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Isoëto-Nanojuncetea in Puglia (S-Italy): first phytosociological survey

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Abstract
Mediterranean temporary ponds (MTP) are considered among the most interesting habitats in the Mediterranean bioclimatic region due to the range of rare and threatened taxa they host. Their ephemeral vegetation presents a particular floristic composition, adapted to unstable ecological conditions due to the alternation between flood and drought. Indeed, these amphibian plant species are established on soils flooded in winter and dry since early summer. The water depth and inundation period determine the plant communities distribution. The vegetation can be referred to the class *Isoëto-Nanojuncetea*, that has a wide distribution and is represented in the study area by two orders: *Isoëtetalia*, Mediterranean and W-European, with spring and early summer bloom, and *Nanocyperetalia*, C-European, with late summer and autumn bloom. This study describes for the first time the *Isoëto-Nanojuncetea* plant communities in Puglia Region, in SE-Italy, where the class distribution was unknown up to now. The here adopted syntaxonomical scheme is consistent with numerical analysis, resulting in homogenous floristic and ecological communities that correspond to syntaxa at association level. The phytosociological approach to the interpretation and management of vegetation and biodiversity has been recently revived by the habitat-type classification adopted by the European 92/43/EEC "Habitat" Directive in its Annex I. The here considered plant communities belong to the priority habitat "3170* Mediterranean temporary ponds". Aiming to typify them, 170 surveys were carried out in temporary pools over a wide area resulting from a detailed survey that took into account the whole Puglia territory. These complexes of vegetation are very sensitive to the environmental and anthropic disturbance, so they might be good bioindicators with high value for habitat monitoring and conservation.

Key words: amphibious vegetation, biodiversity, "Habitat" Directive 92/43/EEC, Mediterranean, Natura 2000, priority habitat, temporary wetlands.

Introduction

Definition of Mediterranean temporary ponds

Mediterranean temporary ponds (MTP) are freshwater habitats, which are flooded in winter or in the end of spring and dry out in summer with a particular water dynamic that relies mainly on rainfall and diffuse run-off cycle (Grillas *et al.,* 2004). The "Habitats Directive" (92/43/EEC) defines MTP as: "temporary, very shallow water bodies (a few centimetres deep) existing only in winter or at the end of spring, with a semiaquatic Mediterranean vegetation consisting of therophytes and geophytes belonging to the *Isoëtion*, *Nanocyperion flavescentis*, *Preslion cervinae*, *Agrostion salmanticae*, *Heleochloion* and *Lythrion tribracteati* alliances" (European Commission, 2013). With regard to the Italian context, the vegetation typically colonizing these habitat types has been defined as "perennial to annual, amphibious, Mediterranean vegetation, mainly composed by dwarf-sized therophytes and geophytes, with a late winter/early spring phenology, developing in wet systems with shallow temporary ponds, in the Mesosub-, Meso-and Thermo-Mediterranean bioclimatic belts" (Biondi *et al.*, 2012). Also the Ramsar Convention on wetlands, adopted in 1971, devoted the resolution VIII.33 to temporary ponds defining them as: "small (generally <10 ha), shallow wetlands characterized by alternating phases of drought and flooding and by very self-contained hydrology" (Ramsar Convention Bureau, 2002).

These habitats are found in the five regions of the world with a Mediterranean climate, where their vegetation is characterized by species of the genera *Isoëtes*, *Marsilea* and *Pilularia* (Quezel, 1998; Deil, 2005; Molina, 2005). Temporary ponds are considered to be among the most interesting habitats in the Mediterranean bioclimatic region (Médail *et al.*, 1998; Quézel, 1998) due to the range of rare and critical *taxa* they host (Biggs *et al.*, 2001; Nicolet *et al.*, 2004).

Ecology of Mediterranean temporary ponds

MTP exhibit great ecological variability depending on their habitat's geology, geomorphology, substrate type, water chemistry and depth, duration of flooding, water source (groundwater or run-off). These environmental features deeply affect also their vegetation, mainly comprising mediterranean therophytic and geophytic species (European Commission, 2013). In general, these communities are characterized by a short life cycle and show a remarkable ability to pro-

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duce seeds in the short favourable season, which favours annual plants both in the wet and the dry period. They occur in depressions, which are often endorheic, 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 (Grillas *et al.*, 2004; Williams, 2006).

Various types of MTP may be distinguished, depending on their origin, the substrate on which they lie, their morphology and their formation. Very different substrate types confer specific physico-chemical characteristics (Gaudillat & Haury, 2002; Grillas *et al.*, 2004). Deil (2005) distinguishes among waterlogged, amphibic, shallow and deep submerged aquatic conditions. The most characteristic type of MTP develops in topographic depressions on impermeable clayey-marly substrates, or where the water table rises to the surface and floods the ground during the rain season (Grillas *et al.*, 2004).

MTP show a self-regulating hydrology that affects the ecosystem composition (Zacharias & Zamparas, 2010). The length of the hydroperiod and the initiation of the inundation period play a substantial role, depending on the substrates permeability and slope. Changes in hydroperiod have important effects on pattern and strength of biotic interactions such as competition and predation, moreover they represent a criterion for deriving flora and fauna (Spencer *et al.*, 1999; Grillas *et al.*, 2004). The chemical composition of the water is always an important factor for flora and fauna. In addition to the usual physico-chemical characteristics (temperature, pH, dissolved oxygen, electrical conductivity), the ionic composition of the water can affect the presence or abundance of certain species (Chauvelon & Heureaux, 2004).

The spatial and temporal distribution of the vegetation is primarily determined by the water depth gradients and the duration of flooding. The topographical gradients correspond to changes in the duration and depth of flooding and the vegetation is organized principally along these gradients (Rudner, 2005; Grillas *et al.*, 2004).

MTP are therefore good biological indicators in relation to environmental phenomena such as climate changes: for example, the reduction or increase in precipitation, which affect the length of the dry or flooding period, leading to modifications of the hydrological regime and consequently altering the right functioning of these delicate ecosystems (Alvarez Cobelas *et al.*, 2005; Jakob *et al.*, 2003).

The objective of the present study was the investigation of the ephemeral phytocoenoses of Mediterranean temporary ponds located in the Puglia Region, in the territories comprised among the Provinces of Lecce and Brindisi (south Italy).

Materials and Methods

Study area

The present work was carried out in Puglia, that forms the Easternmost part of the Italian peninsula. The territory of Puglia is a long, narrow peninsula, mostly occupied by plains and hills, with some lower mountains belonging to the Southern Apennine and the Gargano Promontory, with high, steep cliffs (Tornadore *et al.*, 1988).

The geological substratum is mainly constituted of limestone in a large platform, with a surface drainage network of modest size, fed only by rainwater (Belmonte, 2000).

From the biogeographic and bioclimatic points of view Puglia located in the Eastern Mediterranean subregion with a Mediterranean pluviseasonal oceanic bioclimate (Rivas-Martinez *et al.*, 2004a, 2004b), mostly referable to the upper Thermomediterranean and to the upper and lower Mesomediterranean Thermotypes (Pesaresi *et al.,* 2014).

The information related to MTP in Puglia is fragmented and incomplete and most of the locations were unknown up to now: only 7 sites were already indicated for this region (Petrella *et al.*, 2005). Only recently, through new records and specific investigations, the knowledge about these ecosystems has increased, together with the interest to protect the habitat and its rare species (Ernandes *et al.*, 2006, 2007, 2010, 2011; Ernandes & Gigante, 2010; Ernandes, 2011; Ernandes & Marchiori, 2012a, 2012b, 2013).

Data sampling and processing

The field survey was based on Braun-Blanquet's classical approach (Braun-Blanquet, 1964), including the latest methodological updates (Biondi, 2011). We carried out 185 phytosociological relevés in the period 2008-2013 during the winter, spring and summer in the month of January, April and May-June . All the relevés have been performed in 40x40 cm^2 plots; all of them had no slope, thus slope and exposition are not reported in the tables; localities are listed in Appendix I. In order to capture seasonal changes in species composition and phenology, vegetation sampling was conducted once per season. The description of plant communities followed the phytosociological approach (Braun Blanquet, 1964; Biondi, 2011). The identification of plant species was based on Pignatti (1982) and Tutin *et al.* (1964-1980). The species nomenclature was updated in accordance with Lucarini *et al.* (2014). Specialist MTP plants, communities and habitats were identified according to the European Manual of Union Habitats (European Commission, 2013), Brullo & Minissale (1998), and Rivas-Martínez *et al.* (2001, 2002).

Data were processed by applying a cluster analysis to produce dendrograms of the carried out relevés,

based on the algorithm of complete linkage (Anderson & Underwood, 1997); hierarchical plant community classification was done using MatEdit software package (MatEdit matrix editor, DBPro, Burba *et al.*, 1992). Plant communities were identified as homogeneous groups in the dendrogram of the surveys. For the syntaxonomic frame we followed the standards proposed by Biondi & Blasi (2013), Biondi *et al.* (2014) and, for some syntaxa, Mucina *et al.* (2016).

The habitats in the study area differ geomorphologically and pedologically and, as a consequence, in aspects concerning the water balance. The vegetation is spatially distributed according to the hydrological regime developing in different communities for different types of ponds. The types here investigated can be classified, according to Ernandes & Marchiori (2013), as: a) cupular pools (Fig. 1) that are small cavities (a few tens of square centimetres or square metres), with very reduced catchment areas created by dissolution on rock layers, with depth less than 2 cm; b) dolines (Fig. 2), *i.e.* depressions created by karstic dissolution and/or subsidence with deep soils, generally with depth between 20-40 cm; c) waterlogged soils (Fig. 3), occurring on impermeable substrates with low hydraulic conductivity (clayey-silty substrates) in slight depressions on the land surface, mostly isolated from the water table and often situated in the clearings of woods, with a soil depth less than 20 cm.

Results

The surveyed vegetation has been referred to the class *Isoëto-Nanojuncetea* Br.-Bl. & Tüxen ex Westhoff, Dijk & Paschier 1946, in which two orders were identified: *Isoëtetalia* Br.-Bl. 1935, best represented in Puglia with 13 communities, and *Nanocyperetalia flavescentis* Klika 1935 that includes only one. The detected vegetation types, resulting from the hierarchical classification, are described in the next section, including also a short ecological characterization of the upper rank syntaxa. The dendrogram (fig.4) resulting from cluster analysis show the groups belong to the coenoses described; we have only highlighted the groups related to the new associations and subassociations that will be described in detail in the next paragraph. The A cluster, related to *Junco capitati-Isoëtetum histricis*, is subdivided into the subclusters A1, A2, A3 that correspond respectively to the new subassociations *pleurochaetetosum squarrosae*, *solenopsietosum laurentiae* and *cheiloteletosum chloropii*. The B cluster is related to *Triglochino barrelieri-Isolepidetum cernuae* ass. nova while the C one refers to *Pleurochaeto squarrosae-Isoëtetum todaroanae* ass. nova and its two new subassociations *isoetetosum todaroanii* (C1) and *cheiloteletosum chloropii* (C2). Cluster D brings the vegetation communities of the *Junco pygmaei- Isoëtetum velati* and in particular that of *pilularietosum minutae* subass. nova (D1).

The latest two E and F refer respectively to *Tillaea*

Fig. 1 - Cupular pools at Felline (Lecce).

Fig. 2 - Dolina at Laccu Feretru (Sternatia, Lecce).

Fig. 3 - Waterlogged soils at Bosco Preti (Brindisi).

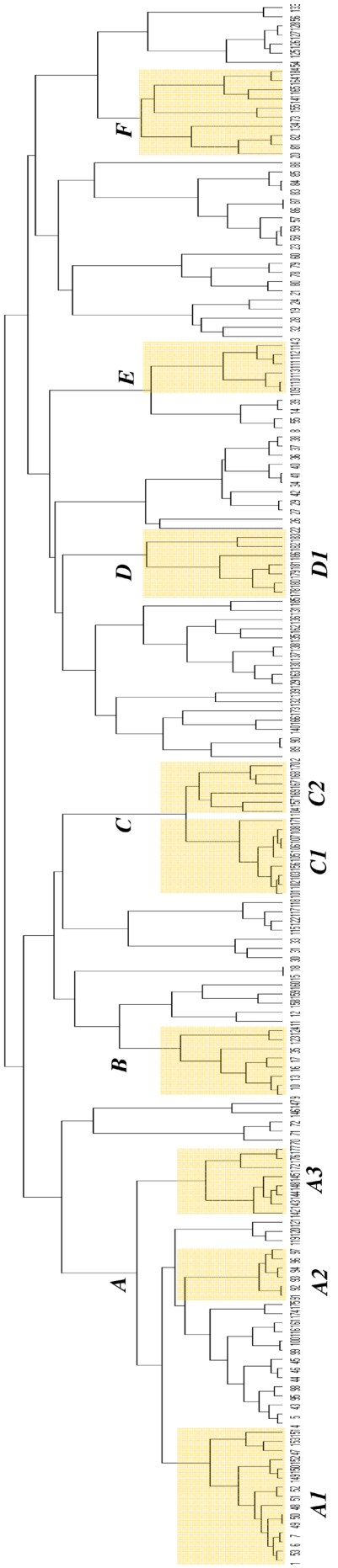

Fig. 4 - Dendrogram from the cluster analysis show the associations named A, B, C, D, E, F and the related subassociations described in the text.

vaillanti-Ptychostometum capillaris ass. nova and *Eryngium pusillum* dominated community.

Description of the detected communities

Ord.: *ISOËTETALIA* Br.-Bl. 1935

The order brings together several thermophylous and subthermophilous micro-associations from the W-Mediterranean, growing on siliceous substrates with acidic to neutral pH, which get already dry in spring (Biondi & Blasi, 2013). Type and duration of the soil flooding are changeable and determine the subdivision into alliances.

All.: *ISOËTION* Br.-Bl. 1935

The alliance groups spring dwarf ephemeral phytocoenoses with a Mediterranean distribution, generally developed on small surfaces flooded for a short period, on limestone soils, rich in *Isoëtes* species: *I. histrix*, *I. gymnocarpa*, *I. iapygia* (now named *I. todaroana*) (Troìa & Greuter, 2014; Bagella *et al.*, 2015). These plant communities tipically show topographic contacts with the small-size annual dry grasslands belonging to the class *Tuberarietea guttatae* (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 nom. mut. propos. Rivas-Martínez *et al.* 2002, with which they often develop a chronological sequence.

In the study area, the waterlogged soils, when affected by trumpling, sometimes show the presence of nitrophilous elements (*e.g. Poa annua* or *Plantago coronopus*), while the cupular pools can host *taxa* from the classes *Saginetea* and *Poetea bulbosae*.

Ass.: *CRASSULO VAILLANTII-PTYCHOSTOMETUM CAPILLARIS* ass. nova (Tab. 1)
(*Holotypus*: Rel. 110, Tab. 1)

Typical community of rocky substrates (cupular pools) that develops on margins of pools with a thickness of few centimeters. Singular is the formation of a moss layer dominated by *Ptychostomum capillare* which covers the limestone base and which, by ensuring a moderate water retention, acts as a substrate for the growth of *Tillaea vaillantii* and other microphytes. *P. capillare* is present in all the Italian regions (Aleffi *et al.*, 2008). It has been reported as a companion species in the *Campylopus introflexus*-dominated community recorded by Puglisi *et al.* (2015) in Lazio region, a bryocoenosis that tends to colonize the outermost zones of the ponds on seasonally moist sandy soil. This is the first time that its role in a plant community was surveyed in Italy.

Ass.: *LYTHRO HYSSOPIFOLIAE-CRASSULETUM VAILLANTII* Bagella, Caria, Filigheddu & Farris 2009 (Tab. 2)

Pioneer amphibious community developing in early spring on cupular pools with a diameter less than 1 m, dominated by *T. vaillantii* and other small therophytes of the class *Isoëto-Nanojuncetea* on silty substrate is less than 2 cm depth. The presence of *Polypogon maritimus* in 2 rel-

Tab. 1 - *Crassulo vaillanti-Ptychostometum capillaris* ass. nova (Type: CP = cupular pools; Locality: TP = Torre Pali).

Rel. N.	109	110	113	114	
Cover (%)	100	100	100	100	Presences
Locality	TP	TP	TP	TP	
Type of MTP	CP	CP	CP	CP	
Charact. and diff. *taxa* of the *Crassulo vaillanti-Ptychostometum capillaris* ass. nova					
Ptychostomum capillare (Hedw.) D.T. Holyoak	4	5	2a	3	4
Tillaea vaillantii Willd.	1	1	1	3	4
Charact. *taxa* of the upper units					
Juncus bufonius L.	3	3	2a	2a	4
Juncus capitatus Weigel	2a	2a	2a	1	4
Anagallis arvensis L.	2a	2a	.	.	2
Lythrum hyssopifolia L.	+	2a	.	3	3
Other *taxa*					
Sedum annum L.	2a	2a	+	.	3
Sagina apetala Ard.	2a	.	1	2a	3
Draba verna L.	2b	2b	.	.	2
Tripolium pannonicum (Jacq.) Dobrocz. subsp. pannonicum	2a	.	.	.	1
Ochlopoa infirma (Kunth) H. Scholz	1	.	.	.	1
Trifolium arvense L.	.	+	.	.	1

Tab. 2 - *Lythro hyssopifoliae-Crassuletum vaillantii* Bagella, Caria, Filigheddu & Farris 2009 (Type: CP = cupular pools; Locality: CB = Contrada Badessa, PC = Palude del Capitano, TP = Torre Pali, LS = La Strea).

Rel. N.	8	55	112	39	14	
Cover (%)	90	10	10	65	85	Presences
Locality	BA	PC	TP	PS	TP	
Type	CP	CP	CP	CP	CP	
Charact. and diff. *taxa* of the ass. *Lythro hyssopifoliae-Crassuletum vaillantii* Bagella, Caria, Filigheddu & Farris 2009						
Tillaea vaillantii Willd.	5	2a	2a	4	4	5
Lythrum hyssopifolia L.	.	.	+	+	1	3
Polypogon maritimus Willd.	.	.	.	+	+	2
Charact. *taxa* of the upper units						
Juncus bufonius L.	+	.	+	.	.	2
Juncus hybridus Brot.	.	.	.	+	2b	2
Gaudinia fragilis (L.) P. Beauv.	+	.	.	.	.	1
Juncus capitatus Weigel	.	.	+	.	.	1
Other *taxa*						
Polygonum aviculare L.	+	.	.	.	+	2
Gastridium ventricosum (Gouan) Schinz et Thell.	+	.	.	.	.	1
Ochlopoa infirma (Kunth) H. Scholz	.	.	+	.	.	1
Sedum caespitosum (Cav.) DC.	.	.	.	.	+	1
Spergula salina (J. Presl et C. Presl) D. Dietr.	.	.	.	.	+	1

Tab. 3 - *Elatinetum macropodae* Br. Bl. 1931 (Type: CP = Cupular pools; Locality: TP = Torre Pali, FE = Felline).

Rel. N.	15	18	
Cover (%)	100	90	Presences
Locality	TP	FE	
Type	CP	CP	
Charact. and diff. *taxa* of the ass. *Elatinetum macropodae* Br. Bl 1931			
Elatine macropoda Guss.	5	5	2
Lythrum portula (L.) D. A. Webb	2a	.	1

evés could represent a differential role with respect to the Sardinian association described by Bagella *et al.* (2009). A similar community was also described for the rock pools at Crete, in Greece (Bergmeier, 2001) but without any specific syntaxonomical location.

Ass.: *ELATINETUM MACROPODAE* Br. Bl 1931 (Tab. 3)

Monospecific community that starts developing in late spring dominated by *Elatine macropoda*, a steno-mediterranean species considered Critically Endangered (CE) in Italy (Conti *et al.*, 1997). This community develops in the center of rock pools where the water depth is generally between 2 and 5 cm and the soil thickness about 2 cm. It develops a spatial contact with the above reported *Lythro-Crassuletum* that colonize the wetter core of the rock pools.

Ass.: *JUNCO CAPITATI-ISOËTETUM HISTRICIS* Br.-Bl. 1935 *TYPICUM* Br.-Bl. 1935 (Tab. 4, Rels. 44-116)

Ephemeral community developing on temporarily flooded soils in open patches of cork-oak woodlands in early spring dominated by therophyte, including several of the class *Tuberarietea*, a typical trait of this vegetation type (Molina, 2005). This community is here referred to the association *Junco capitati-Isoëtetum histricis* Br.-Bl. 1935 described on the basis of one single relevé (Braun-Blanquet, 1935, p. 9) carried out in the surroundings of Meloula, Tunisia. Being the only one reported in the mentioned paper, and being defined by the author himself as "typique" (Braun-Blanquet, 1935, p. 8), this relevé must also be considered the holotype for the typical subassociation. Among the species considered characteristic of this association there are: *Isoëtes histrix*, *Juncus capitatus*, *Cicendia filiformis*, *Solenopsis laurentia*. The soils are clayey, 10 to 20 cm deep, flooded with the first rains and dried up in spring.

Together with the characteristics species of the association several moss species grow in this community, playing a significative ecological role in organic enrichment of soils and protection of the sediment from external stresses (radiation, wind, erosion etc.). Very peculiar is also the presence of *I. subinermis*, formerly described as a form of *I. histrix* but recently promoted to the species level, based on karyological and morfological traits observed in Calabrian specimens (Cesca & Peruzzi, 2001).

From data analysis different aspects can be detected, that are spatially contiguous in response of hydrological gradients and light expositions. They are here referred to different subassociassions and briefly described hereafter.

Ass.: *JUNCO CAPITATI-ISOËTETUM HISTRICIS* Br.-Bl. 1935 *PLEUROCHETETOSUM SQUARROSAE* subass. nova (Tab. 4, Rels. 91-117)
(*Holotypus*: Rel. 96, Tab. 4)

Tab. 4 - *Junco capitati-Isoëtetum histricis* Br.-Bl. 1935 *typicum* Br.-Bl. 1935 (rels. 44-116), *pleurochetetosum squarrosae* subass. nova (rels. 91-117), *solenopsietosum laurentiae* subass. nova (rels. 6-153), *cheilotelosum chloropi* subass. nova (rels. 174-177) (Type: WS = Waterlogged soils; Locality: BC = Bosco del Compare, BP = Bosco Preti)

Rel. N.	44	46	45	95	98	43	4	5	99	100	97	172	142	143	144	145	148	116	91	92	93	94	96*	115	122	117	6	53*	1	7	50	49	48	51	52	47	149	150	152	153	174	175[a]	176	177	Presences
Cover (%)	100	55	80	95	65	65	100	100	80	70	55	80	45	25	80	65	95	100	100	100	100	65	100	100	95	80	100	755	100	100	40	65	65	100	100	55	35	55	55	95	100	100	100	100	
Locality	BC	B	B	B	B	B	BP	BP	BC	BC	BC	BP	BC	BC	BC	BC	BP	BP	BC	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BP	BP	BP	BP	
Type of MTP	WS	W	W	W	W	W	WS	WS	W	WS	W	W	W	W	W	W	W	WS	WS	WS	WS	W	WS	WS	W	W	WS	WS	WS	WS	W	W	W	WS	WS	W	W	W	W	W	WS	WS	WS	WS	
Charact. and diff. taxa of the ass. *Junco capitati-Isoëtetum histricis* Br.-Bl. 1936																																													
Isoëtes histrix Bory	3	2b	2a	3	3	3	4	3	3	3	2b	1	.	1	1	+	1	2b	3	3	3	2b	3	.	2a	2a	4	3	4	3	2b	3	2b	2a	1	2b	1	1	1	2b	2a	3	3	3	42
Lotus angustissimus L.	+	+	.	.	.	.	1	.	.	.	.	.	+	+	.	2a	+	1	.	.	2a	.	.	1	.	2a	1	1	1	+	.	+	1	.	.	.	1	1	1	.	+	1	+	+	24
Juncus capitatus Weigel	.	.	.	.	2a	1	3	2b	.	.	.	2a	1	2a	2a	1	1	.	.	.	.	.	2b	.	.	.	.	1	2b	+	.	.	2m	.	.	.	2m	2m	2m	+	1	2b	2b	2b	23
Cicendia filiformis (L.) Delarbre	.	.	.	.	.	.	1	4	.	.	.	3	1	1	1	.	.	.	.	.	.	.	.	.	.	.	2b	1	2m	+	1	+	1	+	.	1	1	+	1	1	3	1	2a	1	23
Juncus bufonius L.	.	.	.	.	.	1	.	.	.	.	.	1	.	+	+	1	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	1	.	1	1	2a	2a	13
Local diff. taxa																																													
Isoëtes subinermis (Durieu) Cesca et Peruzzi	1	1	1	2b	1	1	3	3	1	1	1	1	.	.	.	.	1	1	.	.	1	2a	2a	1	.	1	3	2a	3	2b	1	2a	1	.	2a	1	1	1	1	2a	2a	3	3	3	36
Diff. *taxa* of the subass. *pleurochaetetosum squarrosae* subass. nova																																													
Pleurochaete squarrosa (Brid.) Lindb.	.	.	.	.	.	.	.	.	.	.	2a	.	.	.	.	.	.	.	5	2b	3	2a	2b	4	2b	2a	.	.	.	.	.	.	2a	.	.	.	.	.	.	.	.	.	.	.	10
Pseudoscleropodium purum (Hedw.) M. Fleisch.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	4	2a	2a	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Diff. *taxa* of the subass. *solenopsietosum laurentiae* subass. nova																																												
Centaurium maritimum (L.) Fritsch	.	1	.	.	.	+	+	+	.	.	.	.	1	+	1	.	3	.	.	.	.	.	.	.	.	.	+	2a	2a	+	1	1	1	1	1	1	1	1	.	.	.	.	.	.	20
Solenopsis laurentia (L.) C. Presl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	2m	.	+	.	.	2m	1	1	2m	+	1	1	2m	.	.	.	.	11
Diff. *taxa* of the subass. *cheiloteletosum chloropi* subass. nova																																												
Ranunculus paludosus Poir.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2a	2a	2a	5
Cheilotela chloropus (Brid.) Broth.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	2b	1	1	4
Serapias lingua L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	2b	2b	3
Charact. *taxa* of the upper units																																													
Gaudinia fragilis (L.) P. Beauv.	.	.	+	+	2a	1	.	.	.	.	+	.	+	1	1	1	1	.	2a	3	3	2b	2b	.	.	.	2b	1	3	2b	2a	2a	1	3	2b	.	1	+	2b	.	.	.	.	.	27
Agrostis pourretii Willd.	.	.	.	.	.	.	.	.	2a	2a	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	1	1	.	.	+	+	.	.	.	.	11
Juncus pygmaeus Rich. ex Thuill.	.	.	.	.	.	+	.	.	.	.	.	2a	.	1	2m	1	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	1	.	1	.	11
Lythrum thymifolia L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	1	.	.	.	.	3
Lythrum hyssopifolia L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	3
Anagallis minima (L.) E.H.L. Krause	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	3
Anagallis arvensis L. subsp. parviflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2
Riccia crozalsii Levier	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2a	2
Isolepis cernua (Vahl) Roem. et Schult.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	1
Centaurium pulchellum (Sw.) Druce	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1
Mentha pulegium L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Transgressive *taxa* from the class *Tuberarietea guttatae*																																												
Trifolium campestre Schreb.	+	1	.	.	.	+	2b	.	.	.	.	.	1	+	3	3	3	4	.	.	.	.	.	2b	1	1	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	15
Plantago serraria L.	2a	+	.	.	.	+	2a	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2a	.	.	.	.	1	9
Trifolium cherlerii L.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	6
Romulea bulbocodium (L.) Sebast. et Mauri	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	.	+	.	.	.	.	+	.	.	.	.	.	5
Briza maxima L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	1	.	.	.	.	+	.	5
Aira caryophyllea L.	.	.	.	.	.	.	2m	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	4
Euphorbia exigua L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	4
Vulpia ciliata Dumort.	.	1	.	.	.	+	.	.	.	.	.	.	2b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Briza minor L.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	3
Aira elegantissima Schur subsp. elegantissima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.	.	.	3
Brachypodium distachyon (L.) P. Beauv.	.	.	.	.	.	.	2b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Filago gallica L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Ornithopus compressus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1
Vulpia muralis (Kunth) Nees	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1

Other *taxa*																																													
Oenanthe pimpinelloides L.	+	1	+	3	2a	1	2a	+	2b	2a	2a	1	1	+	2a	+	+	2a	3	1	1	.	2a	2a	1	.	+	.	+	+	.	.	.	+	.	.	.	.	+	.	.	2a	1	2a	32
Galatella linosyris (L.) Rchb. fil.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	.	1	4	4	+	1	1	1	+	.	.	+	2a	14
Carex flacca Schreb.	.	.	.	1	+	.	.	.	2a	2a	.	.	.	.	.	.	.	1	1	2a	.	+	.	1	2a	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	13
Carex flacca Schreb. subsp. serrulata (Biv.) Greuter	.	.	.	.	.	1	+	+	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	2b	2a	4	.	.	1	.	11
Plantago lanceolata L.	2a	+	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	2b	.	.	.	.	.	.	.	.	7
Romulea columnae Sebast. et Mauri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	2a	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	7
Eurhynchium striatum (Hedw.) Schimp.	5	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Ranunculus sardous Crantz	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	2a	3	2b	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Bellis annua L.	.	.	.	.	.	.	.	.	.	.	.	2a	.	.	.	.	.	.	3	2a	2a	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Linum trigynum L.	2m	2b	4	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Hainardia cylindrica (Willd.) Greuter	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Poa sylvicola Guss.	.	+	.	.	.	1	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Plantago coronopus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Lolium perenne L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Crepis rubra L.	.	.	.	.	.	.	.	.	.	1	2b	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Gastridium ventricosum (Gouan) Schinz et Thell.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	.	.	.	.	.	2a	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Linum bienne Mill.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	3
Vicia villosa Roth	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Trifolium arvense L.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2
Anagallis arvensis L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2
Prunella laciniata (L.) L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Hypericum australe Ten.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Galium murale (L.) All.	.	.	1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2

One aspect of the association is floristically poor of species and is located at margins of patches in small depressions, mostly in shady sites. It is dominated by bryophytes (*Pseudoscleropodium purum*, *Pleurochaete squarrosa*, *Eurhynchium striatum*) that form a thick layer on which the other species develop. The subassociation is marked by the presence of typical *Isoëtion* microphytes and by the presence of this community develops in marginal shady moist areas of ponds. The chorology of species tends to a steno-mediterranean atlantic but there is the costant presence of *I. subinermis*, with annual rushes.

Ass.: *JUNCO CAPITATI-ISOËTETUM HISTRICIS* Br.-Bl. 1935 *SOLENOPSIETOSUM LAURENTIAE* subass. nova (Tab. 4, Rels. 6-153)
(*Holotypus*: Rel. 53, Tab. 4)

Another aspect of the association develops in deeper soils, drier and more exposed to light, dominated by theropytes. This vegetation type is referred to the new subassociation *solenopsietosum laurentiae*. It is a late spring community that is spatially localized next to the subassociation *pleurochetetosum squarrosae*, in open maquis of cork oak woods. In particolar, this community prefers slightly higher altitudes and more prolonged light exposure than *pleurochetetosum squarrosae*. Besides several species of the *Junco-Isoëtetum*, the subassociation includes as differential species *Solenopsis laurentia*, *Centaurium maritimus* and, with high constancy and cover values, annual therophytes such as *Gaudinia fragilis*, *Agrostis pourretii*, *Bellis annua*, *Galatella lynosiris*.

Ass.: *JUNCO CAPITATI-ISOËTETUM HISTRICIS* Br.-Bl. 1935 *CHEILOTELETOSUM CHLOROPI* subass. nova (Tab. 4, Rels. 174-177)
(*Holotypus*: Rel. 175, Tab. 4)

The subassociation is differentiated by the presence of *Cheilotela chloropus*, a moss species described by Bridel (1818) under the name of *Dicranum chloropus*, based on an Italian type from the region of Rome. In Italy it has a central-southern distribution (Aleffi *et al.*, 2008). In the surveyed sites it creates often a thick layer maintaining a certain condition of humidity where *I. histrix* and the other species can survive longer in the dry period. It has been observed on bare wet soils, with a slightly concave shape. Other diagnostic species of this subassociation are *Serapias lingua* and *Ranunculus paludosus*.

Ass.: *PLEUROCHAETO SQUARROSAE-ISOËTETUM TODAROANAE* ass. nova *ISOËTETOSUM TODAROANAE* subass. nova (Tab. 5)
(*Holotypus*: Rel. 101, Tab. 5)

This new proposed association and its subassociation *isoëtetosum todaroanae* (corresponding to the typical subassociation) have specific ecological characteristics and include communities strictly related to limestone lythology with rock surfacing, in a context dominated by mediter-

ranean maquis with *Myrtus communis*, *Pistacia lentiscus*, *Cystus salvifolius*, *Cystus monspeliensis*. The community is like a grassy cushion consisting mainly of mosses, in particular *Pleurochaete squarrosa*, on which *I. todaroana* a recently described species (Troìa & Raimondo, 2010) grows. This association has an autumnal development and grows on thin deposits of soil in the concavities on calcareous plateaus, where the water supply depends both on run-off and superficial waterflow.

Ass. *PLEUROCHAETO SQUARROSAE-ISOËTETUM TODAROANAE* ass. nova *CHEILOTELETOSUM CHLOROPII* subass. nova (Tab. 5)
(*Holotypus*: Rel. 167, Tab. 5)

The subassociation *cheiloteletosum chloropii* is a community in spatial continuity with the *typicum Pleurochaeto squarrosae-Isoëtetum todaroanae*, developing where the slope increases. It is differentiated by the high constancy of *Cheilotela chloropus*, diagnostic species of the proposed subassociation. In late spring and summer most of the species disappear due to the environmental conditions and the absence of precipitations; very peculiar is the ecological role of the moss species for the development of these communities, as highlighted by Poirion & Barbero (1965) for the description of *Isoëtion* in Costa Azzurra. They act as sponges, retaining water and preventing its rapid flow; they preserve the soil moisture and promote the growth of the other species related to the association. Also Poponessi *et al.* (2015a, 2015b, 2016a, 2016b), showed the co-occurrence of bryophytes and vascular plants due to the climatic conditions of sites. The community is dominated by plants that appear in late winter, such as *I. todaroana* and *P. squarrosa*, and also geophytes as *R. columnae* and *R. bulbocodium* in addition to annual therophytes.

AGROSTIS POURETII-dominated community (Tab. 6)

It is a community typical of dolines, with shallow soils (<10 cm) but a long inundation period, composed of ephemeral grasses that develop in late spring to summer, on raised areas near the margins of ponds that dry up before the core wet areas.

The relèves were performed in grasslands developed in mosaic with perennial grasses-dominated communities, such as *Carex divisa*, occurring on deeper soils. This community has some floristic affinities with the association *Anthoxanto aristati-Agrostietum salmanticae* described by Biondi & Bagella (2009), however it presents some peculiarities such as the presence of *Carex divisa* subsp. *chaetophylla* with high levels of coverage. For this reason, it is here treated only at the level of community, postponing to a deeper investigation its syntaxonomic attribution.

All. *CICENDIO FILIFORMIS-SOLENOPSION LAURENTIAE* Brullo & Minissale 1998

This phytosociological alliance, described by Brullo & Minissale (1998), groups the Mediterranean communities which show more remarkable thermo-xerophylous features, compared to the Atlantic alliance *Cicendion* (Rivas Goday in Rivas Goday & Borja, 1961) Br.-Bl. 1967 (Deil, 2005; Bagella *et al.*, 2007, 2009, 2013; Gigante *et al.*, 2007, 2013).

In particular, for the waterlogged soils in Puglia, under this alliance a new association is here described that develops in spring, characterized by the high constancy of *Isolepis cernua*.

Ass. *TRIGLOCHINO BARRELIERI-ISOLEPIDETUM CERNUAE* ass. nova (Tab. 7)
(*Holotypus*: Rel. 13, Tab. 7)

This community is like a small turf with microphytes as *Triglochin barrelieri* and other characteristics taxa of the upper units. This community is localized in temporary pools near the coast with the presence of salty soils. In particularly sub-halophilous places, the relevés result rich in *Polypogon maritimus*. Other frequent species are *Juncus hybridus*, *Lythrum hyssopifolia*, *Lythrum tribracteatum*, sometimes with high cover values. Apart from these taxa, the plant community appears rather species-poor with the only exception of Rel. 173.

All. *PRESLION CERVINAE* Br.-Bl. ex Moor 1937

Annual Mediterranean vegetation developed on largely flooded soils with deep waters, generally wet till the end of spring (Biondi & Blasi, 2013). As concerns its ecology, this alliance presents an intermediate character between *Isoëto-Nanojuncetea* and *Phragmito-Magnocaricetea*. It has a W-Mediterranean character and a variable affinity for the water level: inundated during the winter and very dry in summer. In the study areas, the communities belonging to *Preslion cervinae* seem to be linked to palustrine sites, with high water levels and waterlogged soils until late spring.

Ass. *JUNCO PYGMAEI - ISOËTETUM VELATI TYPICUM* (Tab. 8, Rels. 180-181) and *PILULARIETOSUM MINUTAE* subass. nova (Tab. 8, Rels. 178-183)
(*Holotypus*: Rel. 178, Tab. 8)

Amphibious ephemeral vegetation with a Stenomediterranean-Atlantic distribution, characteristic of small depressions on clayey soils with a long inundation period. This community frequently develops along the banks of ponds with extended periods of flooding and water stagnation. The association has been described by Rivas-Goday (1956) in the surroundings of Guadarrama (Embalse de Santillana). The subassociation *typicum* was described later by the same author (Rivas-Goday, 1970).

As concerns the here reported plant community, the

Tab. 5 - *Pleurochaeto squarrosae-Isoëtetum todaroanae* ass. nova, *isoëtetosum todaroanae* subass. nova and *cheiloteletosum chloropii* subass. nova (Type: CP = Cupular pools; Locality: DC = M. Don Cesare, LS = La Strea).

Rel. N.	101*	102	156	103	105	106	107	108	6	7	171	11	12	170	167*	168	104	157	
Cover (%)	100	100	100	100	100	100	100	##	100	100	100	100	95	154.5	100	100	100	90	Presences
Locality	MD	MD	MD	MD	MD	MD	PS	PS	MD	MD	MD	MD	MD	MV	MV	MD	MD	MD	
Type	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	
Charat. and diff. *taxa* of *Pleurochaeto squarrosae-Isoëtetum todaroanae* ass. nova, *isoëtetosum todaroanae* subass. nova																			
Isoëtes todaroana Troia et Raimondo	2b	2a	.	2a	2a	2a	2b	2b	1	1	2a	3	3	2a	2b	1	2b	+	17
Pleurochaete squarrosa (Brid.) Lindb.	5	5	5	5	5	5	5	5	.	.	5	.	.	2a	2b	4	.	.	12
Diff. taxa of the ass. *Pleurochaeto squarrosae-Isoëtetum todaroanae* ass. nova, *cheiloteletosum chloropii* subass. nova																			
Cheilotela chloropus (Brid.) Broth.					2a									5	5	2b	4	4	6
Charact. *taxa* of the upper units																			
Romulea bulbocodium (L.) Sebast. et Mauri	2a	2a	2b	2a	2a	1	2a	1	+	2a	1	.	.	.	1	+	2a	1	15
Polypogon maritimus Willd.	1	2a	2a	+	1	.	+	+	2b	+	.	.	.	.	.	.	3	1	11
Romulea columnae Sebast. et Mauri	.	.	.	.	2b	2a	2a	2a	.	.	1	.	1	.	1	+	.	1	9
Ranunculus sardous Crantz	+	.	1	.	1	3	2b	2a	2b	5	.	.	.	.	.	.	.	.	8
Juncus bufonius L.	+	.	.	.	.	.	.	1	.	.	1	.	.	2a	2b	+	.	+	7
Gaudinia fragilis (L.) P. Beauv.	.	.	.	.	.	.	.	.	1	.	1	1	2a	.	2b	.	.	.	5
Lythrum hyssopifolia L.	.	.	+	.	.	.	.	.	2a	.	.	1	.	.	.	.	+	.	4
Lotus angustissimus L.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	1	3
Ranunculus paludosus Poir.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	2a	1	.	.	3
Mentha pulegium L.	.	.	.	.	.	.	.	.	3	3	.	.	.	.	.	.	.	.	2
Oenanthe pimpinelloides L.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1
Juncus hybridus Brot.	.	.	.	.	.	.	.	.	.	.	.	2m	.	.	.	.	.	.	1
Anagallis arvensis L. subsp. parviflora (Hoffmanns. et Link) Arcang.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1
Anagallis minima (L.) E.H.L. Krause	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1
Transgressive *taxa* from the class *Helianthemetea*																			
Euphorbia exigua L.	1	1	2b	1	1	.	1	+	.	.	1	1	.	1	3	2b	.	.	12
Antoxantum aristatum Boiss.	2a	2a	1	1	.	.	.	.	.	.	.	.	.	.	.	.	2a	+	6
Catapodium rigidum (L.) C.E. Hubb. ex Dony	.	.	.	.	.	.	2a	1	.	.	.	+	.	+	.	.	.	2a	5
Trifolium cherlerii L.	.	.	.	.	2b	.	.	.	.	.	2b	.	.	1	.	.	.	.	3
Hypochoeris achyrophorus L.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	+	.	.	.	3
Plantago bellardii All.	.	.	.	.	.	.	.	.	.	.	3	.	.	1	.	.	.	.	2
Vulpia ciliata Dumort.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	2
Trifolium scabrum L. subsp. lucanicum (Gasp. ex	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	2
Gastridium ventricosum (Gouan) Schinz et Thell.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1
Asterolinon linum-stellatum (L.) Duby	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1
Cynosurus echinatus L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1
Ornithopus compressus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1
Other *taxa*																			
Ranunculus garganicus Ten.	1	2b	2a	2a	2a	1	2b	2b	.	.	+	+	+	+	.	.	1	.	13
Linum bienne Mill.	1	.	.	.	1	2a	1	1	.	.	1	+	1	+	2a	1	.	1	12
Trifolium resupinatum L.	2a	2b	3	2a	2b	2b	2b	.	4	+	.	.	.	.	.	.	1	.	10
Bellis annua L.	2b	.	2a	2a	.	.	.	2a	2b	1	1	.	.	1	.	.	1	.	9
Anagallis arvensis L.	1	.	.	+	.	1	.	2a	.	.	.	1	+	+	.	.	.	1	8
Plantago lagopus L.	.	.	.	3	2a	2a	1	+	.	.	.	+	3	.	.	.	2a	.	8
Sedum rupestre L.	.	.	.	.	1	1	.	.	.	.	+	1	.	+	.	.	.	1	6
Ornithogalum gussonei Ten.	.	.	.	.	.	.	.	.	.	.	1	+	+	1	.	.	.	.	4
Trifolium stellatum L.	.	.	.	.	.	.	.	.	.	.	2a	.	1	+	.	+	.	.	4
Scandix pecten-veneris L.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	r	1	.	.	4
Crepis rubra L.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	3
Hainardia cylindrica (Willd.) Greuter	.	.	.	.	.	.	.	.	.	.	1	1	.	+	.	.	.	.	3
Sherardia arvensis L.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	+	.	.	3
Cerastium pumilum Curtis	.	.	.	.	.	.	.	.	.	.	+	.	.	1	2a	.	.	.	3
Carex flacca Schreb.	2b	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	2
Saxifraga tridactylites L.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	2
Triglochin bulbosum L. subsp. barrelieri (Loisel.) Rouy	.	.	.	.	.	.	.	.	1	2a	.	.	.	.	.	.	.	.	2
Vulpia muralis (Kunth) Nees	.	.	.	.	.	.	.	.	.	.	2b	.	.	1	.	.	.	.	2
Trifolium lappaceum L.	.	.	.	.	.	.	.	.	.	.	.	2b	2a	.	.	.	.	.	2
Cerastium diffusum Pers. subsp. diffusum	.	.	.	.	.	.	.	.	.	.	.	2a	+	.	.	.	.	.	2
Sideritis romana L.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	2
Ochlopoa infirma (Kunth) H. Scholz	.	.	.	.	.	.	.	.	.	.	.	3	.	2a	.	.	.	.	2
Parentucellia latifolia (L.) Caruel	.	.	.	.	.	.	.	.	.	.	.	r	.	+	.	.	.	.	2
Centaurium pulchellum (Sw.) Druce	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	2
Sagina apetala Ard.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	r	.	.	.	2
Aira caryophyllea L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	2

last 2 relevés in Tab. 8 (180 and 181) can be referred to *Junco pygmaei-Isoëtetum velatae* Rivas Goday 1956 *typicum*. The other relevés (178-183) are locally differentiated by the presence of *Pilularia minuta*, which is here proposed as a diagnostic taxon for the new subassociation *pilularietosum minutae*. A similar community has been observed by Lorenzoni & Paradis (1997) in Corsica.

Ord.: *NANOCYPERETALIA* Klika 1935

This order groups together the plant communities developed in summer-autumn on flooded substrates which start to get dry not before the end of spring, with eutrophic to hypertrophic, subalkaline to basic soils, often salt- and nitrogen-tolerant, with a C-European and Atlantic distribution, also occurring in Mediterranean areas (Biondi & Blasi, 2013).

Tab. 6 - *Agrostis pourretii* (Willd)-dominated community (Type: D = dolines; Locality: LC = Lago del Capraro, LF = Laccu Feretru).

Rel. N.	70	24	71	72	
Cover (%)	100	100	100	100	
Locality	LC	LF	LC	LC	Presences
Type	D	D	D	D	
Charact. *taxa* of the *Agrostis pourretii* -dominated community					
Agrostis pourretii Willd.	5	5	4	4	4
Charact. *taxa* of the upper units					
Lotus angustissimus L.	4	2b	1	+	4
Ranunculus sardous Crantz	.	+	1	.	2
Centaurium pulchellum (Sw.) Druce	.	+	.	.	1
Centaurium maritimum (L.) Fritsch	.	+	.	.	1
Other *taxa*					
Polypogon maritimus Willd.	1	+	1	.	3
Carex divisa Huds.	.	4	5	5	3
Aira cupaniana Guss.	1	.	.	1	2
Trifolium nigrescens Viv. subsp. nigrescens	1	.	.	.	1
Phalaris minor Retz.	.	1	.	.	1
Symphyotrichum squamatum (Spreng.) G.L. Nesom	.	+	.	.	1
Poa sylvicola Guss.	.	.	1	.	1
Rumex pulcher L.	.	.	+	.	1

Tab. 7 - *Triglochino barrelieri-Isolepidetum cernuae* ass. nova (Type: CP = cupular pools, WS: waterlogged soils; Locality: LS = La Strea, BP = Bosco Preti).

Rel. N.	3	5	173	12	14	13*	10	17	16	
Cover (%)	100	85	95	70	70	75	100	100	90	
Locality	PS	PS	BP	PS	PS	PS	PS	PS	PS	Presences
Type	CP	CP	WS	CP	CP	CP	CP	CP	CP	
Charact. e diff. *taxa* of the ass.*Triglochino barrelieri-Isolepidetum cernuae* ass. nova										
Isolepis cernua (Vahl) Roem. et Schult.	5	4	4	2a	1	3	5	3	2b	9
Lythrum hyssopifolia L.	r	.	+	.	1	1	4	4	2b	7
Polypogon maritimus Willd.	.	.	.	+	1	2b	1	+	3	6
Juncus hybridus Brot.	2a	2b	.	.	1	1	.	.	2a	5
Triglochin barrelieri Loisel.	.	.	.	+	.	1	1	+	2a	5
Lythrum tribracteatum Salzm. ex Spreng.	.	.	.	4	4	2b	1	.	.	4
Charatt. *taxa* of the upper units										
Centaurium maritimum (L.) Fritsch	2b	1	.	.	.	.	.	.	.	2
Centaurium pulchellum (Sw.) Druce	+	.	.	.	.	.	.	.	.	1
Bellis annua L.	.	+	.	.	.	.	.	.	.	1
Antinoria agrostidea (DC.) Parl.	.	.	2b	.	.	.	.	.	.	1
Juncus bufonius L.	.	.	2a	.	.	.	.	.	.	1
Romulea columnae Sebast. et Mauri	.	.	1	.	.	.	.	.	.	1
Juncus pygmaeus Rich. ex Thuill.	.	.	1	.	.	.	.	.	.	1
Agrostis pourretii Willd.	.	.	1	.	.	.	.	.	.	1
Isoëtes histrix Bory	.	.	1	.	.	.	.	.	.	1
Isoëtes subinermis (Durieu) Cesca et Peruzzi	.	.	1	.	.	.	.	.	.	1
Ranunculus paludosus Poir.	.	.	+	.	.	.	.	.	.	1
Oenanthe pimpinelloides L.	.	.	+	.	.	.	.	.	.	1
Other *taxa*										
Spergula salina (J. Presl et C. Presl) D. Dietr.	.	.	.	+	+	.	.	.	+	3
Plantago crassifolia Forssk.	1	+	.	.	.	.	.	.	.	2
Symphyotrichum squamatum (Spreng.) G.L. Nesom	1	.	.	.	.	.	1	.	.	2

All. *VERBENION SUPINAE* Slavnić 1951

Sub-halophilous nitrophilous Mediterranean phytocoenoses with an autumnal phenology, developed on long-flooded substrates, generally dominated by prostrate species of various size (Biondi & Blasi, 2013).

ERYNGIUM PUSILLUM-dominated community (Tab. 9)

This plant community develops on very deep soils (> 20cm), and presents two variants, differentiated by the helophytes *Eleocharis multicaulis* and *E. palustris*. It has a late spring-summer cycle, typical of the MTP named doline. It is dominated by *Eryngium pusillum* (syn.: *E. barrelieri* Boiss.), a stenomediterranean

Tab. 8 - *Junco pygmaei-Isoëtetum velati* Rivas Goday 1956 *typicum* Rivas Goday 1970 (Rels. 180-181) and *pilularietosum minutae* subass. nova (Rels. 178-183) (Type: D = dolines; Locality: BE = Bellimento).

Rel. N.	178	179	182	183	181	180	
Cover (%)	35	15	70	65	15	35	
Locality	BE	BE	BE	BE	BE	BE	Presences
Type	D	D	D	D	D	D	
Charact. and diff. *taxa* of the ass. *Junco pygmaei-Isoëtetum velati* Rivas Goday 1956							
Isoetes velata A. Braun subsp. velata	2b	1	4	4	1	2a	6
Lythrum thymifolia L.	2a	2a	.	.	2a	2b	4
Juncus pygmaeus Rich. ex Thuill.	+	.	.	.	.	+	2
Charact. *taxa* of the subass. *pilularietosum minutae* subass. nova							
Pilularia minuta Durieu ex A. Braun	1	+	r	1	.	.	4
Charact. *taxa* of the upper units							
Isolepis cernua (Vahl) Roem. et Schult.	1	1	2	.	1	1	5
Eleocharis multicaulis (Sm.) Sm.	+	.	+	.	.	.	2
Juncus hybridus Brot.	.	+	.	.	.	1	2
Other *taxa*							
Polypogon subspathaceus Req.	.	1	2	.	+	1	4
Cynodon dactylon (L.) Pers.	1	+	.	.	.	.	2
Symphyotrichum squamatum (Spreng.) G.L. Nesom	.	.	.	.	.	+	1
Ranunculus peltatus Schrank subsp. baudotii (Godr.) Meikle ex C.D.K. Cook	.	.	1	.	.	.	1
Lepidium coronopus (L.) Al-Shehbaz	.	.	.	.	.	+	1

Tab. 9 - *Eryngium pusillum*-dominated community (Type: D = dolines; Locality: LF = Laccu Feretru, BE = Bellimento).

Rel. N.	81	82	20	134	126	127	
Cover (%)	60	85	90	35	15	85	
Type	D	D	D	D	D	D	Presences
Charact. *taxa* of the *Eryngium pusillum* -dominated community							
Eryngium pusillum Desf.	3	5	4	2b	2a	4	6
Charact. *taxa* of the upper units							
Ranunculus sardous Crantz	1	.	+	.	.	.	2
Lythrum junceum Banks et Sol.	.	.	.	1	.	.	1
Isolepis cernua (Vahl) Roem. et Schult.	.	.	.	+	.	.	1
Callitriche brutia Petagna	.	.	.	.	1	.	1
Other *taxa*							
Eleocharis palustris (L.) Roem. et Schult.	3	2a	.	.	.	.	2
Spergula salina (J. Presl et C. Presl) D. Dietr.	.	.	.	1	+	.	2
Polygonum aviculare L.	.	.	.	.	1	2b	2
Eleocharis multicaulis (Sm.) Sm.	.	.	.	.	1	2	2
Convolvulus arvensis L.	.	.	3	.	.	.	1
Rumex conglomeratus Murray	.	.	1	.	.	.	1
Polypogon maritimus Willd.	.	.	1	.	.	.	1
Symphyotrichum squamatum (Spreng.) G.L. Nesom	.	.	.	2a	.	.	1

hemicriptophyte, included in the Puglia Regional Red List as vulnerable (VU). It develops in contact with the deepest area of the pond and reflects the progressive lowering of the water level, when spring arrives; at the same time the community tolerate the emergence for long periods. Singular is the presence of the two above-mentioned variants, occurring in different sites following the alophytic gradient. The variant with *Eleocharis multicaulis* was observed in temporary ponds at Masseria Bellimento, in proximity of the Ionian coast, while the variant with *E. palustris* was found at the pond named Laccu Feretru, in the inland areas of Salento.

Spatial distribution and temporal succession of the plant communities

The essential ecological characteristic of temporary wetlands is the alternation of flooded and dry phases; during each of these phases various environmental factors play an important role in the structure and dynamics of the vegetation. The hydrological regime of the pools depends on a range of variables, such as water level, duration of flooding, soil type and topographical gradient.

We note that in a given pool the spatial and temporal distribution (related to changing seasons) of the vegetation is sometimes determined by the water depth gradients and the duration of flooding (*e.g.* at Laccu Feretru and Bellimento, that are dolines), while in other cases the driving forces are represented by the topographical gradients and slope (*e.g.* at Macchie Don Cesare, cupular pool and Bosco Preti, waterlogged soil). At Macchie Don Cesare the slope allows water stagnation only for a short time but the formation of a moss layer keeps the soil wet and allows the growth of the MTP species typical of *Pleurochaeto squarrosae-Isoëtetum todaroanae*.

In the dolines three zones are generally recognized: i) a central zone where communities of aquatic annuals are replaced, in spring, by communities of amphibious annuals, such as *Eryngium barrelieri* and *Mentha pulegium* or, in deeper soil, perennials such as *Eleocharis palustris*, and then in summer by communities of hygrophilous terrestrial annual plants such as *Agrostis pourretii*; ii) an intermediate zone where perennial species form a mosaic with annuals; iii) an outer zone, which dries out more quickly, where both hygrophilous vegetation and more generalist terrestrial species are present.

As concerns the waterlogged soils, where the soil is subject to human disturbance, ponds develop along the borders of Mediterranean maquis and firebreaks; in the more shaded areas there is a moss layer on which the typical species of *Junco capitati-Isoëtetum histricis* grow. In the more exposed sites the subassociation *solenopsietosum laurentiae* develop.

New investigations are under way to define the vegetation of new sites, also regarding the bryophyte component. In particular the studies are focusing on an area of Salento characterized by a high concentration of MTP sites and biodiversity of related flora, that includes the territories of Supersano, Cutrofiano, Scorrano and Ruffano in the province of Lecce.

Discussions and conclusions

This is the first paper specifically reporting on MTP vegetation in Puglia. The surveyed communities are referred to four alleances: *Isoëtion*, *Preslion*, *Cicendio-Solenopsion* and *Verbenion*. Seven associations and 2 plant communities were found in the study area, 3 of wich are here described for the first time as new association, with 6 new subassociations. The order Isoëtetalia is the most represented in the study area, while the order *Nanocyperetalia*, including the summer vegetation, is only represented by the *Eryngium pusillum*-dominated community.

Additionally, the present paper provides new insights on the role of moss species in the vegetation of Italy, a topic which recently received a vivifying pulse as indicated by a number of specific studies (Puglisi & Privitera, 2012; Poponessi *et al.*, 2015a, 2015b, 2016a, 2016b; Puglisi *et al.*, 2015).

MTP represent a priority habitat (Natura 2000 code: 3170*) listed in Annex I of the Directive 92/43/EC. This vulnerable and unstable habitat exists in areas that, due to their specific characteristics, are under significant human and natural pressures and have become prone to extinction (Bagella *et al.*, 2016).

The conservation value of the studied pools is shown by the richness and rarity of the species they host. The results of our study show that several rare plants at national level are distributed in Puglia, *e.g. E. macropoda* Guss., *E. multicaulis* (Sm.) Sm., *P. minuta* Durieu and *I. velata* A. Braun subsp. *velata* are listed as endangered in Italy (Scoppola & Spampinato, 2005). It should be emphasized that *Pilularia minuta* and *Eleocharis multicaulis* are actually present in only one site in Puglia. At a regional level, 7 species are on the Regional Red List (Conti *et al.*, 1997): *Elatine macropoda*, *Eryngium pusillum*, *Isoëtes histrix*, *Juncus pygmaeus*, *Lythrum thymifolia*, *Lythrum tribracteatum*, *Moenchia mantica*.

Regarding IUCN categories, the recent Red List of the Italian Flora, focusing only on policy species (Rossi *et al.*, 2013, 2014), took into account only a restricted number of the typical MTP species, (*e.g. Pilularia minuta*, considered VU at the national level). We suggest to extend protection to others particularly rare species present in just one or two sites such as *Antinoria agrostidea*, *Elatine alsinastrum*, *Eleocharis multicaulis*, *Juncus hybridus*, *Solenopsis laurentia*, *Verbena supina*, *Isoëtes todaroana*, *Lythrum borysthenicum*.

The species that colonize the MTP are habitat-specif-

ic, rare and difficult to detect. Many of these taxa are poorly understood and little studied because of their small size and short life-cycle, and most of them are classifiable according to the concept of rarity for their abundance, distribution, range area, frequency and phytosociology (Rabinowitz, 1981; Izco, 1998).

Additionally, particular care should be given to the fact that these vegetation types display an intrinsically restrict, scattered and fragmented distribution, demanding for appropriate tools for evaluating area and extent of occurrence, as pointed out by Gigante *et al.* (2016b).

Therefore it is necessary to conduct active and constant monitoring to remove negative effects, preserve biological diversity and restore the sites ecological functions (Bagella *et al.*, 2016; Gigante *et al.*, 2016a). Long-term monitoring of distribution, density and extent of the ponds and their vegetation is indispensable in order to safeguard species and communities of conservation priority.

Syntaxonomic scheme

ISOËTO-NANOJUNCETEA Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946
ISOËTETALIA Br.-Bl. 1935
Isoëtion Br.-Bl. 1935
Crassulo vaillantii-Ptychostometum capillaris ass. nova
Lythro hyssopifoliae-Crassuletum vaillantii Bagella, Caria, Filigheddu & Farris 2009
Elatinetum macropodae Br. Bl 1931
Junco capitati-Isoëtetum histricis Br.-Bl. 1935
typicum Br.-Bl. 1935
pleurochaetetosum squarrosae subass. nova
solenopsietosum laurentiae subass. nova
cheiloteletosum chloropii subass. nova
Pleurochaeto squarrosae-Isoëtetum todaroanae ass. nova
isoetetosum todaroanii subass. nova
cheiloteletosum chloropii subass. nova
Preslion cervinae Br.-Bl. ex Moor 1937
Junco pygmaei-Isoëtetum velatae Rivas Goday 1956
typicum Rivas Goday 1970
pilularietosum minutae subass. nova
Agrostis pourretii-dominated community
Cicendio filiformis-Solenopsion laurentiae Brullo & Minissale 1998
Triglochino barrelieri-Isolepidetum cernuae ass. nova
NANOCYPERETALIA Klika 1935
Verbenion supinae Slavnić 1951
Eryngium pusillum-dominated community

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Appendix I: Sampling site (Provinces are Lecce and Brindisi; Type of ponds D: Doline, CP: Cupular pools, WS: Waterlogged soils; Lithology C: Calcareous, L: Limestone).

Localities	Country	Province	Latitude	Longitude	Altitude (m)	Type of ponds	Lithology
Masseria Bellimento	Nardò	LE	40°11'47"	17°55'22"	4	D	C
Penisola della Strea	Porto Cesareo	LE	40°14'24"	17°54'24"	0.5	CP	C
Macchie Don Cesare	Salve	LE	39°51'36"	18°13'21"	106	CP	C
Torre Pali	Salve	LE	39°50'52"	18°12'47"	43	CP	C
Laccu Feretru	Soleto	LE	40°13'00"	18°11'07"	69	D	L
Bosco del Compare	Brindisi	BR	40°39'27"	17°53'14"	20.5	WS	L
Bosco Preti	Brindisi	BR	40°33'54"	17°52'59"	41.5	WS	L
Lago del Capraro	Sternatia	LE	40°13'99"	18°11'65"	68	D	C
Felline	Alliste	LE	39°55'53"	18°07'15"	38	CP	C
C.da. Badessa	Ostuni	BR	40°43'40"	17°31'20"	275	CP	C
Montevergine	Palmariggi	LE	40°09'52"	18°22'53"	42	CP	C
Palude del Capitano	Nardò	LE	40°12'36"	17°55'32"	12	CP	C