. diffusus (Moris) Arrigoni	+	.	.	2.3	1.1	2.2	.	.	.	+	1.2	1.2	1.1	1.2	2.2	2.3	+	+	.	1.2	1.2	15
T	Myosotis sicula Guss.	.	.	.	1.1	+.2	1.2	.	.	.	1.2	.	1.2	1.2	1.1	1.2	1.2	r	r	.	+	+.2	13
T	Juncus pygmaeus Richard	+	.	.	+	+.2	r	.	.	.	1.1	.	.	+	1.1	+.2	.	.	.	.	1.2	1.2	10
T	Illecebrum verticillatum L.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	r	.	.	r	.	+.2	.	4
T	Isolepis cernua (Vahl) R. & S.	.	.	.	.	.	.	.	.	.	.	.	+	+	+.2	.	.	.	.	.	+.2	.	4
G	Isoetes histrix Bory	.	.	+	.	.	.	.	.	1.1	.	.	.	+	+	.	.	.	.	.	.	.	4
T	Juncus bufonius L.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	+	.	2
T	Lythrum hyssopifolia L.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	r	.	2
G	Ophioglossum lusitanicum L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	2
T	Trifolium michelianum Savi	.	.	.	.	.	.	+	.	.	.	+.2	.	.	.	.	.	.	.	.	.	.	2
T	Crassula vaillantii (Willd.) Roth	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
H	Eryngium barrelieri Boiss.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
T	Juncus capitatus Weigel	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1
T	Silene laeta (Aiton) Godron	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
	Other taxa																						
H	Lotus uliginosus Sckuhr	2.2	+	2.2	+.2	2.2	2.2	1.2	2.2	.	+.2	+.2	+.2	+	1.3	+	.	1.1	1.1	+	2.2	1.2	19
T	Bellis annua L.	1.1	.	+	2.2	+	+.2	.	+.2	.	.	.	.	1.2	1.2	1.1	+.2	.	.	.	1.1	+.2	12
H	Alopecurus bulbosus Gouan	+	.	.	.	.	+	.	.	.	1.1	+	+	+	+	.	.	.	.	.	.	+	8
T	Trifolium subterraneum L.	.	.	.	1.2	.	.	.	.	.	+.2	.	+.2	+.2	+	+.2	+.2	.	.	.	.	+.2	8
H	Carex divisa Hudson	+	.	.	.	.	.	+	.	.	.	.	+	.	+	+	+	.	.	.	.	+	7
I	Ranunculus baudotii Godron	.	4.4	3.3	.	.	.	.	.	+.2	.	.	.	.	.	.	.	.	+	+	.	.	5
T	Anthemis arvensis L.	.	.	.	.	1.1	+	+	+	.	.	.	+.2	.	.	.	.	.	.	.	.	.	5
G	Glyceria spicata Guss.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	+	1.1	1.1	.	.	5
I	Callitriche stagnalis Scop.	.	+.2	+.2	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	4
T	Montia fontana L. subsp. amporitana Sennen	.	.	.	r	.	.	.	+	.	+	.	+	.	.	.	.	.	.	.	.	.	4
T	Anthoxanthum aristatum Boiss.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	+	3
He	Eleocharis palustris (L.) R. & S.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r	.	.	.	3
H	Linum bienne Miller	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	1.1	2
G	Romulea requienii Parl.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2
	Accidental taxa	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	

Tab. 7 - *Romuleo requienii-Isoetetum histricis* ass. nova (holotypus rel. no. 13)

	Rel. No.	1	2	3	4	5	6	7	8	9	10	11	12	13*	14	15	16	17	18	19	20	21	22	23	P
	TWH	WS	WS	WS	TP	TP	WS	TP	TP	WS	WS	WS	WS	WS	WS	WS	WS	WS	WS	WS	WS	WS	WS	WS	r
	Coverage (%)	70	70	80	100	90	90	80	100	100	95	100	90	90	90	90	90	90	85	90	90	100	70	100	e
	Area (m²)	1	1	1	2	1	4.5	1	1	1	2	2	2	14	20	27	12	20	18	8	34	9	1	2	s.
	Charact. and diff. taxa of the ass.																								
G	Isoetes histrix Bory	1.1	1.1	1.1	4.4	4.4	3.3	3.3	4.4	4.4	2.3	3.3	3.3	4.4	2.3	3.3	4.4	3.3	4.4	4.4	3.3	4.4	4.4	4.4	23
G	Romulea requienii Parl.	r	.	.	+	+	+	1.1	1.1	1.1	1.1	2.2	2.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	2.2	1.1	1.1	21
	Charact. taxa of the upper units																								
T	Lythrum hyssopifolia L.	1.1	+	1.2	+	+	+	1.1	.	.	.	r	r	+	+	+	+	+	1.1	+	+	1.1	1.1	+	20
T	Juncus hybridus Brot.	.	.	.	+	2.2	+	+	.	+.2	2.3	2.3	1.2	1.1	+.2	+	1.2	+.2	+.2	+	+	+	+.2	.	18
T	Lotus subbiflorus Lag.	1.2	.	+	.	.	+	.	.	1.2	1.2	1.2	1.2	+	+	2.3	1.2	1.2	+	+	1.1	1.1	+	1.2	18
T	Juncus pygmaeus Richard	.	.	.	.	.	+.2	.	.	.	.	.	+.2	2.2	1.2	2.2	1.1	1.2	1.2	1.2	+	+.2	.	r	12
T	Cicendia filiformis (L.) Delarbre	+	.	.	.	.	.	.	.	+	+	+	.	r	.	+	.	.	+	r	+	+	.	1.1	11
G	Ophioglossum lusitanicum L.	.	.	.	.	.	+.2	.	.	+	+	+	.	.	.	.	.	.	+	+.2	1.1	+	.	r	9
T	Laurentia gasparrinii (Tineo) Strobl	.	.	.	.	.	1.1	.	.	.	.	.	.	1.1	r	1.1	.	.	r	+	.	+	.	.	7
T	Isolepis cernua (Vahl) R. & S.	.	.	.	.	.	2.3	.	.	.	.	.	.	1.3	2.3	2.2	+	.	.	.	+	.	.	.	6
T	Silene laeta (Aiton) Godron	.	.	+.2	.	.	r	.	.	.	.	.	.	.	.	.	+	.	+	r	.	.	.	.	5
G	Isoetes tiguliana Gennari	.	.	.	.	+	.	1.1	.	.	.	.	.	.	.	r	r	r	.	.	.	.	.	.	5
H	Apium crassipes (Koch) Rchb. fil.	.	.	.	.	.	r	.	.	.	.	.	.	r	r	.	.	.	.	.	.	.	.	r	4
T	Hordeum hystrix Roth	.	.	.	.	.	.	.	.	2.2	2.2	2.2	2.2	.	.	.	.	.	.	.	.	.	.	.	4
T	Juncus bufonius L.	3.4	3.3	3.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
T	Poa infirma H.B.K.	r	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	3
T	Ranunculus ophioglossifolius Vill.	.	.	.	1.2	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	3
T	Juncus capitatus Weigel	.	1.1	2.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
T	Crassula vaillantii (Willd.) Roth	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	2
T	Lythrum borysthenicum (Schrank) Litv.	+	.	.	+.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
T	Centaurium maritimum (L.) Fritsch	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
T	Trifolium michelianum Savi	.	.	.	1.2	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
	Other taxa																								
T	Bellis annua L.	1.2	+	+	1.1	+	+	2.3	+	.	3.3	1.1	1.2	+	.	.	r	.	+	r	r	r	+	+	19
T	Anthoxanthum aristatum Boiss.	.	.	+	.	.	1.1	.	.	2.2	2.2	.	.	+	+	+	+	r	+.2	+	+	+	.	1.1	14
T	Anagallis foemina Miller	+.2	r	.	+.2	.	+	.	.	.	.	.	.	+	+	+	1.1	+	1.2	+	+	1.1	.	+	14
T	Euphorbia exigua L.	.	.	.	+	.	.	.	.	1.1	1.1	1.1	1.1	.	1.1	.	r	1.1	+	+	+	+	.	+	13
G	Romulea ligustica Parl.	.	.	.	+	.	1.1	.	.	+	.	.	.	+	+.2	+	2.2	1.1	1.2	+	+	+	.	.	12
T	Trifolium subterraneum L.	+	+.2	r	.	.	+.2	.	.	.	.	.	.	+	+.2	r	+	+.2	+.2	.	.	r	.	+	12
T	Anthemis arvensis L.	.	2.2	1.1	.	+	.	.	.	1.1	1.1	1.1	2.2	.	.	r	r	.	.	.	.	.	1.2	+	11
T	Plantago coronopus L. subsp. commutata (Guss.) Pilger	+.2	1.2	+	.	+	.	.	.	r	+	.	r	+	.	.	.	.	.	.	.	+.2	.	r	r	11
H	Linum bienne Miller	.	.	.	.	.	1.1	.	.	.	.	.	.	2.2	1.1	1.1	+	1.1	1.2	1.2	1.1	1.1	.	.	10
T	Oglifa gallica (L.) Chrtek & Holub	.	.	.	.	.	.	.	.	.	.	.	.	1.1	r	+	+	+	+.2	+	r	+	.	.	9
G	Carex flacca Schreber subsp. serrulata (Biv.) Greuter	.	.	.	.	.	+.2	.	.	.	.	.	.	.	+.2	+.2	+	r	+.2	+.2	r	+	.	.	9
H	Ranunculus flabellatus Desf.	.	.	.	.	.	+.2	.	.	.	.	.	.	.	+.2	r	.	.	r	.	.	.	.	.	4
H	Lotus uliginosus Sckuhr	.	.	.	+.2	.	.	3.4	2.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
T	Cynosurus polybracteatus Poiret	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1.1	r	.	.	.	.	.	.	3
H	Echium vulgare L.	.	.	.	+	.	.	.	.	+.2	.	.	.	.	.	r	.	.	.	.	.	.	.	.	3
T	Medicago minima (L.) Bartal	r	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
G	Romulea columnae Seb. & Mauri	.	.	.	1.1	1.1	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	3
G	Asphodelus microcarpus Salzm. & Viv.	.	.	.	r	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	2
	Accidental taxa	0	0	0	0	0	0	2	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	2	

Isoetes histrix, *Laurentia gasparrinii*, and *Lythrum hyssopifolia*), in addition to species of the class *Saginetea maritimae* (e.g. *Polypogon maritimus*), and the class *Helianthemetea guttati* (e.g. *Anagallis foemina* and *Oglifa gallica*).

ANTHOXANTHO ARISTATI-AGROSTIETUM SALMANTICAE Biondi & Bagella 2005 (Table 9)

The communities in this association, described initially of La Maddalena (Biondi & Bagella, 2005), develope at the end of spring (May-June), when the OB of the TPs and WSs were completely dry. The dominant life form was that of therophytes, which contribute 75% of the plant cover, followed by hemicryptophytes (Fig. 6). The high level of diversity (richness: 41, and evenness: 3.1) was due to the large number of species of the class *Isoeto-Nanojuncetea* (e.g. *Agrostis salmantica*, *Mentha pulegium* and *Hordeum histrix*), plus the presence of several uncharacteristic species, such as *Lotus uliginosus*, *Trifolium resupinatum*, and *Polypogon maritimus*.

LYTHRO HYSSOPIFOLIAE-CRASSULETUM VAILLANTII ass. nova hoc loco (holotypus rel. no. 6, Table 10)

The dwarf communities dominated by *Crassula vaillantii* were referred to this new association of the *Isoetion* alliance. No association dominated by *Crassula vaillantii* was indicated until now for Sardinia. The communities of the study area have floristic differences to the other communities already described in the Iberian peninsula: *Damasonio bourgaei-Crassuletum vaillantii* O. Bolòs & Llorens in O. Bolòs 1966 and *Lythro thymifoliae-Crassuletum vaillantii* Rivas Goday ex Ruiz & A. Valdés 1987; and in France: *Isoeto velatae-Crassuletum vaillantii*

Tab. 8 - *Bellido annuae-Cicendietum filiformis* De Foucault 1988
solenopsidetosum laurentiae Paradis & Pozzo di Borgo 2005

	Rel. no.	1	2	3	4	5	6	7	8	P
	TWH	WS	WS	WS	WS	WS	TP	TP	TP	r
	Coverage (%)	80	80	85	90	90	90	80	95	e
	Area (m²)	3	2	3	2	2	2	4	4	s.
	Charact. taxa of the ass.									
T	Cicendia filiformis (L.) Delarbre	2.2	1.1	2.2	2.3	2.2	1.1	1.1	1.1	8
T	Bellis annua L.	.	r	+.2	.	.	.	.	.	2
	Diff. taxa of the subass. *solenopsidetosum laurentiae*									
T	Laurentia gasparrinii (Tineo) Strobl	+	1.1	1.2	+	1.2	1.2	1.2	1.2	8
	Charact. taxa of the upper units									
T	Lythrum hyssopifolia L.	+.2	2.2	2.2	1.2	+	+.2	1.1	1.1	8
G	Romulea requienii Parl.	+	+	+	+	+	+	+	+	8
G	Isoetes histrix Bory	+	+	+	+	+	+	+	+	8
T	Centaurium maritimum (L.) Fritsch	r	r	r	r	r	+	+	+.2	8
T	Lotus subbiflorus Lag.	.	+	+	1.2	1.1	.	r	+	6
T	Juncus capitatus Weigel	.	r	1.2	+.2	+.2	r	+.2	+.2	7
G	Ophioglossum lusitanicum L.	r	.	+.2	.	.	+	+	+.2	5
T	Isolepis cernua (Vahl) R. & S.	+.2	.	+.2	.	r	+.2	.	.	4
T	Agrostis salmantica (Lag.) Kunth	.	.	.	.	.	+	1.2	+.2	3
T	Silene laeta (Aiton) Godron	.	.	.	r	.	.	r	.	2
T	Juncus bufonius L.	.	.	.	.	r	r	.	.	2
T	Juncus pygmaeus Richard	.	+	.	.	.	.	.	.	1
	Other taxa									
H	Linum bienne Miller	1.1	2.3	2.2	1.1	2.2	1.2	1.1	1.2	8
T	Brachypodium distachyum (L.) Beauv.	1.2	1.2	1.2	2.2	1.1	2.2	1.1	1.1	8
T	Bromus hordeaceus L.	2.2	1.2	1.1	1.1	1.1	1.2	+	+	8
T	Polypogon maritimus Willd.	+	2.2	1.2	1.2	2.2	+.2	+.2	1.2	8
T	Vulpia myuros (L.) Gmelin subsp. sciuroides (Roth) Rouy	+	2.2	1.1	1.1	1.2	+	2.2	1.2	8
T	Cynosurus polybracteatus Poiret	+.2	+	1.1	+	+	1.1	1.1	1.1	8
T	Anagallis foemina Miller	+.2	+	+.2	r	+.2	+	+.2	+.2	8
T	Anthoxanthum aristatum Boiss.	+	1.2	1.1	.	+	+	+	1.2	7
T	Oglifa gallica (L.) Chrtek & Holub	.	1.1	.	+.2	r	+	+.2	+.2	6
T	Euphorbia exigua L.	.	r	.	r	+	.	+.2	+	5
H	Ranunculus flabellatus Desf.	r	.	.	.	r	r	r	r	5
T	Briza maxima L.	.	.	.	+.2	+	r	+	+.2	5
T	Gastridium ventricosum (Gouan) Sch. et Th.	.	1.1	.	.	+	.	.	+	3
G	Carex flacca Schreber subsp. serrulata (Biv.) Greuter	+	.	r	.	.	.	.	.	2
G	Asphodelus microcarpus Salzm. & Viv.	+	.	.	.	r	.	.	.	2
	Accidental taxa	0	1	1	0	1	0	0	1	

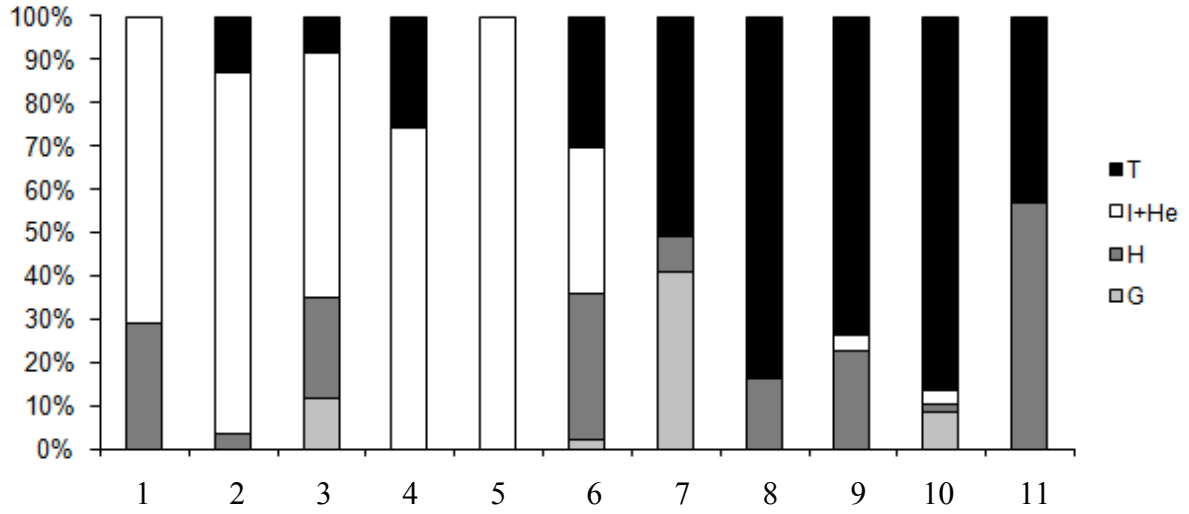

Fig. 6 – Weighted life form spectra of the 11 communities (1 = *Eleocharo palustris-Juncetum heterophylli*; 2 = *Callitrichetum stagnalis*; 3 = *Baldellio ranunculoidis-Eleocharitetum palustris*; 4 = *Apio crassipedis-Elatinetum macropodae*; 5 = *Isoeto tigulianae-Callitrichetum brutiae*; 6 = *Apio crassipedis-Isoetetum tigulianae*; 7 = *Romuleo requienii-Isoetetum histricis*; 8 = *Bellido annuae-Cicendietum filiformis* subass. *solenopsidetosum laurentiae*; 9 = *Anthoxantho aristati-Agrostietum salmanticae*; 10 = *Lythro hyssopifoliae-Crassuletum vaillantii*; 11 = *Mentho pulegii-Exaculetum pusilli* subass. *eryngetosum barrelieri*).

Poiron & Barbero 1965, endemic to Esterel (Poiron & Barbero 1965) and *Myosuro-Crassuletum vaillantii* Br.-Bl. 1935.

In these communities therophytes are the dominant life form, contributing 88% of the total cover (Fig. 6). They are typical of the RPs, where they grow in March-April. The richness value was 22, and evenness 2.5; these values were due to the extensive cover of *Crassula vaillantii*.

Summer vegetation

Summer vegetation includes communities belonging to the order *Nanocyperetalia* of the class *Isoeto-Nanojuncetea,* which develop in July-August.

MENTHO PULEGII-EXACULETUM PUSILLI Paradis & Pozzo di Borgo 2005
eryngetosum barrelieri subass. nova hoc loco (holotypus rel. no. 4, Table 11)

This new proposed subassociation included the only communities present in summer time. The association *Mentho pulegii-Exaculetum pusilli* has been described for Southern Corsica on granitic substrata (Paradis & Pozzo di Borgo, 2005), but communities found in the study area differ because of the consistent presence of *Eryngium barrelieri*. Two subassociations can be recognized: *exaculetosum pusilli*, which represents the holotypus of the association (typus rel. no. 6, Table 21 in Paradis & Pozzo di Borgo, 2005), but which is not found in the study area, and *eryngetosum barrelieri.* The last subassociation, present in the study area, includes paucispecific communities (richness = 9), which develop in the CB of TPs where water was present until June and where the soils were still waterlogged in July-August. The dominant biologial form is that of hemicryptophytes (Fig. 6), which provide 57% of the cover.

Spatial distribution and temporal succession

Spatial distribution and temporal succession of plant communities were related to the different typologies of Mediterranean TWHs and hydrological regimes.

Aquatic vegetation, with a percentage of hydrophytes + helophytes being 34 - 100%, was found in the CBs and IBs of the TPs and within the RPs. Late winter–spring amphibious communities, dominated by therophytes, and with 50 - 87% cover, were present in almost all TWHs. Summer plant communities, with higher percentages of hemicryptophytes (57%), were found exclusively in the CBs of TPs (Fig. 6).

Overall, the CB of TWHs, because of a longer flooding duration, contained a higher number of plant communities in chrono-succession, all with a strong dominance of aquatic ones: *Isoeto tigulianae-Callitrichetum brutiae* subass. *myriophylletosum verticillati*, *Eleocharo palustris-Juncetum heterophylli*, *Baldellio ranunculoidis-Eleocharitetum palustris,* and *Mentho pulegii-Exaculetum pusilli* subass. *eryngetosum barrelieri*. Periods of temporal overlap existed between successional communities (Fig. 7).

Tab. 9 - *Anthoxantho aristati-Agrostietum salmanticae* Biondi & Bagella 2005

	Rel. no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	P
	TWH	TP	TP	WS	WS	TP	TP	TP	TP	WS	WS	WS	WS	WS	WS	WS	r
	Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	e
	Area (m²)	10	10	6	6	6	4	6	4	8	4	4	4	5	4	6	s
	Charact. taxa of the ass.																
T	Agrostis salmantica (Lag.) Kunth	3.3	2	4.4	4.4	3.3	3.3	2.2	3.3	4.4	4.4	4.4	4.4	4.4	4.4	4.4	15
T	Gaudinia fragilis (L.) Beauv.	+	+	1.1	+	1.1	1.1	+	r	1.1	1.1	1.2	1.2	1.1	.	1.1	14
T	Anthoxanthum aristatum Boiss.	+	+	.	+	1.1	1.1	+	.	1.1	+	.	.	1.1	.	.	9
	Charact. taxa of the upper units																
T	Hordeum hystrix Roth	1.1	1.2	.	+	1.1	3.4	4.4	3.3	+	+	+	+	+	3.4	4.4	14
T	Lythrum hyssopifolia L.	+	.	r	1.1	1.1	1.1	1.1	+	+	+	+	1.1	1.1	1.1	1.1	14
H	Ranunculus cordiger Viv. subsp. diffusus (Moris) Arrigoni	1.2	2.2	.	.	1.2	2.2	1.2	.	.	.	1.2	+	.	+	.	8
T	Lotus subbiflorus Lag.	.	.	.	.	.	.	.	.	2.3	1.2	1.2	4.4	3.3	+.2	3.3	7
H	Mentha pulegium L.	.	.	.	r	.	+	.	.	.	+	1.2	1.2	+	+	.	7
H	Eryngium barrelieri Boiss.	.	.	.	r	.	.	.	.	.	.	1.2	1.1	+	r	+	6
T	Juncus bufonius L.	.	.	.	.	2.2	.	.	.	1.1	.	.	.	r	1.2	1.2	5
T	Juncus pygmaeus Richard	.	.	.	1.2	+.2	1.1	.	.	.	.	.	.	.	+.2	.	4
T	Laurentia gasparrinii (Tineo) Strobl	+	+	.	.	.	r	1.2	.	.	.	.	.	.	.	.	4
T	Trifolium michelianum Savi	+	.	.	.	+	+	r	.	.	.	.	.	.	.	.	4
T	Centaurium maritimum (L.) Fritsch	.	.	.	.	+.2	.	.	.	.	+	.	+	.	.	.	3
T	Illecebrum verticillatum L.	+	+	.	.	.	.	+	.	.	.	.	.	.	.	.	3
T	Lythrum borysthenicum (Schrank) Litv.	.	.	.	.	.	+	r	.	.	.	.	.	.	.	.	2
T	Myosotis sicula Guss.	+	.	.	.	r	.	.	.	.	.	.	.	.	.	.	2
T	Isolepis cernua (Vahl) R. & S.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1
T	Juncus tenageja Eheh.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	1
T	Silene laeta (Aiton) Godron	.	.	.	+.2	.	.	.	.	.	.	.	.	.	.	.	1
	Other taxa																
T	Polypogon maritimus Willd.	3.3	1.2	2.2	2.2	.	1.2	+	.	3.4	.	+	+	+	2.3	+.2	12
T	Trifolium resupinatum L.	.	.	1.2	.	.	1.2	.	.	3.3	2.2	3.3	3.3	4.4	2.3	1.2	9
H	Lotus uliginosus Sckuhr	4.4	3.3	3.3	3.3	3.3	3.4	4.4	4.4	.	.	.	.	.	.	.	8
T	Lolium multiflorum Lam.	.	.	.	.	.	+	.	.	+	r	+.2	+	+	+	+.2	8
T	Cynosurus polybracteatus Poiret	.	.	r	+	1.1	.	.	.	.	r	.	+.2	.	r	.	6
H	Alopecurus bulbosus Gouan	.	.	.	.	.	+	+	.	.	.	+.2	.	+	r	.	5
T	Bellis annua L.	+	+	.	.	.	+	+	.	.	.	r	.	.	.	.	5
T	Bromus hordeaceus L.	.	.	r	r	.	.	.	+.2	r	.	.	+	.	.	.	5
H	Plantago lanceolata L.	.	.	+	+	+	.	.	.	+	1.2	.	.	.	.	.	5
T	Anthemis arvensis L.	.	.	+	.	.	.	.	.	r	+	.	.	.	+.2	.	4
T	Plantago coronopus L. subsp. commutata (Guss.) Pilger	.	.	1.2	.	.	+	.	.	.	.	.	.	+	+.2	.	4
H	Echium vulgare L.	.	.	+.2	.	.	.	.	.	+	.	.	.	.	+.2	.	3
H	Carex divisa Hudson	.	.	.	.	.	.	.	.	.	.	.	(+)	+	.	.	2
H	Linum bienne Miller	.	.	.	.	.	.	+.2	.	.	.	.	.	+	.	.	2
G	Romulea requienii Parl.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	2
G	Serapias lingua L.	.	.	r	r	.	.	.	.	.	.	.	.	.	.	.	2
	Accidental taxa	0	0	0	2	0	0	0	0	0	0	0	2	1	0	1	

Tab. 10 - *Lythro hyssopifoliae-Crassuletum vaillantii* ass. nova (holotypus rel no. 6)

	Rel. no.	1	2	3	4	5	6*	7	8	9	10	11	P
	TWH	RP	RP	RP	RP	RP	RP	RP	RP	RP	RP	RP	r
	Coverage (%)	80	80	70	90	70	90	70	100	80	80	60	e
	Area (m^2)	1	2	0.5	1	1	2	1	0.5	2	1	1	s.
	Charact. taxa of the ass.												
T	Crassula vaillantii (Willd.) Roth	3.3	4.5	3.4	5.5	4.4	4.4	3.4	3.4	3.4	3.4	3.3	11
T	Lythrum hyssopifolia L.	+	+.2	1.1	+	+	1.1	1.1	1.1	1.1	+	+.2	11
	Charact. taxa of the upper units												
T	Juncus hybridus Brot.	1.1	+	+	+	+	1.1	1.1	+	1.1	2.2	1.2	11
T	Poa infirma H.B.K.	+	.	+	+	+	1.1	1.1	1.2	1.2	1.2	+	10
G	Isoetes histrix Bory	+	+	+	.	.	.	.	+	1.1	2.2	2.2	7
T	Silene laeta (Aiton) Godron	+	+.2	.	.	.	.	.	.	+	.	.	3
T	Juncus pygmaeus Richard	.	.	+	.	.	.	+.2	.	.	.	.	2
H	Apium crassipes (Koch) Rchb. fil.	1.2	.	.	.	.	.	.	.	.	.	.	1
G	Isoetes tiguliana Gennari	.	.	.	.	+	.	.	.	.	.	.	1
	Other taxa												
T	Plantago coronopus L. subsp. commutata (Guss.) Pilger	.	+	+	+	r	r	r	2.3	2.2	+.2	r	10
T	Anthemis arvensis L.	+	.	+	.	.	+	+	+	1.2	.	1.2	7
T	Sedum caeruleum L.	.	.	.	.	r	+.2	.	r	+	1.1	+	6
T	Lotus subbiflorus Lag.	.	.	+	.	(+)	.	+	.	+	+	+.2	6
G	Romulea columnae Seb. & Mauri	.	+.2	.	.	+	.	r	r	.	+	.	5
I	Callitriche stagnalis Scop.	.	2.3	.	+	.	+	+	.	.	.	.	4
T	Bellis annua L.	.	.	+	.	.	.	.	+	+.2	+.2	.	4
	Accidental taxa	0	0	1	0	0	1	0	1	1	2	0	

Tab. 11 - *Mentho pulegii-Exaculetum pusilli* Paradis & Pozzo di Borgo 2005 *eryngetosum barrelieri* subass. nova (holotypus rel. no. 4)

	Rel. no.	1	2	3	4*	5	P
	TWH	TP	TP	TP	TP	TP	r
	Coverage (%)	70	70	70	70	70	e
	Area (m^2)	9	10	10	10	10	s.
	Charact. taxa of the ass.						
H	Mentha pulegium L.	1.2	3.3	3.4	3.4	3.4	5
T	Exaculum pusillum (Lam.) Caruel	1.2	1.1	1.2	1.2	1.2	5
	Diff. taxa of the subass. *eryngetosum barrelieri*						
H	Eryngium barrelieri Boiss.	3.4	+.2	1.1	1.1	1.1	5
	Charact. taxa of the upper units						
T	Pulicaria vulgaris Gaertner	.	.	1.1	.	.	1
T	Agrostis salmantica (Lag.) Kunth	r	.	.	.	.	1
	Accidental taxa	2	0	0	0	0	0

The IB of TPs was similar to the CB. Its peculiarity was mainly due to the presence of communities of the association *Apio crassipedis-Isoetetum tigulianae*. Usually, the succession proceeded from *Isoeto tigulianae-Callitrichetum brutiae* subass. *isoetetosum tigulianae* to *Apio crassipedis-Isoetetum tigulianae,* and finally to *Apio crassipedis-Elatinetum macropodae* (Fig. 7). *Callitrichetum stagnalis* was present on shallow soils.

In the OBs of TPs and in the WSs, the succession was quicker from *Romuleo requienii-Isoetetum histricis* to *Bellido annuae-Cicendietum filiformis* subass. *solenopsidetosum laurentiae,* and finally to *Anthoxantho aristati-Agrostietum salmanticae.*

Two successional communities were found in the RPs, where the flooding period was very brief: *Callitrichetum stagnalis* and *Lythro hyssopifoliae-Crassuletum vaillantii.*

Discussion

This is the first paper specifically reporting on TWHs vegetation of Sardinia. The communities are referred to four classes: *Potametea, Isoeto-Nanojuncetea, Isoeto-Littorelletea,* and *Phragmito-Magnocaricetea*. The classes *Isoeto-Nanojuncetea, Isoeto-Littorelletea* include typical amphibious vegetation. The former had been reported in Sardinia by Biondi & Bagella (2005), Camarda *et al*. (1995), De Marco & Mossa (1980), and Mossa (1987); the latter is here reported for the first time in the island, but it was previously reported for Corsica (Paradis & Pozzo di Borgo, 2005).

In the study area, 11 associations were found, 4 of which are here described for the first time (*Isoeto tigulianae-Callitrichetum brutiae, Romuleo requienii-Isoetetum histricis, Apio crassipedis-Elatinetum macropodae,* and *Lythro hyssopifoliae-Crassuletum vaillantii*).

Within the *Isoeto-Nanojuncetea* class, communities of the 2 orders *Isoetetalia* and *Nanocyperetalia* were found, the majority of communities (7 out of 8) being part of *Isoetetalia*. The other order includes the summer vegetation which develops in July-August, here referred to the association *Mentho pulegii-Exaculetum pusilli* which develops in the deepest part of TPs where the water persists until June-July.

Seven communities have been referred to the order

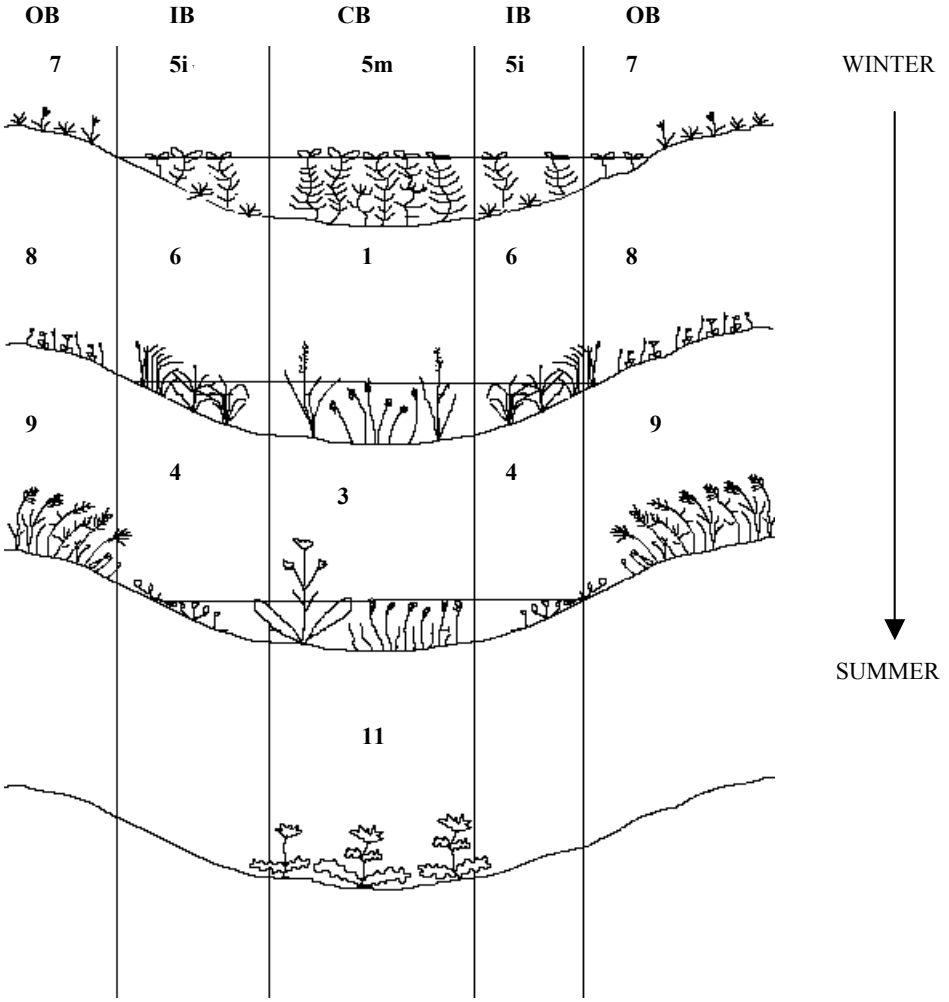

Fig. 7 – Spatial distribution and temporal succession of the plant communities in the temporary ponds (1 = *Eleocharo palustris-Juncetum heterophylli*; 3 = *Baldellio ranunculoidis-Eleocharitetum palustris*; 4 = *Apio crassipedis-Elatinetum macropodae*; 5m = *Isoeto tigulianae-Callitrichetum brutiae* subass. *myriophylletosum verticillati*; 5i = *Isoeto tigulianae-Callitrichetum brutiae* subass. *isoetetosum tigulianae*; 6 = *Apio crassipedis-Isoetetum tigulianae*; 7 = *Romuleo requienii-Isoetetum histricis*; 8 = *Bellido annuae-Cicendietum filiformis* subass. *solenopsidetosum laurentiae*; 9 = *Anthoxantho aristati-Agrostietum salmanticae*; 11 = *Mentho pulegii-Exaculetum pusilli* subass. *eryngetosum barrelieri*).

Isoetetalia, including the late winter–spring aquatic vegetation of the *Preslion cervinae* alliance, and the amphibious vegetation of *Isoetion,* developing in late winter, *Cicendio-Solenopsion laurentiae,* developing in spring, and *Agrostion salmanticae*, developing in late spring.

The *Preslion cervinae* alliance, represented by 3 associations (*Apio crassipedis-Elatinetum macropodae, Isoeto tigulianae-Callitrichetum brutiae,* and *Apio crassipedis-Isoetetum tigulianae*), shows ecological traits intermediate between communities of the *Isoetion* alliance and the *Phragmito-Magnocaricetea* class (Brullo & Minissale, 1998). Otherwise, even if the *Preslion cervinae* alliance is well represented in Sardinia by some species considered characteristic of this syntaxon following Brullo & Minissale (1998), e.g. *Callitriche brutia* (sub *Callitriche peduncolata* DC.)*, Damasonium alisma* subsp. *bourgaei* (Cosson) Maire (sub *Damasonium bourgaei* Cosson), *Juncus foliosus* Desf.*,* and *Veronica anagalloides* Guss. or in Rivas-Martìnez *et al*. (2002), e.g. *Isoetes velata* A. Braun subsp. *velata*, or in both, e.g. *Eryngium corniculatum* Lam., several characteristic species of the alliance indicated by the same authors are not present in the island, e.g. *Callitriche platycarpa* Kutz*, Eryngium galioides* Lam.*, Isoetes setacea* Lam.*, Juncus tenageja* Eheh. subsp. *perpusillus* Fern.-Carv. & F. Navarro, *Marsilea batardae* Launert*, Mentha cervina* L.*, Pulicaria paludosa* Link*, Ranunculus lateriflorus* DC.*, R.*

nodiflorus L. and *Sysimbrella aspera* (L.) Spach. Some of these species are not present in Sardinia or in the Italian peninsular Tyrrhenian lands, Corsica, Sicily and Mediterranean parts of Tunisia and Algeria. In the same areas, communities of the *Preslion cervinae* alliance are instead characterized by the presence of some endemic and sub-endemic taxa such as *Antinoria insularis, Apium crassipes,* and *Isoetes tiguliana*. Therefore, within the *Preslion cervinae* alliance, the new Tyrrhenian endemic suballiance *Apienion crassipedis* suball. nova hoc loco, is established. As characteristic and differential species are proposed: *Antinoria insularis, Apium crassipes,* and *Isoetes tiguliana. Apio crassipedis-Isoetetum tigulianae* is indicated as typical association. As a consequence, the continental northern suballiance *Preslienion cervinae* is established, whose characteristic and differential species could be considered to be *Callitriche platycarpa, Eryngium galioides, Isoetes setacea, Marsilea batardae, Mentha cervina, Pulicaria paludosa,* and *Sysimbrella aspera* and whose typical association is the *Preslietum cervinae* Br.-Bl. ex Moor 1937. Characteristic and differential species of the *Preslion cervinae* alliance as a whole are *Callitrichebrutia, Damasonium alisma* subsp. *bourgaei, Eryngium corniculatum, Juncus foliosus, J. tenageja* subsp. *perpusillus, Isoetes velata* subsp. *velata*, *Ranunculus lateriflorus, R. nodiflorus,* and *Veronica anagalloides*. The geographical distribution of the new suballiance *Apienion crassipedis* coincides with the Italo-Tyrrhenian biogeographic province established by Rivas-Martìnez *et al*. (2001).

All the communities of the *Isoeto-Nanojuncetea* and of the *Isoeto-Littorelletea* classes have to be considered habitat of community interest (European Commission 1992). Following the scheme proposed by Bagella *et al*. (2007), they can be assigned to the following habitats: 3170* (*Romuleo requienii-Isoetetum histricis* and *Lythro hyssopifoliae-Crassuletum vaillantii*); 3120 (*Bellido annuae-Cicendietum filiformis* subass. *solenopsidetosum laurentiae*, *Apio crassipedis-Elatinetum macropodae*, *Isoeto tigulianae-Callitrichetum brutiae* subass. *isoetetosum tigulianae*, *Isoeto tigulianae-Callitrichetum brutiae* subass. *myriophylletosum verticillati*, *Apio crassipedis-Isoetetum tigulianae,* and *Anthoxantho aristati-Agrostietum salamanticae*); 3130 (*Mentho pulegii-Exaculetum pusilli* subass. *eryngetosum barrelieri, Baldellio ranunculoidis-Eleocharitetum palustris,* and *Eleocharo palustris-Juncetum heterophylli*).

Syntaxonomical list

Potametea Klika in Klika & Novák 1941
  Potametalia Koch 1926
    Ranunculion aquatilis Passarge 1964
      Callitrichetum stagnalis Segal 1965
Isoeto-Nanojuncetea Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946
  Isoetetalia Br.-Bl. 1936
    Isoetion Br.-Bl. 1936
      Romuleo requienii-Isoetetum histricis ass. nova
      Lythro hyssopifoliae-Crassuletum vaillantii ass. nova
    Cicendio-Solenopsion laurentiae Brullo & Minissale 1998
      Bellido annuae-Cicendietum filiformis de Foucault 1988
      solenopsidetosum laurentiae Paradis & Pozzo di Borgo 2005
    Preslion cervinae Br.-Bl. ex Moor 1937
    Apienion crassipedis suball. nova
      Apio crassipedis-Elatinetum macropodae ass. nova
      Isoeto tigulianae-Callitrichetum brutiae ass. nova
        isoetetosum tigulianae subass. nova
        myriophylletosum verticillati subass. nova
      Apio crassipedis-Isoetetum tigulianae Biondi & Bagella 2005 corr. hoc loco
    Agrostion salmanticae Rivas Goday 1958
      Anthoxantho aristati-Agrostietum salmanticae Biondi & Bagella 2005

Nanocyperetalia Klika 1935
Verbenion supinae Slavinic 1951
Mentho pulegii-Exaculetum pusilli Paradis & Pozzo di Borgo 2005
exaculetosum pusilli subass. nova
eryngetosum barrelieri subass. nova
Isoeto-Littorelletea Br.-Bl. & Vlieger in Vlieger 1937
Littorelletalia Koch 1926
Hyperico elodis-Sparganion Br.-Br. & Tüxen ex Oberdorfer 1957
Eleocharo palustris-Juncetum heterophylli Paradis & Pozzo di Borgo 2005
Phragmito-Magnocaricetea Klika in Klika & Novák 1941
Nasturtio-Glycerietalia Pignatti 1954
Glycerio-Sparganion Br.-Bl. & Sissingh in Boer 1942
Glycerienion fluitantis (Géhu & Géhu-Franck 1987) J. A. Molina 1996
Baldellio ranunculoidis-Eleocharitetum palustris Biondi & Bagella 2005

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Accidental taxa

Tab. 2: rel. 1: *Lotus subbiflorus* Lag. +; rel. 3: *Poa infirma* H. B. K. +; rel. 5: *Glyceria spicata* Guss. +, *Apium crassipes* (Koch) Rchb. fil. 1.1.

Tab. 3: rel. 1: *Eryngium barrelieri* Boiss. +; rel. 2: *Ranunculus baudotii* Godron r; rel. 4 *Myriophyllum verticillatum* L. 3.3, *Cuscuta planiflora* Ten.+.2.

Tab. 6: rel. 13 *Anagallis foemina* Miller +.2; rel. 15: *Medicago minima* (L.) Bartal r; rel. 17: *Oenanthe fistulosa* L.+.

Tab. 7: rel. 2: *Lolium multiflorum* Lam. +, *Plantago lanceolata* L. +; rel. 3: *Alopecurus bulbosus* Gouan +; rel. 4: *Montia fontana* L. subsp. *amporitana* Sennen r; rel. 5: *Ranunculus cordiger* Viv. subsp. *diffusus* (Moris) Arrigoni 2.3; rel. 8: *Trifolium resupinatum* L. 1.2; rel. 9: *Galactites tomentosa* Moench r; rel. 21: *Plantago lagopus* L. r.

Tab. 8: rel. 2: *Ranunculus cordiger* Viv. subsp. *diffusus* (Moris) Arrigoni r; rel. 3: *Anthemis arvensis* L. +; rel. 5: *Serapias lingua* L. r ; rel. 8: *Tuberaria guttata* (L.) Fourr. r.

Tab. 9: rel. 4: *Anagallis foemina* Miller r, *Vulpia myuros* (L.) Gmelin subsp. *sciuroides* (Roth) Rouy r; rel. 12: *Oenanthe silaifolia* Bieb. r, *Rumex pulcher* L. r; rel. 14: *Plantago lagopus* L. r.

Tab. 10: rel. 3: *Linum bienne* Miller +; rel. 6: *Lotus uliginosus* Sckuhr + ; rel. 8: *Trifolium resupinatum* L. +; rel. 9 : *Oglifa gallica* (L.) Chrtek & Holub r; rel. 10: *Trifolium subterraneum* L +.2, *Romulea requienii* Parl. r.

Tab. 11: rel. 1: *Carex divisa* Hudson +.2, *Plantago lanceolata* L. 1.2.

Dates of surveys

Tab. 1: rel. 1, 2, 3, 4: 21/04/2004. Tab. 2: rel. 1, 2, 3, 4: 12/02/2004; rel. 5, 6, 7: 15/03/2004. Tab. 3: rel. 2: 21/04/2004; rel. 1, 3, 4, 5, 6: 09/06/2004. Tab. 4: rel. 1, 2, 3, 4: 09/06/2004. Tab. 5: rel. 2, 3: 15/03/2004; rel. 1, 4, 5, 6,7: 21/04/2004. Tab. 6: rel. 2, 3, 7, 8, 9: 15/03/2004; rel. 1, 4, 5, 6, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21: 21/04/2004. Tab. 7: rel. 4, 5, 7, 8, 9, 10, 11, 12: 15/03/2004; rel. 6, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23: 07/04/2004; rel. 1, 2, 3: 21/04/2004. Tab. 8: rel. 1, 2, 3, 4, 5, 6, 7, 8: 27/05//2004. Tab. 9: rel. 14: 27/05/2004; rel. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,13, 15: 09/06/2004. Tab. 10: rel. 1, 2, 4, 5, 6, 7, 8, 9, 10, 11: 15/03/2004; rel. 3: 07/04/2004. Tab. 11: rel. 1, 2, 3, 4, 5: 05/08/2004.