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Contribution to the knowledge of the vegetation of the Lake Massaciuccoli (northern Tuscany, Italy)

L. Lastrucci, L. Dell'Olmo, B. Foggi, L. Massi, C. Nuccio, C. Vicenti, D. Viciani
Department of Biology, University of Florence, Via G. La Pira 4, I-50121 Florence, Italy.

Abstract
The Lake Massaciuccoli is one of the largest and most important wetlands of Italian peninsula and is included in a protected area of regional and international relevance. In the present study, an update of the knowledge on aquatic and hygrophilous vegetation has been carried out, according to the phytosociological method. Some ecological analyses of the water trophism have been carried out, showing the high trophic level of the lake waters. The vegetation survey allowed to identify 31 plant communities belonging to 10 vegetation classes: *Lemnetea minoris, Potametea pectinati, Bidentetea tripartitae, Isoëto-Nanojuncetea, Littorelletea uniflorae, Phragmito australis-Magnocaricetea elatae, Scheuchzerio palustris-Caricetea nigrae, Galio aparines-Urticetea dioicae, Molinio-Arrhenatheretea* and *Alnetea glutinosae*. Aspects with *Sphagnum* sp. and other Bryophytes, present in small patches within the peculiar floating reed beds of the *Thelypterido-Phragmitetum* association, have been recorded and analyzed. A new association (*Samolo valerandi-Eleocharitetum caducae*) has been described. Nine Habitats of conservation interest have been identified; among them, two (Natura 2000 codes: 7210 and 91E0) are considered of priority interest.

Key words: aquatic coenoses, conservation, habitat, hygrophilous vegetation, *Sphagnum* sp., wetlands.

Introduction

Wetlands represent hot-spots of biodiversity, hosting highly specialized plants and animals (Bedford *et al*., 2001). These habitats are however exposed to several threats and pressures such as reclamations, unsuitable management of the aquatic and riparian vegetation, water pollution, land drainages, alteration of the natural water cycles or invasion by alien species (Brinson & Malvárez, 2002; Zedler & Kercher, 2004). Especially in the Mediterranean basin, the conservation of wetlands represents a primary goal because these habitats are particularly scarce, mostly due the arid climate and human pressures (Brinson & Malvárez, 2002). Recently, Angiolini *et al*. (2016) put in evidence the high conservation value of freshwater Mediterranean wetlands in hosting coenoses rich in rare and threatened species, highlighting however as only a part of these are included in habitats of conservation interest according to the European Habitat Directive (92/43 EEC). Action plans and strategies of conservation are strictly related to the degree of knowledge about the local biodiversity (Sousa-Baena *et al*., 2013). Due to the high number of threats and pressures and the relatively high rate of loss affecting wetlands in European countries (Casale, 2000), an updating of the knowledge of floristic and vegetation data may be regarded as an useful tool for the conservation of historically well known sites. Aim of this paper is therefore to update and study in deep, with the phytosociological method, the hygrophilous vegetation of the Special Area of Conservation "Lago e Padule di Massaciuccoli", which is one of the largest and most important wetlands of the Italian peninsula.

Materials and Methods

Study area: physical, climatic and hydrological notes

Lake Massaciuccoli (Fig. 1) is mainly located in the municipality of Massarosa and Viareggio (Lucca Province), and partly in the municipality of Vecchiano (Pisa Province). Its surface area is 1908.01 ha and its altitude is 0-1 m a.s.l. The lake waters rarely exceed 2.5 m of depth, reaching in almost all the lake depths between 1 to 2.5 m (Spandre & Meriggi, 1997). The study area is one of the most important Tuscan Ramsar wetlands (MedWet Inventory site code: ITE12W0400, see D'Antoni *et al*., 2011). The lake is included in the Regional Park Migliarino-San Rossore-Massaciuccoli and has been designated part of the Natura 2000 network as Special Area of Conservation (SAC) named "Lago e Padule di Massaciuccoli", code IT5120017. The area also became an Important Bird Area (IBA 077) in 1989 according to BirdLife International (Brunner *et al*., 2001). Following the climatic classification of Thornthwaite & Mather (1957), the climate formula of Massaciuccoli is C_2 B_2' r b_4' (Rapetti *et al*., 1987), a sub-humid climate, with reduced summer deficit and considerable maritime character. From a bioclimatic point of view, the study area almost entirely falls into the Bioclimate Mediterranean Pluviseasonal oceanic Upper Mesomediterranean Lower Humid and, to a lesser extent, into the Bioclimate Mediterranean

Corresponding author: Lorenzo Lastrucci. *Department of Biology, University of Florence, Via G. La Pira 4, I-50121 Florence, Italy; e-mail: lastruccilorenzo73@gmail.com*

Pluviseasonal Lower Mesomediterranean Lower Humid, according to Pesaresi *et al*. (2014). Only the eastern bordering areas belong to the Temperate Oceanic Bioclimate. The study area appears as a dense network of channels surrounding the lake; the most important tributaries are the following ditches: Barra and Barretta ditches, Fosso Confine, Fosso La Vite and Fossa Nuova. The Burlamacca canal is the only emissary. The hydraulic regime of the lake and channels is strongly influenced by seasonal rainfall, temperature and by the contribution of the aquifer (Spandre & Meriggi, 1997).

One of the main problems of Lake Massaciuccoli is eutrophication (see also Baldaccini *et al*., 1997), i.e. the abundance of nutrients (especially nitrates and phosphates) in the aquatic environment. Human pressure in the surrounding areas is the main cause of this phenomenon started from the 1950-1960s. In particular, eutrophication is due to sewage waters arising both from residential buildings and productive processes, both from peat mineralization and agricultural land use (Ente Parco Regionale Migliarino San Rossore Massaciuccoli, 2013). Eutrophication produces an abnormal increase in phytoplankton, a decrease of gas exchange and water clearness. Another problem of the study area is the entrance of seawater in Massaciuccoli lacustrine system, especially during the dry season (June-July-August); when the average level of the lake is below the sea, there is the direct arrival of brackish water from Burlamacca channel and its ramifications (Spandre & Meriggi, 1997; Cavazza *et al*., 2002).

Ecological analysis

To obtain a snapshot on the trophic conditions of the

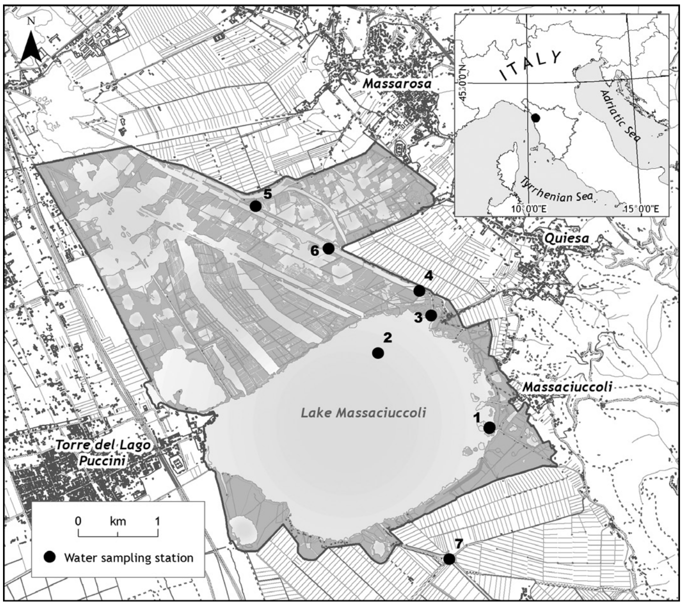

Fig. 1 - Study area. The ecological sampling stations are reported with black dots.

waters, analysis of Chlorophyll *a* (Chl*a*), as autotrophic biomass indicator, and nutrients involved in eutrophication processes were carried out in 7 stations (Fig. 1), located at the southern edge (st. 1), in an inland channel (st. 7), in the center of the lake (st. 2) and along the Burlamacca channel (st. 3, 4, 5, 6). At each station 5 L of water were sampled under the surface (about 50 cm) for Chl*a*, diagnostic pigments, and nutrients analysis. An aliquot of 1.5 L was filtered (Whatman GF/F, ø 47 mm) for Chl*a* and 8 main diagnostic pigments were analysed with HPLC (Shimadzu Class VP), following Barlow *et al*. (1997) and Vidussi *et al*. (1996). The analysed diagnostic pigments (in brackets the abbreviations) were: fucoxanthin (fuco), diatoms; peridinin (perid), dinoflagellates; 19'-hexanoyl-oxy-fucoxanthin (hex-fuco), Prymnesiophytes; alloxanthin (allo), Cryptophytes; 19'-butanoyl-oxy-fucoxanthin (but-fuco), Chrysophytes/Pelagophytes; Chlorophyll *b* (Chl*b*), Chlorophytes/Euglenoids; prasinoxanthin (prasino), Prasinophytes; zeaxanthin (zea), Cyanobacteria. The relative contribute of the single pigment was obtained as ratio between its concentration and the sum of the concentrations of the eight pigments. An aliquot of the filtered water (fixed with $HgCl_2$ 1%) was used for the determination of inorganic dissolved nutrients (phosphates, nitrites, nitrates) with Autoanalyzer3 (Bran Lubbe) following standard methods (Saggiomo *et al*., 2010). An unfiltered aliquot of the samples was used for the determination of total Nitrogen (Ntot) and Phosphorus (Ptot) (Cozzi *et al*., 2010). Water filtering and the following analyses were performed at the Biology Department (Plant Physiology and Ecology Laboratories) of the University of Florence.

Botanical knowledge

The area of Massaciuccoli has been subjected in the more or less recent past to numerous botanical explorations, mainly with floristic focus (Caruel, 1860; Baroni, 1897-1908; D'Amato, 1957; Montelucci, 1964, 1970; Del Prete & Tomei, 1981; Tomei & Garbari, 1982; Tomei & Marracci, 1987; Tomei, 1991; Tomei & Guazzi, 1996; Tomei *et al*., 1995, 2001) and educational studies (AA.VV., 1983; Cavalli & Lambertini, 1990). Data on plant communities are generally rather ancient and less numerous (D'Amato, 1957; Montelucci, 1964; Ferrarini, 1972; Tomei & Garbari, 1982; Tomei *et al*., 1994, 1997, 1998, 2001), sometimes missing of phytosociological relevés and tables. In recent times, Petraglia (unpublished report) prepared an updated and detailed unpublished report about the vegetation of the Regional Park Migliarino San Rossore Massaciuccoli, concerning however only certain vegetation types present in the Lake Massaciuccoli. This document was made kindly available thanks to the Regional Park "Migliarino San Rossore Massaciuccoli". More recently the detailed map of Natura

2000 Habitats of the Massaciuccoli Lake was published by Viciani *et al*. (2017).

Vegetation data collection and analysis

A total number of 88 relevés were carried out according to the phytosociological method (Braun-Blanquet, 1932; Pott, 2011; Biondi, 2011) in the protected area of the Lake Massaciuccoli and some neighbouring water courses in June/September 2015 and April/May 2016. The phytocoenoses were sampled according to the principle of "local and physiognomic micro-homogeneity" (Géhu, 1988). Seven relevés concerning a peculiar vegetation type characterized by the presence of *Sphagnum* sp. and other Bryophytes, have been obtained by Petraglia (unpublished report). The whole dataset of 95 relevés has been firstly subdivided in three sub-groups based on the growth form of the dominant species as following: woody-species sub-group (2 relevés), hydrophyte sub-group (16 relevés) and hygrophilous-species sub-group (helophytes and other herbs, 77 relevés).

The matrices of the last two sub-groups of relevés, previously transformed according to the ordinal scale proposed by van der Maarel (1979), were subjected to cluster analysis with the software Syntax2000 (Podani, 2001), using the Similarity Ratio distance measure and the average linkage clustering method. In order to classify and attribute the groups resulting from the dendrogram, a comparison with the main European and Italian phytosociological literature was performed.

The nomenclature of species has been updated following the species database of the project anArchive (Lucarini *et al*., 2015). The syntaxonomic scheme follows Biondi & Blasi (2015) and, specifically for some aquatic coenoses, Lastrucci *et al*. (2014); the nomenclature of syntaxa up to the alliance level follows Biondi & Blasi (2015) and Peterka *et al*. (2016) specifically for the fen vegetation. Association nomenclature follows mainly Chytrý (2011), Landucci *et al*. (2013) and the specific literature eventually cited in each paragraph. The syntaxa correspondence with the habitat codes of the 92/43 EEC Directive follows the European Interpretation Manual (European Commission, 2013) and Biondi *et al*. (2009, 2012). Localities and dates of the relevés are listed in Appendix I (available in the online version of the article).

Results and discussion

Ecological analysis

All the sites showed very high level of nutrients and biomass (Table 1). Following the OECD classification (Vollenweider & Kerekes, 1982) all the values of Ptot exceeded the boundary between eutrophic/hypertrophic conditions. Chl*a* confirmed this highly eutrophic status with concentrations mainly > 10 μg L^{-1}. Nitrates too appeared very high (about 87% of the sum of nitrites plus nitrates), accounting for the definition of the lake of Massaciuccoli as "Nitrate Vulnerable Zone" (NVZ, Nitrates Dir. 91/676, WFD 2000/60). Furthermore, using the diagnostic pigments as a proxy for phytoplankton taxonomic composition (Fig. 2), the major contributes were provided by zeaxanthin (Cyanobacteria), on average about the 56%, alloxanthin (Cryptophytes), with the 18% and Chl*b* (Chlorophytes), around the 13%. The sharp dominance of Cyanobacteria represents a good indicator of the highly eutrophic condition of the lake waters (see. Reynolds, 2006). These results confirm the assessment about the trophic status of the lake (including the Burlamacca channel) resulting from previous studies on the phytoplanktonic composition of the Massaciuccoli basin (Simoni & Biancucci, 1997).

Vegetation analysis

We identified 31 plant communities belonging to 10 vegetation classes: *Lemnetea minoris, Potametea pectinati, Bidentetea tripartitae, Isoëto-Nanojuncetea,*

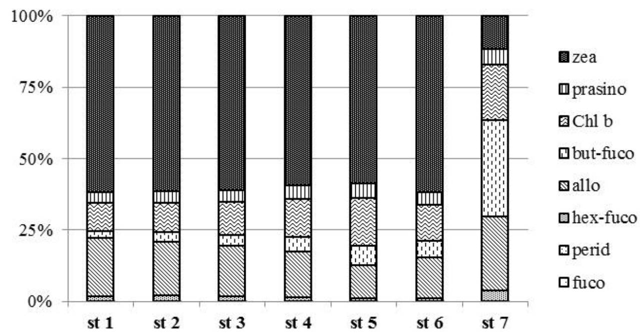

Fig. 2 - Relative concentrations of the diagnostic pigments in the seven stations. Abbreviations of pigments as in the text.

Tab. 1 - Nutrients and Chlorophyll *a* (Chl*a*) concentrations (μg L^{-1}) in the sampled stations.

Sampling stations	1	2	3	4	5	6	7
Phosphates PO^{--}_4	8.479	39.339	6.681	3.395	34.751	63.953	89.249
Total Phoshorus Ptot	188.120	181.947	176.775	179.596	163.651	172.739	458.163
Nitrites + Nitrates NO^-_2+NO^-_3	294.525	64.344	41.153	71.344	33.278	49.469	1890.686
Total Nitrogen Ntot	2277.344	2532.235	2138.823	2342.782	2396.526	2964.685	5020.184
Chlorophyll *a*	10.479	11.102	11.324	11.081	6.256	5.016	31.955

Littorelletea uniflorae, Phragmito australis-Magnocaricetea elatae, Scheuchzerio palustris-Caricetea nigrae, Galio aparines-Urticetea dioicae, Molinio-Arrhenatheretea and *Alnetea glutinosae*.

Regarding the hydrophytic vegetation, the cluster analysis allowed to identify 7 groups of plant communities (Fig. 3).

The cluster analysis of the relevés of helophytic and hygrophilous vegetation (Fig. 4) allowed the identification of 23 plant communities.

Considering Fig. 4, the dendrogram in particular showed the separation of two different *Phragmites australis* communities, that can be attributed, respectively, to the associations *Phragmitetum australis* (B) and *Thelypterido-Phragmitetum* (D). The cluster analysis showed also the strong relationships between *Thelypterido-Phragmitetum* and the vegetation with *Sphagnum* sp. (E, in Fig. 4), forming small patches within the floating reed beds. In this latter group some original relevés and all the relevés obtained by Petraglia (unpublished report) are included.

Aquatic vegetation of the classes *Lemnetea minoris* and *Potametea pectinati*

LEMNETUM MINUTO-GIBBAE Liberman Cruz, Pedrotti & Venanzoni 1988 (Tab. 2, rels. 1-2; Fig. 3 A)

This association has been described for Lake Titicaca in Bolivia (Liberman Cruz *et al*., 1988) and recently it was reported in Central Italy for the Lakes Trasimeno (Landucci *et al*., 2011) and Porta (Lastrucci *et al*., 2016). *Lemna minuta* is a species with a high invasive potential, due to its plasticity in respect to chemical water features and its high vegetative propagation capacity (Bramley *et al*., 1995). According to Iamonico *et al*. (2010) this alien species is present in many Italian regions, often showing an invasive behaviour and competing with native species such as *L. minor* (see also Ceschin *et al*., 2016).

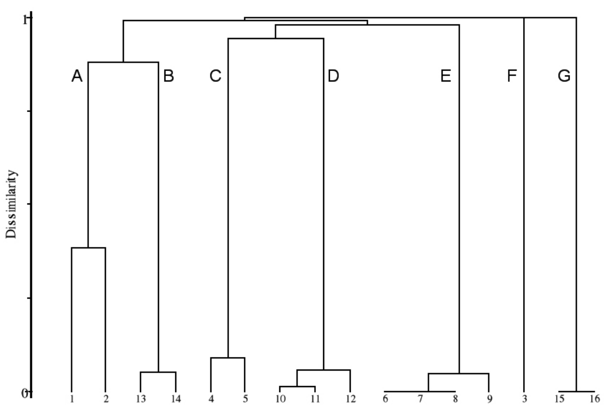

Fig. 3 - Dendrogram resulting from the cluster analysis of the relevés of aquatic vegetation. In the figure, the following groups are put in evidence: A (*Lemnetum minuto-gibbae*); B (*Potametum crispi*); C (*Nymphaeetum albae*); D (*Potamo pectinati-Myriophylletum spicati*); E (*Najadetum marinae*); F (*Lemnetum gibbae*); G (*Myriophyllum aquaticum* community).

In the study area this species grows in small stands very poor in species, sometimes in contact with the helophytic coenoses, but in some channels near the Lake it forms large and dense monophytic stands.

LEMNETUM GIBBAE Miyawaki & J. Tüxen 1960 (Tab. 2, rel. 3; Fig. 3 F)

This association is dominated by *Lemna gibba*, a small free-floating species. *L. gibba* grows preferentially on eutrophic to hypertrophic water bodies, in diffuse light conditions tolerating high concentrations of nitrogen, as we have found in the water sampling (Tab. 1), phosphorus, calcium and chlorides (Scoppola, 1982; Šumberová, 2011a). In the study area the association seems to be rather infrequent, forming small but dense stands with the congeneric *Lemna minor* at the edge of the *Phragmites australis*-dominated vegetation.

NYMPHAEETUM ALBAE Vollmar 1947 (Tab. 2, rels. 4-5; Fig. 3 C)

This vegetation type can be found in mesotrophic to eutrophic lakes and alluvial ponds, usually 50-100 cm deep with stagnant waters (Šumberová, 2011b). *Nymphaea alba*-dominated communities show some syntaxonomical interpretation criticisms; they were sometime classified in the association *Nymphaeo albae-Nupharetum luteae* Nowiński 1927. This association has several aspects with the coexistance of *Nuphar lutea* and *Nymphaea alba*, or facies dominated by only one of the two species (see Meriaux & Wattez, 1983; Sburlino *et al*., 2008; Lastrucci *et al*., 2014; Lastrucci *et al*., 2016). According to Šumberová (2011b), however, *Nymphaea alba*-dominated coenoses should be attributed to the association *Nymphaeetum albae* Vollmar 1947. Similar interpretation, confirming the autonomy of some *Nymphaea alba* communities, was adopted by Tomaselli *et al*. (2006). Due to the absence in our relevés of *Nuphar lutea* (not recorded during our field activity in the study area) we attribute our coenoses to the association *Nymphaeetum albae*.

In the study area, the association has been recorded in ponds and channels with limited water level fluctuations and stagnant waters. Our relevés are very poor in species or monophytic. The presence of coenoses with *Nymphaea alba* in the study area has been mentioned also by Tomei *et al*. (1994, 1997, 1998).

NAJADETUM MARINAE Fukarek 1961 (Tab. 2, rels. 6-9; Fig. 3 E)

This vegetation type can be found in natural and artificial habitats in the early stages of dynamic series, in mesotrophic to eutrophic waters, rich in calcium and salts, often brackish (Landucci *et al*., 2011). *Najadetum marinae* has been reported for several freshwater habitat of Central Italy (Pedrotti & Orsomando, 1982; Iberite *et al*., 1995; Ceschin & Salerno, 2008; Lastrucci *et al*., 2012, 2014). In the study area the association is rather frequent and grows in rather deep and open waters of the lake, where it forms mats of considerable extent and biomass, often monospecific or with the sporadic presence of *Myriophyllum spicatum*.

POTAMO PECTINATI-MYRIOPHYLLETUM SPICATI Rivas Goday 1964 corr. Conesa 1990 (Tab. 2, rels. 10-12; Fig. 3 D)

Coenoses dominated by the submerged species *Myriophyllum spicatum* were assigned to the association *Potamo pectinati-Myriophylletum spicati* which has a wide ecological diversity, but is more common in streams with calcareous and eutrophic waters (Loidi *et al*., 1997). This type of vegetation is considered an indicator of poor water quality (Ceschin *et al*., 2010). In the study area the association grows in the lake and in the channels, often occupying large surface areas, having high cover values and forming monophytic or species-poor stands. Coenoses with *M. verticillatum* have been reported for the study area by Tomei *et al*. (1994, 1997). This vegetation type was not found during our field surveys; its disappearing is possible, due to the heavy impacts of the alien species *Procambarus clarkii* on the aquatic coenoses of the study area (Tomei *et al*., 1994; 2001), as well as to a misidentification with *M. spicatum* community.

POTAMETUM CRISPI Soó 1927 (Tab. 2, rels. 13-14; Fig. 3 B)

This association occurs both in lentic and lotic waters, from eutrophic to hypertrophic or polluted conditions (Šumberová, 2011b). Communities dominated by *Potamogeton crispus* seem to be rather frequent in lakes, channels and rivers of Tuscany (e.g. Lastrucci *et al*., 2010a, 2014, 2016; Mereu *et al*., 2012). In the study area it was found in some channels at the edge of the protected area, forming very dense stands, hosting the alien species *Lemna minuta* and *Paspalum distichum*.

MYRIOPHYLLUM AQUATICUM community (Tab. 2, rels. 15-16, Fig. 3 G)

Myriophyllum aquaticum is an alien species, native of the South America, formerly recorded in Tuscany at the Lake Porta, in the north-western part of the Region (Lastrucci *et al*., 2016, 2017).

One of our relevés (Tab. 2, rel. 15) refers to the channel near the "Idrovora di Vecchiano", where this species has been recently reported (Peruzzi *et al*., 2016). It must be noted that one of our relevés (Tab. 1, rel. 16) has been performed in the lake of Massaciuccoli, where unfortunately this species has been recorded for the first time, probably coming from the above mentioned channel. Our relevés testify the ability of this invasive species to form dense and monospecific communities, as already stated by Lastrucci *et al*. (2016).

HYGRO-NITROPHILOUS THEROPHYTIC VEGETATION OF THE CLASS *BIDENTETEA TRIPARTITAE* (Tab. 3; rel. 1 of Fig. 4)

At the edge of the common reed-dominated vegetation, on muddy soil emerged in the late summer, a dense community dominated by the therophyte alien species *Cyperus odoratus* was found. The presence and distribution of this species in Tuscany has been put in evidence by Galasso *et al*. (2016). Through a herbarium survey, the authors showed that in the past *C. odoratus* was confused with *C. strigosus*. After the revision of herbarium materials, this latter species was excluded from Tuscany, while the most part of the specimens previously identified as *C. strigosus* have been attributed to *C. odoratus*.

In Europe *C. odoratus* was found mostly along the rivers (estuaries, mud flats, gravelly or sandy expo-

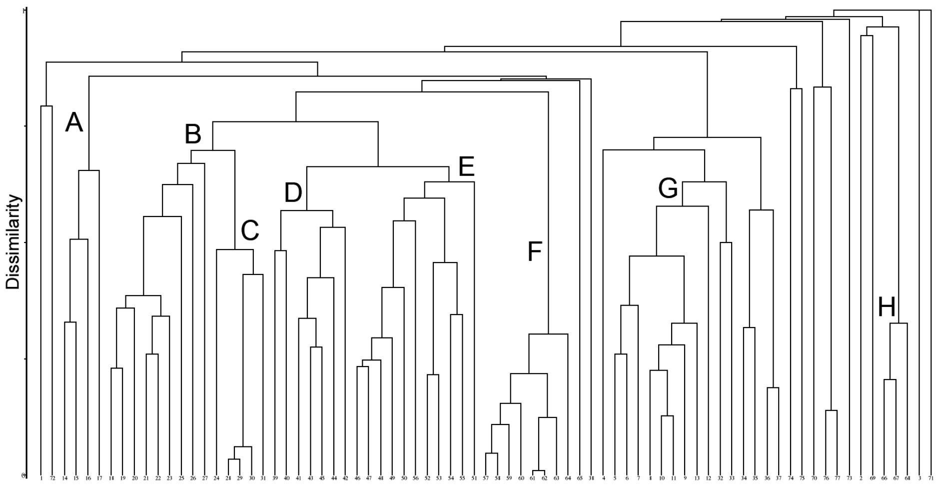

Fig. 4 - Dendrogram resulting from the cluster analysis of the relevés of helophytic and hygrophilous vegetation. In the figure, the following main groups (communities with three or more relevés) are put in evidence: A (*Hydrocotyle vulgaris* comm.) B (*Phragmitetum australis*); C (*Typhetum angustifoliae*); D (*Thelypterido-Phragmitetum*); E vegetation with *Sphagnum subnitens*, *S. palustre* and other Bryophytes; F (*Cladietum marisci*); G (*Samolo valerandi-Eleocharitetum caducae*); H (*Caricetum acutiformis*).

Tab. 2 - Vegetation of the classes *Lemnetea minoris* and *Potametea pectinati* (rel. numbers correspond to the numbers reported in the dendrogram of Fig. 3).

Rel. number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Cover (%)	40	40	100	100	80	100	100	100	100	60	100	100	85	100	100	100
Surface (mq)	1	1	2	10	10	2	10	10	10	2	10	10	4	4	4	4
Lemnetea minoris communities																
Charact. of *Lemnetum minuto-gibbae*																
Lemna minuta Kunth	3	2	.	.	.	.	.	.	.	.	.	.	1	+	.	.
Charact. of *Lemnetum gibbae*																
Lemna gibba L.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.
Potametea pectinati communities																
Charact. of *Nymphaeetum albae*																
Nymphaea alba L.	.	.	.	5	5	.	.	.	.	.	.	.	.	.	.	.
Charact. of *Najadetum marinae*																
Najas marina L.	.	.	.	.	.	5	5	5	5	.	.	.	.	.	.	.
Charact. of *Potamo pectinati-Myriophylletum spicati*																
Myriophyllum spicatum L.	.	.	.	+	.	.	.	.	+	4	5	5	.	.	.	.
Charact. of *Potametum crispi*																
Potamogeton crispus L.	.	.	.	+	.	.	.	.	.	.	.	.	5	5	.	.
Dom. of *Myriophyllum aquaticum* community																
Myriophyllum aquaticum (Vell.) Verdc.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5
Charact. of *Lemnetea minoris*																
Lemna minor L.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Other species																
Paspalum distichum L.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.
Hydrocotyle vulgaris L.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Typha angustifolia L.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.

sed banks) but also in ditches, drainage channels, riparian woodlands and as weed in orchards (Verloove, 2014). From a phytosociological point of view, the *C. odoratus*-dominated vegetation of the Lake Massaciuccoli has been attributed provisionally to the class *Bidentetea* and the alliance *Bidention*, both due to the life form and ecology of the dominant species and to substrate type, although there are no other species accompanying the dominant one, which may support this attribution.

Tab. 3 - Vegetation of the class *Bidentetea tripartitae*.

Rel. number	1
Number in the dendrogram of Fig. 4	1
Cover (%)	100
Surface (mq)	25
Dom. of *Cyperus odoratus* community	
Cyperus odoratus L.	5
Other species	
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	2
Calystegia sepium (L.) R. Br. subsp. sepium	1
Eupatorium cannabinum L. subsp. cannabinum	1
Galium palustre L. subsp. elongatum (C. Presl) Lange	1
Oenanthe silaifolia M. Bieb.	+

HYGROPHILOUS DWARF VEGETATION OF THE CLASS *ISOËTO-NANOJUNCETEA*

SAMOLO VALERANDI-ELEOCHARITETUM CADUCAE ass. nova *hoc loco* (Tab. 4, rels. 1-9; Fig. 4 G. *Holotypus*: rel. 6 of Tab. 4, this paper)

In some muddy open-areas covered by a thin film of water within the tall helophytic vegetation (*Phragmites australis* or *Schoenoplectus lacustris* subsp. *glaucus*-dominated stands), some patches dominated by small hygrophilous species such as *Eleocharis caduca* and *Samolus valerandi* have been detected.

Eleocharis caduca was previoulsly recorded in Tuscany only at Viareggio and Macchia Lucchese (Arrigoni, 1990, sub *E. geniculata* (L.) Roem. et Schult.; Pierini & Peruzzi, 2010), not far from the Lake Massaciuccoli. For the nomenclatural problems concerning this species we refer to Greuter *et al*. (2002), Lastrucci & Becattini (2007) and Verloove (2010). Some problems regard also the status of this species in Italy, because it has been recently considered as alien by some authors (Celesti-Grapow *et al*., 2009; Arrigoni & Viegi, 2011) and as native for Italy by others (Jiménez-Mejías & Luceño, 2011; Lansdown, 2013). From a phytosociological point of view, currently no information is available for Europe, while some notes can be found in Lacoste *et al*. (2011) for the island La Réunion. The floristic composition of this vegetation type in the study area appears rather complex. Together with *E. caduca*, the subcosmopolitan *Samolus valerandi* is constantly present, sometimes with high cover value. This species is reported often as characteristic or differential of some association of the *Nanocyperetalia* order such as the *Samolo valerandi-Caricetum serotinae* Biondi, Vagge, Baldoni & Taffetani 1997 or the *Cypero fusci-Samoletum valerandi* Müller-Stoll & Pietsch ex Pietsch 1973 (see respectively Biondi *et al*., 1997 and Brullo & Minissale, 1998). According to Biondi & Blasi (2015), in Italy the *Nanocyperetalia*

Tab. 4 - Vegetation of the class *Isoëto-Nanojuncetea*. Rels. 1-9: *Samolo valerandi-Eleocharitetum caducae* ass. nova *hoc loco* (*Holotypus*: rel. 6). Rels. 10-11: transitional aspects between the *Samolo-Eleocharitetum* and the *Phragmito-Schoenoplectetum tabernaemontani*. Rel. 12: impoverished aspect of *Samolo-Eleocharitetum*. Rel. 13: *Lythrum hyssopifolia* community. Rel. 14: *Juncus bufonius* community.

Rel. number	1	2	3	4	5	6*	7	8	9	10	11	12	13	14
Number in the dendrogram of Fig. 4	5	6	7	8	10	11	9	13	12	32	33	4	2	3
Cover (%)	70	85	40	80	100	100	70	100	100	100	100	100	100	50
Surface (mq)	6	4	1	4	1	2	2	2	4	6	4	1	1	1
Charact. of *Samolo valerandi-Eleocharitetum caducae* ass. nova														
Samolus valerandi L.	2	4	3	2	1	+	2	1	+	r	+	5	.	.
Eleocharis caduca (Delile) Schult.	2	2	2	4	5	5	3	4	5	2	1	.	.	.
Dom. of *Lythrum hyssopifolia* community														
Lythrum hyssopifolia L.	.	.	.	.	.	.	.	.	.	.	.	.	5	.
Dom. of *Juncus bufonius* community														
Juncus bufonius L.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Diagnostic species of *Verbenion* alliance														
Paspalum distichum L.	.	.	1	.	r	+	.	.	.	.	.	.	.	.
Other species														
Schoenoplectus lacustris (L.) Palla subsp. glaucus (Sm. ex Hartm.) Bech	+	1	.	1	2	2	+	1	1	4	4	.	.	.
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	.	+	+	2	1	1	1	2	.	1	1	2	.	.
Lycopus europaeus L. subsp. europaeus	.	.	.	1	+	+	.	1	2	2	2	1	.	.
Bolboschoenus maritimus aggr.	1	+	1	.	.	+	.	.	+	.	.	.	.	.
Lythrum salicaria L.	+	.	.	.	+	+	.	.	+	+	.	.	.	.
Symphyotrichum squamatum (Spreng.) G.L. Nesom	.	.	1	.	.	.	.	1	.	r	.	.	+	.
Agrostis stolonifera L. subsp. stolonifera	.	.	.	+	.	.	.	.	2	.	3	.	r	.
Juncus articulatus L. subsp. articulatus	.	.	1	.	.	.	.	.	2	.	.	.	+	.
Typha angustifolia L.	.	.	.	.	.	1	1	.	.	.	.	.	.	.
Pulicaria dysenterica (L.) Bernh. subsp. dysenterica	.	.	.	.	+	.	.	.	.	.	1	.	1	.
Paspalum dilatatum Poir.	.	.	.	.	.	.	.	1	.	2	.	.	.	.
Mentha aquatica L.	.	.	.	.	.	.	.	1	.	1	.	.	.	.
Oxybasis urbica (L.) S. Fuentes, Uotila et Borsch	.	+	.	.	.	.	+	.	.	.	.	.	.	.
Calystegia sepium (L.) R. Br. subsp. sepium	.	.	.	.	.	.	.	.	+	.	+	.	.	.
Galium palustre L. subsp. elongatum (C. Presl) Lange	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Oenanthe silaifolia M. Bieb.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Lysimachia arvensis (L.) U. Manns et Anderb.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Plantago major L.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Potentilla reptans L.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Ranunculus repens L.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Rubus ulmifolius Schott	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Lolium arundinaceum (Schreb.) Darbysh.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Trifolium repens L.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Hydrocotyle vulgaris L.										1	.	.		
Euphorbia palustris L.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Bidens frondosus L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Cynodon dactylon (L.) Pers.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Oenanthe aquatica (L.) Poir.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Solanum dulcamara L.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Limniris pseudacorus (L) Fuss	.	.	r	.	.	.	.	.	.	.	.	.	.	.

order includes two alliances, one mostly characterized by eurosiberian species (*Nanocyperion flavescentis*) and one more distinctly mediterranean (*Verbenion supinae*). The distribution of *E. caduca*, mostly present from sub-Saharian Africa to the Mediterranean basin (Greuter *et al*., 2002; Verloove & Sánchez Gullón, 2010; Lansdown, 2013) and the climate features of the study area suggest the attribution of this vegetation type to the *Verbenion* alliance. We describe this vegetation with the proposal of a new association, named *Samolo valerandi-Eleocharitetum caducae* ass. nova. The group of tall helophytes such as *Bolboschoenus maritimus* aggr., *Schoenoplectus lacustris* subsp. *glaucus* and *Phragmites australis* testifies the contact with *Phragmition* coenoses which surround the association. In particular, rels. 10-11 of Tab. 4 show the transition between the *Samolo-Eleocharitetum* and the *Phragmito-Schoenoplectetum tabernaemontani*. Rel. 12 of Tab. 4 shows an impoverished aspect of the above described coenosis, without the presence of *E. caduca*.

Other communities of the class *Isoëto-Nanojuncetea*

In the study area two other communities referred to the class *Isoëto-Nanojuncetea* have been sampled. The first one (Tab. 4, rel. 13; Fig. 4, rel. 33) is dominated by *Lythrum hyssopifolia*, a species characteristic of several associations of the order *Nanocyperetalia* such as *Veronico anagalloidis-Lythretum hyssopifoliae* Wagner ex Holzner 1973 of the *Verbenion supinae* Slavnić 1951 alliance (Šumberová & Hrivnák, 2013). The community of the Lake Massaciuccoli appears rather heterogeneous from the floristic point of view, poor in typical species and rich in species of disturbed or trampled habitats. This lead us to classify the community only as a basal phytocoenon. The second hygrophilous therophyte coenosis (Tab. 4, rel. 14; Fig. 4, rel. 4) is dominated by *Juncus bufonius*. This species falls into various associations of the *Nanocyperetalia* order (Brullo & Minissale, 1998). The extreme floristic poorness of the sampled coenosis does not allow to deepen the classification at the association level, making preferable to treat it as a basal phytocoenon.

Small perennial helophytic vegetation of the class *Littorelletea uniflorae*

HYDROCOTYLE VULGARIS community (Tab. 5, rels. 1-4, Fig. 4 A)

Hydrocotyle vulgaris is a rather rare species in Italy (Pignatti, 1982); from a phytosociological point of view it shows a certain amplitude, belonging both to woody marsh vegetation, like *Hydrocotylo-Alnetum glutinosae* Gellini, Pedrotti et Venanzoni 1986, described not far from the study area, and to herbaceous plant communities. Among them, two associations can be mentioned: the first one (*Sphagno-Hydrocotyletum vulgaris* Fijałkowski 1991) grows on peat rich in *Sphagnum* species and belongs to the class *Scheuchzerio-Caricetea fuscae*; the second one (*Junco-Hydrocotyletum vulgaris* Fijałkowski 1991) appears floristically poorer, with bryophytic component almost absent and low presence of *Scheuchzerio-Caricetea* species and belongs to the class *Littorelletea uniflorae* (see Fijalkowski *et al*., 1995). The communities observed in the Lake Massaciuccoli show some floristic and ecologic affinities with the latter association. In the study area *Hydrocotyle vulgaris* forms coenoses preferentially on muddy and long-flooded soils at the edge of reeds or saw-sedges. For the attribution at the alliance level we propose the use of the *Hyperico elodis-Sparganion* Br.-Bl. et Tx. ex Oberd. 1957 (syn. *Hydrocotylo-Baldellion* Tüxen et Dierßen in Dierßen 1972).

Tab. 5 - Vegetation of the class *Littorelletea uniflorae*.

Rel. number	1	2	3	4
Number in the dendrogram of Fig. 4	14	15	16	17
Cover (%)	100	100	100	50
Surface (mq)	10	2	10	1
Dom. of *Hydrocotyle vulgaris* community				
Hydrocotyle vulgaris L.	3	4	4	3
Local differential species				
Myosotis laxa Lehm. subsp. cespitosa (Schultz) Hyl. ex Nordh.	2	2	.	.
Other species				
Typha angustifolia L.	3	1	.	1
Agrostis stolonifera L. subsp. stolonifera	2	2	2	.
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	.	1	2	1
Schoenoplectus lacustris (L.) Palla subsp. glaucus (Sm. ex Hartm.) Bech	1	+	1	.
Samolus valerandi L.	+	.	2	.
Lysimachia vulgaris L.	+	.	.	1
Lythrum salicaria L.	+	.	.	1
Calystegia sepium (L.) R. Br. subsp. sepium	+	.	.	+
Helosciadium nodiflorum (L.) W.D.J. Koch subsp. nodiflorum	+	r	.	.
Sphagnum palustre L.	.	.	.	2
Bolboschoenus maritimus aggr.	.	.	1	.
Alnus glutinosa (L.) Gaertn. subsp. glutinosa	.	.	.	1
Cirsium creticum (Lam.) d'Urv. subsp. triumfettii (Lacaita) K. Werner	1	.	.	.
Osmunda regalis L.	.	.	.	1
Mentha aquatica L.	+	.	.	.
Euphorbia palustris L.	+	.	.	.
Frangula alnus Mill. subsp. alnus	.	.	.	+
Juncus subnodulosus Schrank	+	.	.	.
Juncus articulatus L. subsp. articulatus	.	r	.	.

Helophytic vegetation of the *Phragmito australis-Magnocaricetea elatae* class

PHRAGMITETUM AUSTRALIS Savič 1926 (Tab. 6, rels. 1-10; Fig. 4 B, incl. rel. 24 of Fig. 4)

This association grows in different wetland types and environmental conditions, from meso- to eutrophic waters, on clayey, sandy and stony substrates (Landucci *et al*., 2013). The association, typically poor in species, is very common in wetlands of Central Italy (Landucci *et al*., 2013). *Phragmitetum australis* is widespread in the whole study area (see also Tomei *et al*., 1994, 1997) forming large stands often poor in species and with a strong dominance of *P. australis* along the lake and the channels. A relevé with high cover value of *Juncus subnodulosus* (Tab. 6, rel. 8) testifies the transition toward wet meadows of the *Holoschoenetalia* order, in accordance with Lastrucci *et al*. (2012). According to the cluster analysis and the resulting dendrogram of Fig. 4, *Phragmitetum australis* differs from other types of reed-beds, which grow on mats of floating organic matter, attributed to the *Thelypterido palustris-Phragmitetum australis* association (Pedrotti, 1988; Lastrucci *et al*., 2014), as below specified. Rel. 9 of the Tab. 6 shows a particular aspect of the reed bed, with *P. australis* covered by a dense layer of climbing species such as *Periploca graeca* and *Rubus ulmifolius*. Rel. 10 of Tab. 6 testifies a contact of the association with the *Typhetum angustifoliae*.

TYPHETUM ANGUSTIFOLIAE Pignatti 1953 (Tab. 6, rels. 11-14; Fig. 4 C)

Typhetum angustifoliae is rather common in Italy; the association grows along water courses or lakes, in mesotrophic to eutrophic waters on clayey and sandy bottoms, often with organic sediments (Landucci *et al*., 2013); in the study area *Typha angustifolia* forms dense stands along the banks of the main channels and in the palustrine areas of the lake. The association appears often in contact with *Phragmites australis*-dominated communities, generally occupying sites at greater depths. The presence of this vegetation type in the study area was already mentioned by Tomei *et al*. (1994, 1997, 1998).

PHRAGMITO-SCHOENOPLECTETUM TABERNAEMONTANI Passarge (1964) 1978 (Tab. 6, rels. 15-16; Fig. 4, rels. 34 and 35)

Schoenoplectus lacustris subsp. *glaucus* (=*S. ta-*

Tab. 6 - Vegetation of the alliances *Phragmition communis* and *Scirpion compacti*.

Rel. number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Number in the dendrogram of Fig. 4	18	19	20	21	22	23	25	26	27	24	28	29	30	31	34	35	36	37	38
Cover (%)	100	100	100	90	100	90	80	100	100	60	100	100	90	100	65	85	100	100	100
Surface (mq)	20	60	20	10	30	6	16	20	6	8	10	20	16	20	4	16	4	10	4
Phragmition communis alliance																			
Charact. of *Phragmitetum australis*																			
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	5	5	5	5	5	5	4	3	3	5	3	3	2	+	.	+	2	2	2
Charact. of *Typhetum angustifoliae*																			
Typha angustifolia L.	.	.	.	.	.	1	.	+	.	2	4	4	5	5	.	.	+	.	.
Charact. of *Phragmito-Schoenoplectetum tabernaemontani*																			
Schoenoplectus lacustris (L.) Palla subsp. glaucus (Sm. ex Hartm.) Bech	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	4	1	+	.
Dom. of *Bolboschoenus maritimus* community																			
Bolboschoenus maritimus aggr.	.	.	.	.	+	.	1	.	.	.	.	.	.	.	1	2	5	4	r
Scirpion compacti alliance																			
Dom. of Juncus *maritimus* community																			
Juncus maritimus Lam.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Charact. of upper units:																			
Lythrum salicaria L.	.	.	+	.	.	1	+	+	.	+	.	.	.	.	.	+	+	+	.
Lycopus europaeus L. subsp. europaeus	.	+	.	.	.	.	1	.	.	+	.	.	.	+	.	.	.	.	.
Euphorbia palustris L.	1	.	.	+	+	+	.	r	.	.	.	.	.	.	.	.	.	.	.
Hibiscus palustris L.	.	.	+	.	.	.	+	+	.	1	.	+	.	.	.	.	.	.	.
Galium palustre L. subsp. elongatum (C. Presl) Lange	.	.	+	+	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladium mariscus (L.) Pohl subsp. mariscus	.	.	.	.	.	2	.	1	.	.	.	.	.	.	.	.	.	.	.
Limniris pseudacorus (L) Fuss	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.
Rumex hydrolapathum Huds.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex elata All. subsp. elata	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Eleocharis palustris (L.) Roem. & Schult.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Alisma plantago-aquatica L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Persicaria amphibia (L.) Delarbre	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Oenanthe aquatica (L.) Poir.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Typha latifolia L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Other species																			
Calystegia sepium (L.) R. Br. subsp. sepium	1	+	1	2	1	2	+	1	1	+	.	.	.	+	.	.	.	+	.
Samolus valerandi L.	.	.	.	.	r	.	+	.	.	+	.	.	.	.	+	2	+	2	.
Oenanthe silaifolia M. Bieb.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.
Agrostis stolonifera L. subsp. stolonifera	.	.	+	.	r	.	.	.	.	+	.	.	.	2	.	.	.	.	.
Cirsium creticum (Lam.) d'Urv. subsp. triumfettii (Lacaita) K. Werner	.	.	.	.	1	1	.	.	.	2	.	.	.	1	.	.	.	.	.
Juncus articulatus L. subsp. articulatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	+	.	.
Eupatorium cannabinum L. subsp. cannabinum	.	.	.	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Periploca graeca L.	+	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.
Juncus subnodulosus Schrank	.	.	+	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.
Hydrocotyle vulgaris L.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Rubus ulmifolius Schott	+	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Lotus pedunculatus Cav.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.
Symphyotrichum squamatum (Spreng.) G.L. Nesom	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.
Sonchus maritimus L.	.	.	.	.	.	r	+	.	.	.	.	.	.	.	.	.	.	.	.
Symphytum tanaicense Steven	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Linum maritimum L. subsp. maritimum	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Juncus effusus L. subsp. effusus	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Osmunda regalis L.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eleocharis caduca (Delile) Schult.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Phyla nodiflora (L.) Greene	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Thelypteris palustris Schott	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Plantago major L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Cyperus odoratus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.
Persicaria lapathifolia (L.) Delarbre subsp. lapathifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.
Ranunculus repens L.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.
Stachys palustris L.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.

bernaemontani) is typical of both brackish and fresh water coenoses (see Passarge, 1978; Oťaheľová *et al*., 2001). In the study area it forms small, fragmented and species-poor stands, in submerged conditions and sometimes in the reed bed clearings, forming a sort of mosaic with the small helophyte vegetation of the *Samolo valerandi-Eleocharitetum caducae* association. The absence of species indicating any brackish conditions in our relevés leads us to include our coenoses in the *Phragmition* alliance (see also Landucci *et al*. 2013). Due to the tolerance of *S. lacustris* subsp. *glaucus* to salinity conditions, however, the presence of sub-halophilous coenoses localized in some areas of the lake more subjected to the phenomenon of salinization cannot be excluded.

BOLBOSCHOENUS MARITIMUS aggr. community (Tab. 6, rels. 17-18; Fig. 4, rels. 36 and 37)

After the taxonomic revisions of the genus *Bolboschoenus* by Hroudová *et al*. (1999, 2007), the knowledge on the vegetation dominated by *Bolboschoenus* sp. pl. has been deeply updated (Hroudová *et al*., 2009). In Italy, until few years ago only *Bolboschoenus maritimus* was reported (see Pignotti, 2003) and also for the study area no further information is recently available (see Pierini & Peruzzi, 2014). In our relevés, the collected *B. maritimus* s.l. specimens did not have fully developed inflorescences or achenes (very important for an updated identification) thus we prefer to treat our coenoses as *B. maritimus* aggr. communities (see Landucci *et al*., 2013), even if the mostly head-like inflorescences of some individuals might suggest the presence of *B. maritimus* subsp. *maritimus*. For the assignment at the alliance level, the absence of halophilous species in our relevés lead us to attribute this vegetation type to the *Phragmition alliance*, in accordance with Landucci *et al*. (2013). Also in this case, the existence of more marked sub-halophilous coenoses of *B. maritimus* attributable to the *Scirpion compacti* alliance could be possible in some areas of the lake more subjected to the phenomenon of salinization.

JUNCUS MARITIMUS community (Tab. 6, rel. 19; Fig. 4, rel. 39)

Juncus maritimus is a diagnostic species of the alliance *Juncion maritimi* Br.-Bl. ex Horvatic 1934, which includes rush communities and Mediterranean salty and brackish meadows (Biondi & Blasi, 2015). In some cases, however, *J. maritimus* has been also observed in other vegetation types, such as the association *Junco maritimi-Cladietum marisci*, described by Géhu & Biondi (1988) for Lakes Alimini in Puglia, attributed to *Scirpetalia compacti* order because of a sub-halophilous character. The presence of *J. maritimus* communities in the Lake Massaciuccoli can be considered an indicator of local condition of increasing salinity. In the study area the *Juncus maritimus* community appears yet very localized and very poor in species.

THELYPTERIDO PALUSTRIS-PHRAGMITETUM AUSTRALIS Kuiper ex van Donselaar 1961 (Tab. 7, rels. 1-7; Fig. 4 D) and aspects with *SPHAGNUM SUBNITENS*, *S. PALUSTRE* and other Bryophytes (Tab. 7, rels. 8-18; Fig. 4 E)

This vegetation type includes peculiar reed-beds developing on floating islands rich in decaying organic matter. *Thelypterido palustris-Phragmitetum australis* is rather rare in Italy, where it has been reported for some wetlands in the northern (Pedrotti, 1988, 1991; Brusa *et al*., 2006) and central regions (Lastrucci *et al*., 2014). In the study area this vegetation type appears rather widespread and differs from *Phragmitetum australis*, as put in evidence by the dendrogram of Fig. 4. *Thelypterido-Phragmitetum* of the Lake Massaciuccoli appears rather complex from a floristic and ecological point of view. In addition to stands where *P. australis* is highly dominant, we can observe also i) aspects with the dominance of *Thelypteris palustris* where the cover of *P. australis* is lower, mostly due to the mowing of the reeds and ii) aspects with *Osmunda regalis* dominance, mainly observed in areas with a lower water presence (see also Petraglia, unpublished report). Locally, the association forms a sort of mosaic with some coenoses characterized by the presence of *Sphagnum subnitens*, *S. palustre* and other Bryophytes, distributed in small patches within the *Thelypterido-Phragmitetum*. In the study area the presence of the *Sphagnum* carpets has been related to peculiar micro-climatic conditions (Rapetti *et al*., 1987); in this ecological context species such as *Lysimachia tenella*, *Rhynchospora alba* and *Drosera rotundifolia* were formerly recorded (Rapetti *et al*., 1987; Tomei *et al*., 1997) and the association *Sphagno-Droseretum rotundifoliae* Tomei, Guazzi & Barsanti 1997 was described. Later, however, neither *Rhynchospora alba* and *Drosera rotundifolia* nor the association *Sphagno-Droseretum rotundifoliae* have been confirmed (see also Petraglia, unpublished report). The *Sphagnum* carpets within the *Thelypterido-Phragmitetum* should be considered a relict of these rare communities that were present until the recent past, without any other typical species of acidophitic bogs (Petraglia, unpublished report).

CLADIETUM MARISCI Allorge 1921 (Tab. 8, rels. 1-8; Fig. 4 F)

This association is typical of oligotrophic to mesotrophic (rarely eutrophic) calcareous marshes (Landucci *et al*., 2013) and is quite rare for the Italian peninsula, especially in inner wetlands (Venanzoni & Gigante, 2000; Lastrucci *et al*, 2014; Viciani *et al*., 2017). In the study area, the association *Cladietum marisci* is broadly diffused, forming communities very poor in species and often in contact with *Phragmites australis* coenoses. It must be noted that *P. australis* tends to penetrate into *Cladietum*, forming also mixed coenoses or becoming dominant in some situations (see also Tomei *et al*., 1994, 1997). According to Mariotti (2009), eutrophic conditions can facilitate *P. australis* to the detriment of *C. mariscus*; the phenomenon of eutrophication of the lake might thus favor the expansion of the reed to the detriment of *C. mariscus*. Moreover, it must be noted that *C. mariscus* is able to form coenoses also in sub-halophilous habitats and associations such as *Soncho maritimi-Cladietum marisci* (Br.-Bl. et O. Bolòs 1958) Cirujano 1980 and *Junco maritimi-Cladietum marisci* Géhu et Biondi 1988 testify this peculiar aspects. The absence in our relevés of any floristic indicator of salinity condition lead us to classify all the *Cladium mariscus* coenoses in the *Cladietum marisci*, even if it is not possible to exclude the presence of locally sub-halophilous conditions leading to the presence of one of the previously mentioned associations.

Tab. 7 - *Thelypterido palustris-Phragmitetum australis* (alliance *Carici pseudocyperi-Rumicion hydrolapathi*) and aspects with *Sphagnum* sp. pl.. Rels. 8-11 and 13-15 have been obtained from Petraglia (unpublished report).

Rel. number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Number in the dendrogram of Fig. 4	39	40	41	43	45	44	42	46	47	48	49	50	56	52	53	54	55	51
Cover (%) of vascular plants	100	100	95	100	90	100	100	80	70	80	60	65	50	70	80	50	35	40
Cover (%) of Briophytes		10				<1		40	70	30	100	90	90	20	50	90	90	80
Surface (mq)	25	16	16	30	30	16	10	4	4	4	4	1	1	4	4	1	1	4
Carici pseudocyperi-Rumicion hydrolapathi alliance																		
Charact. of *Thelypterido-palustris-Phragmitetum australis*																		
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	4	4	3	4	3	3	3	4	3	3	2	2	2	2	2	2	1	2
Thelypteris palustris Schott	2	2	4	4	3	2	3	.	.	+	.	.	1	4	4	3	1	1
Aspects with *Osmunda regalis*																		
Osmunda regalis L.	2	2	+	1	.	4	.	3	2	2	1	3	.	.	.	.	.	.
Charact. of *Phragmito-Magnocariceta* units																		
Lythrum salicaria L.	1	2	.	+	+	r	1	+	+	1	.	+	+	1	.	+	2	.
Cladium mariscus (L.) Pohl subsp. mariscus	.	.	1	2	2	2	.	.	+	+	+	.	2	+	+	+	1	.
Typha angustifolia L.	.	+	+	1	+	.	.	1	+	+	+	.	.	1	2	.	1	1
Oenanthe aquatica (L.) Poir.	1	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Hibiscus palustris L.	.	.	.	.	+	.	3	.	.	.	.	.	.	.	.	.	.	.
Lathyrus palustris L.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Lysimachia vulgaris L.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helosciadium nodiflorum (L.) W.D.J. Koch subsp. nodiflorum	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Limniris pseudacorus (L) Fuss	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mentha aquatica L.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scutellaria galericulata L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Local aspects with *Sphagnum* sp.pl. and other *Bryophytes*																		
Sphagnum subnitens Russow & Warnst.	.	2	.	.	.	r	.	2	4	1	3	5	3	1	2	5	5	+
Sphagnum palustre L.	.	.	.	.	.	.	.	1	+	2	3	.	4	1	2	.	.	4
Aulacomnium palustre (Hedw.) Schwägr.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.
Calypogeia fissa (L.) Raddi	.	.	.	.	.	.	.	1	1	+	+	.	.	.	.	.	.	.
Pleurozium schreberi (Willd. ex Brid.) Mitt.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Other species																		
Frangula alnus Mill. subsp. alnus	1	1	.	+	.	r	1	+	+	1	+	2	1	.	.	+	.	1
Hydrocotyle vulgaris L.	.	+	1	1	.	r	.	.	+	+	+	1	.	1	1	1	.	.
Calystegia sepium (L.) R. Br. subsp. sepium	2	+	.	1	+	.	1	1	.	.	+	.	.	.	.	.	.	.
Eupatorium cannabinum L. subsp. cannabinum	1	1	2	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.
Potentilla erecta (L.) Raeusch.	.	2	.	.	.	.	.	.	.	.	+	.	.	.	1	.	.	1
Lysimachia tenella L.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	1	1	.	1
Salix cinerea L.	.	+	.	.	.	+	.	.	.	.	.	.	+	.	.	.	r	.
Cirsium creticum (Lam.) d'Urv. subsp. triumfettii (Lacaita) K. Werner	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Rubus ulmifolius Schott	1	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Alnus glutinosa (L.) Gaertn. subsp. glutinosa	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	.	.
Holcus mollis L. subsp. mollis	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	2
Hypericum tetrapterum Fr.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix caprea L. subsp. caprea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Epilobium hirsutum L.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Lonicera japonica Thunb.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Agrostis stolonifera L. subsp. stolonifera	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Holcus lanatus L. subsp. lanatus	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Juncus articulatus L. subsp. articulatus	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Juncus conglomeratus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Lactuca serriola L.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oenanthe silaifolia M. Bieb.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Periploca graeca L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Populus alba L.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solanum dulcamara L.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bidens frondosus L.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.

CARICETUM ELATAE Koch 1926 (Tab. 8, rel. 9; Fig. 4, rel. 65)

Stands dominated by *Carex elata* occur in mesotrophic to eutrophic still water rich in carbonates and nutrients, growing in sites characterized by large seasonal fluctuation of the water table (Landucci *et al*., 2013). In several Tuscan marshes, this association is disappearing due to the loss or degradation of habitat or to the abandonment of traditional activities of stuffing, and it is often replaced by common reed-dominated stands (Lastrucci *et al*., 2008). In Lake Massaciuccoli *Carex elata*–dominated vegetation is rather rare and covers small patches. The only relevé is located on the banks of the Fosso Pantaneto, in a marginal position on the border of the SAC, in contact with mixed communities dominated by *Phragmites australis* and *Cladium mariscus*.

Tab. 8 - Vegetation of the alliances *Magnocaricion elatae* and *Caricion gracilis*.

Rel. number	1	2	3	4	5	6	7	8	9	10	11	12	13
Number in the dendrogram of Fig. 4	57	58	59	60	61	62	63	64	65	66	67	68	69
Cover (%)	90	95	90	95	90	90	100	100	100	90	100	100	100
Surface (mq)	50	50	50	50	20	4	10	10	16	4	2	2	10
Magnocaricion elatae alliance													
Charact. of *Cladietum marisci*													
Cladium mariscus (L.) Pohl subsp. mariscus	5	5	5	5	5	4	4	5	.	.	.	.	.
Charact. of *Caricetum elatae*													
Carex elata All. subsp. elata	.	.	.	.	.	.	.	.	4	.	.	.	.
Charact. of *Caricetum acutiformis*													
Carex acutiformis Ehrh.	.	.	.	.	.	.	.	.	.	5	5	5	.
Caricion gracilis alliance													
Charact. of *Caricetum ripariae*													
Carex riparia Curtis subsp. riparia	.	.	.	.	.	.	.	.	.	.	.	.	5
Charact. of upper units													
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	+	.	+	1	2	2	3	.	2	.	.	1	.
Typha angustifolia L.	.	.	+	.	+	+	.	2	.	.	.	.	.
Hibiscus palustris L.	.	.	+	+	.	.	+	.	.	.	.	.	.
Limniris pseudacorus (L) Fuss	.	.	.	.	.	.	r	.	2	.	.	.	.
Other species													
Calystegia sepium (L.) R. Br. subsp. sepium	.	.	.	+	.	.	r	.	+	.	.	.	.
Ranunculus repens L.	.	.	.	.	.	.	.	.	.	.	1	1	+
Poa trivialis L. subsp. sylvicola (Guss.) H. Lindb.	.	.	.	.	.	.	.	.	.	.	.	1	2
Carex otrubae Podp.	.	.	.	.	.	.	.	.	.	.	.	1	+
Potentilla reptans L.	.	.	.	.	.	.	.	.	.	.	.	.	1
Carex hirta L.	.	.	.	.	.	.	.	.	.	.	.	+	.
Eupatorium cannabinum L. subsp. cannabinum	.	.	.	.	.	.	.	.	.	+	.	.	.
Juncus conglomeratus L.	.	.	.	.	.	.	.	.	.	.	+	.	.
Lolium arundinaceum (Schreb.) Darbysh.	.	.	.	.	.	.	.	.	.	.	.	.	+
Periploca graeca L.	.	.	.	.	.	.	.	.	.	+	.	.	.
Solanum dulcamara L.	.	.	.	+	.	.	.	.	.	.	.	.	.
Rumex crispus L.	.	.	.	.	.	.	.	.	.	.	.	.	r

CARICETUM ACUTIFORMIS Eggler 1933 (Tab. 8, rels. 10-12; Fig. 4 H)

This community, dominated almost exclusively by *Carex acutiformis*, occurs in mesotrophic to eutrophic shallow waters, growing on peat and humic, usually nutrient and base-rich, but also moderately acid soils (Landucci *et al*., 2013). In Italy this association is often fragmented because of human disturbance (Venanzoni & Gigante, 2000; Lastrucci *et al*., 2008). In Lake Massaciuccoli the species appears scarcely diffused but it becomes more abundant in the surrounding channels and streams where it forms dense and linear coenoses, often poor in species, along the banks.

CARICETUM RIPARIAE Máthé et Kovács 1959 (Tab. 8, rel. 13; Fig. 4, rel. 69)

This association lives in meso- and eutrophic wetlands emerged since late spring (Landucci *et al*., 2013). It was often found in rather disturbed habitats (Lastrucci *et al*., 2014). In the study area the association is present at the "Idrovora di Vecchiano" in a wet depression near the water course. The community is characterized by the dominance of *Carex riparia* and by the presence of some species typical of disturbed wet meadows, such as *Poa trivialis* subsp. *sylvicola*, *Lolium arundinaceum*, *Rumex crispus* or *Ranunculus repens*.

SPARGANIETUM ERECTI Roll 1938 (Tab. 9, rel. 1; Fig. 4, rel. 70)

Stands dominated by *Sparganium erectum* occur in mesotrophic to eutrophic water, also with organic sediments on the bottom (Landucci *et al*., 2013). This association is frequent across the country and has been recorded by many authors in Central Italy (Venanzoni & Gigante, 2000; Ceschin & Salerno, 2008; Mereu *et al*. 2012, Lastrucci *et al*., 2010b, 2012). In the study area this plant community is extremely localized and poor in species; the only relevé is located on the banks of the Fosso Pantaneto along the boundaries of the SAC. The association is in contact with communities dominated both by *Myriophyllum spicatum* and *Phragmites australis*, according to the ecology of the association as reported by Venanzoni *et al*. (2003).

NASTURTIETUM OFFICINALIS Gilli 1971 (Tab. 9, rel. 2; Fig. 4, rel. 71)

Association typical of still or running, meso- and eutrophic waters, rather common in Central Italy where it was recorded mostly along the banks of streams and rivers (e.g. Baldoni & Biondi, 1993; Ceschin & Salerno, 2008; Pedrotti, 2008; Lastrucci *et al*., 2010b, 2012; Mereu *et al*., 2012). In the study area the association was recorded along the banks of the channel at the

Tab. 9 - Vegetation of the order *Nasturtio officinalis-Glycerietalia fluitantis*.

Rel. number	1	2
Number in the dendrogram of Fig. 4	70	71
Cover (%)	85	100
Surface (mq)	4	4
Charact. of *Sparganietum erecti*		
Sparganium erectum L. subsp. erectum	5	.
Charact. of *Nasturtietum officinalis*		
Nasturtium officinale W.T. Aiton	.	5
Charact. of upper units		
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	1	.
Mentha aquatica L.	+	.
Other species		
Paspalum distichum L.	1	.
Galium aparine L.	.	1
Myriophyllum aquaticum (Vell.) Verdc.	.	1

"Idrovora di Vecchiano" where it grows in contact with the *Myriophyllum aquaticum*-dominated community.

Hygro-nitrophilous perennial communities of the *Galio aparines-Urticetea dioicae* class

CONVOLVULO SEPIUM-EUPATORIETUM CANNABINI Görs 1974 (Tab. 10, rel. 1; Fig. 4, rel. 72)

Hygro-nitrophilous community rather common in Central Italy where it has been reported for several types of wetlands (Baldoni & Biondi, 1993; Pirone, 2000; Landi *et al*., 2002, Pedrotti, 2008; Lastrucci & Becattini, 2009; Mereu *et al*., 2012). In the study area it was found along the Fosso Malfante channel, behind the helophyte vegetation.

ARUNDINI DONACIS-CONVOLVULETUM SEPIUM Tüxen & Oberdorfer ex O. Bolós 1962 (Tab. 10, rel. 2; Fig. 4, rel. 73)

Arundo donax is considered an invasive species for Italy (Celesti-Grapow *et al*., 2009) and results to be widespread in Tuscany (Arrigoni & Viegi, 2011). Native of central Asia, this species has been widely used for agricultural activities, naturalizing along the water courses or at the edge of marshlands (Arrigoni & Viegi, 2011). The association *Arundini-Convolvuletum* has been reported for several sites in Central Italy (Baldoni & Biondi, 1993; Pirone & Ferretti, 1999; Arrigoni & Papini, 2003; Mereu *et al*., 2012). In the study area *Arundini-Convolvuletum* was found along the banks of the Fosso Le Quindici with a relevant presence of climbing species such as *Periploca graeca* and *Calystegia sepium*.

EUPHORBIA PALUSTRIS and *CRISIUM CRETICUM* subsp. *TRIUMFETTII* community (Tab. 10, rel. 3; Fig. 4, rel. 74)

At the edge of the tall helophyte vegetation a mega-

Tab. 10 - Vegetation of the class *Galio aparines-Urticetea dioicae*.

Rel. number	1	2	3
Number in the dendrogram of Fig. 4	72	73	74
Cover (%)	100	100	100
Surface (mq)	4	5	6
Charact. of *Convolvulo sepium - Eupatorietum cannabini*			
Eupatorium cannabinum L. subsp. cannabinum	5	.	.
Charact. of *Arundini donacis-Convolvuletum sepium*			
Arundo donax L.	.	5	.
Dom. of *Euphorbia palustris* and *Cirsium creticum* subsp. *triumfettii* community			
Euphorbia palustris L.	.	.	3
Lotus pedunculatus Cav.	.	.	3
Cirsium creticum (Lam.) d'Urv. subsp. triumfettii (Lacaita) K. Werner	.	.	2
Charact. of upper units			
Calystegia sepium (L.) R. Br. subsp. sepium	2	1	1
Stachys palustris L.	.	.	1
Other species			
Periploca graeca L.	.	2	+
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	+	.	1
Pulicaria dysenterica (L.) Bernh. subsp. dysenterica	.	.	2
Scirpoides holoschoenus (L.) Soják	.	.	1
Galium palustre L. subsp. elongatum (C. Presl) Lange	+	.	.
Cladium mariscus (L.) Pohl subsp. mariscus	.	.	+
Juncus subnodulosus Schrank	.	.	+
Rubus ulmifolius Schott	.	+	.
Populus alba L.	.	.	+
Mercurialis annua L.	.	r	.

phorbic community dominated by *Euphorbia palustris* with *Crisium creticum* subsp. *triumfettii*, *Lotus pedunculatus* and *Stachys palustris* has been sampled. The ecology of *Euphorbia palustris* appears rather complex, because this species has been found in several vegetation types belonging to different syntaxa, from the *Calystegion* alliance to the *Phragmitetea* class (Lastrucci *et al*., 2014 and references therein). In the study area this ecological amplitude is fully evident, because *E. palustris* is present both in the palustrine *Phragmition* coenoses and also in the vegetation located behind the helophyte stands. In the latter context, as showed in Tab. 10, it participates to the floristic composition of coenoses growing at the fringe of the reed beds, with the compresence of several hygrophilous species of the wet meadows such as *Pulicaria dysenterica*, *C. creticum* subsp. *triumfetti*, *L. pedunculatus*, *S. palustris* and *Scirpoides holoschoenus*.

Hygrophilous vegetation of the class *Molinio-Arrhenatheretea*

HOLOSCHOENETUM VULGARIS Br.-Bl. ex Tchou 1948 (Tab. 11, rel. 1; Fig. 4, rel. 75)

This association dominated by *Scirpoides holoschoenus* colonises from fine-grained to sandy, very permeable and moist soils (Tchou, 1948). *Holoschoenetum vulgaris* has been reported for several types of wetlands in Central Italy (Biondi & Baldoni, 1994; Orsomando & Catorci, 1991; Lastrucci *et al*., 2012). In the study area it grows behind the helophyte formations of the class *Phragmito-Magnocaricetea*.

Tab. 11 - Vegetation of the class *Molinio-Arrhenateretea*.

Rel. number	1	2	3
Number in the dendrogram of Fig. 4	75	76	77
Cover (%)	100	100	100
Surface (mq)	10	25	20
Charact. of *Holoschoenetum vulgaris*			
Scirpoides holoschoenus (L.) Soják	4	.	.
Charact. of *Paspalo distichi-Polypogonetum viridis*			
Paspalum distichum L.	.	5	5
Charact. of upper units			
Juncus articulatus L. subsp. articulatus	2	.	.
Juncus subnodulosus Schrank	1	.	.
Other species			
Typha latifolia L.	.	.	1
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	+	.	.
Calystegia sepium (L.) R. Br. subsp. sepium	+	.	.
Lythrum salicaria L.	+	.	.
Oenothera sp.	+	.	.
Periploca graeca L.	+	.	.
Lemna minuta Kunth	.	.	+

Tab. 12 - Vegetation of the class *Alnetea glutinosae*.

Rel. number	1	2
Cover (%)	90	100
Surface (mq)	80	40
Dom. *Alnus glutinosa* community		
Alnus glutinosa (L.) Gaertn. subsp. glutinosa	4	4
Charact. of upper units		
Osmunda regalis L.	3	3
Frangula alnus Mill. subsp. alnus	1	2
Solanum dulcamara L.	1	.
Salix cinerea L.	.	1
Other species		
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis	2	2
Rubus ulmifolius Schott	2	1
Calystegia sepium (L.) R. Br. subsp. sepium	1	1
Lonicera japonica Thunb.	+	1
Eupatorium cannabinum L. subsp. cannabinum	1	.
Lythrum salicaria L.	1	.
Bryophytes		
Calypogeia sphagnicola (Arnell & J. Perss.) Warnst. & Loeske	.	1
Aulacomnium palustre (Hedw.) Schwägr.	.	+

PASPALO DISTICHI-POLYPOGONETUM VIRIDIS Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936 (Tab. 11, rels. 2-3; Fig. 4, rels. 76-77)

The association is characterized by the dominance of the invasive alien species *Paspalum distichum* (Celesti-Grapow *et al*., 2009). *Paspalo-Polypogonetum* has a mostly Mediterranean distribution and often results to be very poor in species (Baldoni & Biondi 1993, Biondi & Baldoni 1994, Lastrucci *et al*., 2010b). This feature is confirmed also by our relevés, showing the strong dominance of *P. distichum*. In the study area the association is located in the disturbed banks of the channels surrounding the lake, forming dense mono- or paucispecific carpets in contact with hydrophyte or helophyte coenoses.

Alnus glutinosa palustrine vegetation of the *Alnetea glutinosae* class (Tab. 12)

In the study area the woody formations are rather discontinuous and fragmented, and often constituted by alien species derived from plantations (e.g. *Eucalyptus* spp.). Among the native tree species, *Alnus glutinosa* and *Fraxinus angustifolia* subsp. *oxycarpa* are the most widespread, but *F. oxycarpa* is mainly present with isolated individuals, while *A. glutinosa* also forms small woods. We here analyze two relevés performed on marshy soils, dominated by *Alnus glutinosa* (Tab. 12). In the tree layer only the black alder is present while the shrub layer is formed by *Salix cinerea* and *Frangula alnus*. In the lower layers *Phragmites australis* and *Rubus ulmifolius* are widespread, but especially *Osmunda regalis* reaches high cover values, sometimes accompanied by small moss carpets. Our relevés are rather poor in species and thus they do not allow to attribute these communities to a specific association. The widespread presence in the study area of species such as *Hydrocotyle vulgaris* and *Periploca graeca* could however suggest that these coenoses are not far from impoverished aspects of the association *Hydrocotylo-Alnetum glutinosae*, described for the nearby Selva di San Rossore by Gellini *et al*. (1986). The same authors also reported a relevé with high cover value of *O. regalis* (formerly attributed at the *Osmundo-Alnetum* Vanden Berghen 1971, see also Tomei *et al*., 1998), rather similar to ours, corresponding to local aspects of the same *Hydrocotylo-Alnetum* association (Pedrotti & Gafta, 1996; Landi & Angiolini 2006). Moreover, Gellini *et al*. (1986) considered reasonable the presence of *Hydrocotylo-Alnetum* in Viareggio area, according to floristic and vegetation information reported by Montelucci (1964).

Other coenoses reported in literature

Some vegetation types have been cited for the study area in literature but they were not found during our field activity. Tomei *et al*. (1994) reported the presence of *Ceratophyllum demersum* and *Chara* sp.-dominated communities. Communities of *Ceratophyllum demersum* have been reported (sub *Ceratophylletum demersi* aggr. Oberd. 1977) also by Tomei *et al*. (1997). Coenoses with the dominance of *Lemna minor* have been recorded by Tomei *et al*. (1997). Tomei *et al*. (1997, 1998) reported the presence of vegetation dominated by *Stuckenia pectinata* (sub *Potametum pectinati* Beg.1941) and *Lemna trisulca* (Tomei *et al*., 1998).

In addition, it must be noted the record of the alien *Hydrocotyle ranunculoides* community (sub *Hydrochotyletum ranunculoidis* Corbetta & Lorenzoni 1976) in the north-eastern part of the Massaciuccoli basin (Tomei *et al*., 1997, 1998).

Conservation aspects

The study of vegetation with the phytosociological approach is a fundamental tool for the identification of habitats of conservation interest in accordance with the European Directive 92/43/EEC (Biondi *et al*., 2012; European Commission, 2013; Gigante *et al*., 2016; Viciani *et al*., 2014, 2016), becoming thus an essential instrument for planning and managing the natural resources. The interpretation of the phytosociological information by means of official documents and scientific literature (e.g. Commission of the European Community, 1991, 1992; Evans, 2006, 2010; Angelini *et al*., 2009; 2016; Biondi *et al*., 2009; 2012; Biondi & Blasi, 2015; European Commission, 2013) allowed to recognize in the study area 9 habitats of European Conservation Interest (Natura 2000 Network), which are reported below (see also Viciani *et al*., 2017).

The habitat "Natural euthrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation" (Natura 2000 code 3150) is quite widespread. It includes almost all the aquatic plant communities recorded in the lake according to the Italian Interpretation Manual (Biondi *et al*., 2009). Also the aquatic communities of the sampled channels around the lake have been attributed to the habitat 3150, due to the uppermost stagnant characters of their waters. Even if the opportunity to attribute alien hydrophyte coenoses to aquatic habitats of conservation value is an extensively debated matter (see Bolpagni, 2013), in the study area the invasion of the alien *Myriophyllum aquaticum* represents more a concrete and dangerous threat than a chance for developing new conservation habitat surface areas. We thus prefer not to consider these communities as belonging to any habitat of conservation interest, due to the strong invasive behaviour of this species and its tendency to replace the native aquatic species (Lastrucci *et al*., 2016; Lastrucci *et al*., 2017). "Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*" (Natura 2000 code 3130) are present in the area in small patches spread within the tall helophyte vegetation. The habitat is present with both *Littorelletea uniflorae* (*Hydrocotyle vulgaris* community) and *Isoëto-Nanojuncetea* (*Verbenion* and *Nanocyperion* communities) components.

The communities with *Paspalum distichum* have been attributed to the habitat "Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*" (Natura 2000 code 3280), present along some disturbed channels around the lake; our choice is driven mostly by the permanent water presence along the water courses. The habitat "Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*" (Natura 2000 code 6420), representend by the association *Holoschoenetum vulgaris*, is sporadically diffused in some open areas in contact with the *Phramito-Magnocaricetea* coenoses.

Also the habitat "Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels" Natura 2000 code 6430), represented by the communities dominated by *Eupatorium cannabinum* or *Euphorbia palustris* seems scarcely diffused, limited to some areas at the edge of the palustrine vegetation. The community dominated by the alien species *Cyperus odoratus* has been provisionally attributed to the habitat "Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation" (Natura 2000 code 3270), often formed by hygro-nitrophilous alien species of the muddy soils of the river and channel banks, according to the Italian Interpretation Manual (Biondi *et al*., 2009). Further phytosociological information about *C. odoratus* vegetation is however required in order to better understand the syntaxonomic classification of these communities and their attribution to habitats of conservation interest. As to the *Sphagnum* carpets within the *Thelypterido-Phragmitetum*, according to Petraglia (unpublished report), these aspects can be attributed to the habitat "Transition mires and quaking bogs" (Natura 2000 code 7140), even if floristically impoverished. The habitat of priority interest "Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*" (Natura 2000 code 7210*) covers very extended surfaces in the study area (Viciani *et al*., 2017). An optimal facies of the habitat is represented by the dense *Cladium mariscus*-dominated communities whilst facies with higher presence and cover of *Phragmites australis* should be carefully monitored. An eventual expansion of the reed, favored by the increasing of eutrophication, might transform the *Cladietum* in a *P. australis*-dominated vegetation, leading to the transformation or the disappearance of the habitat 7210*. This process has been already reported for the study area (Tomei *et al*., 1994, 1997) and could be facilitated by the abandonment of management of *Cladium mariscus* communities for craft purposes. The marshy forests with *Alnus glutinosae* present along the banks of the lake and the Fosso Cava can be attributed to the habitat of priority interest "Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*" (Natura 2000 code 91E0*); the habitat occurs often in small and rather fragmented patches. It should finally be noted that some communities of the alliance *Glycerio-Sparganion sensu* Corine Biotopes (Cod. 53.4) are considered of regional importance according to the laws on biodiversity conservation of the Tuscany Regional Administration.

Syntaxonomic scheme

LEMNETEA MINORIS O. Bolòs & Masclans 1955
LEMNETALIA MINORIS O. Bolòs & Masclans 1955
Lemnion minoris O. Bolòs & Masclans 1955
Lemnetum minuto-gibbae Liberman Cruz, Pedrotti & Venanzoni 1988
Lemnetum gibbae Miyawaki & J. Tüxen 1960

POTAMETEA PECTINATI Klika in Klika & V. Novák 1941
POTAMETALIA PECTINATI Koch 1926
Potamion pectinati (W. Koch 1926) Libbert 1931
Najadetum marinae Fukarek 1961
Potamo pectinati-Myriophylletum spicati Rivas Goday 1964 corr. Conesa 1990
Potametum crispi Soó 1927
Myriophyllum aquaticum community
Nymphaeion albae Oberdorfer 1957
Nymphaeetum albae Vollmar 1947

BIDENTETEA TRIPARTITAE Tüxen, Lohmeyer & Preising ex Von Rochow 1951
BIDENTETALIA TRIPARTITAE Br.-Bl. & Tüxen ex Klika in Klika & Hadac 1944
Bidention tripartitae Nordhagen 1940
Cyperus odoratus community

ISOËTO-NANOJUNCETEA Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946
NANOCYPERETALIA FLAVESCENTIS Klika 1935
Verbenion supinae Slavnić 1935
Samolo valerandi-Eleocharitetum caducae ass. nova hoc loco
Lythrum hyssopifolia community
Nanocyperion flavescentis Koch ex Libbert 1932
Juncus bufonius community

LITTORELLETEA UNIFLORAE Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946
LITTORELLETALIA UNIFLORAE Koch 1926
Hyperico elodis-Sparganion Br.-Bl. et Tx. ex Oberd. 1957
Hydrocotyle vulgaris community

PHRAGMITO AUSTRALIS-MAGNOCARICETEA ELATAE Klika in Klika et Novák 1941
PHRAGMITETALIA AUSTRALIS Koch 1926
Phragmition communis Koch 1926
Typhetum angustifoliae Pignatti 1953
Phragmitetum australis Savič 1926
Phragmito-Schoenoplectetum tabernaemontani Passarge (1964) 1978
Bolboschoenus maritimus aggr. community
MAGNOCARICETALIA ELATAE Pignatti 1953
Carici pseudocyperi-Rumicion hydrolapathi Passarge 1964
Thelypterido palustris-Phragmitetum australis Kuiper ex van Donselaar 1961
Magnocaricion elatae Koch 1926
Cladietum marisci Allorge 1921
Caricetum elatae Koch 1926
Caricetum acutiformis Eggler 1933
Caricion gracilis Neuhäusl 1959
Caricetum ripariae Máthé et Kovács 1959
SCIRPETALIA COMPACTI Heijný in Holub, Heijný, Moraveć & Neuhäusl 1967 corr. Rivas-Martínez, Costa, Castroviejo & E. Valdés 1980
Scirpion compacti Dahl & Hadac 1941 corr. Rivas-Martinez, Costa, Castroviejo & E. Valdés 1980
Aggr. a *Juncus maritimus*

NASTURTIO OFFICINALIS-GLYCERIETALIA FLUITANTIS Pignatti 1953
Glycerio fluitantis-Sparganion neglecti Br.-Bl. & Sissingh in Boer 1942
Sparganietum erecti Roll 1938
Apion nodiflori Segal in Westhoff & Den Held 1969
Nasturtietum officinalis Gilli 1971

SCHEUCHZERIO PALUSTRIS-CARICETEA FUSCAE Tüxen 1937
Sphagnum subnitens and *Sphagnum palustre* community

GALIO APARINES-URTICETEA DIOICAE Passarge ex Kopecký 1969
CALYSTEGIETALIA SEPIUM Tüxen ex Mucina 1993 nom. mut. propos. Rivas-Martínez, T.E. Díaz, Fernandez-Gonzales, Izco, Loidi, Lousã & Penas 2002
Calystegion sepium Tüxen ex Oberdorfer 1957 nom. mut. propos. Rivas-Martínez, T.E. Díaz, Fernandez-Gonzales, Izco, Loidi, Lousã & Penas 2002
Arundini donacis-Convolvuletum sepium Tüxen & Oberdorfer ex O. Bolós 1962
Convolvulo sepium-Eupatorietum cannabini Görs 1974
Euphorbia palustris and *Cirsium creticum* subsp. *triumfettii* community

MOLINIO-ARRHENATHERETEA Tüxen 1937
HOLOSCHOENETALIA VULGARIS Br.-Bl. ex Tchou 1948
Agrostio stoloniferae-Scirpoidion holoschoeni De Foucault 2012
Holoschoenetum vulgaris Br.-Bl. ex Tchou 1948
Paspalo distichi-Agrostion semiverticillatae Br.-Bl. in Br.-Bl., Roussine & Nègre 1952
Paspalo distichi-Polypogonetum viridis Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936

ALNETEA GLUTINOSAE Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946
ALNETALIA GLUTINOSAE Tüxen 1937
Alnion glutinosae Malcuit 1929
Alnus glutinosa community

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Appendix I: Localities and dates of the relevés

Tab. 2: Rel. 1, Fosso Burlamacca, 01/07/2015, GBX=1607239, GBY=4856168; Rel. 2, Fosso Ferro di Cavallo, 10/07/2015, GBX=1606530, GBY=4857061; Rel. 3, Idrovora di Vecchiano, 27/10/2015, GBX=1608107, GBY=4852545; Rel. 4, Channel near M. Cocco, 29/07/2015, GBX=1609693, GBY=4853711; Rel. 5, Channel near M. Cocco, 29/07/2015, GBX=1609723, GBY=4853704; Rel. 6, Near Porto di Massaciuccoli, 01/07/2015, GBX=1608732, GBY=4854635; Rel. 7, Chiaro Grande near Padule del Nelli, 01/07/2015, GBX=1608581, GBY=4854975; Rel. 8, Chiaro Grande near Bigongiari, 10/07/2015, GBX=1608724, GBY=4854447; Rel. 9, Chiaro Grande near Bigongiari, 10/07/2015, GBX=1608742, GBY=4854124; Rel. 10, Chiaro Grande near Padule del Nelli, 01/07/2015, GBX=1608460, GBY=4855226; Rel. 11, Fosso Le Quindici, 29/07/2015, GBX=1603211, GBY=4857126; Rel. 12, Fosso Pantaneto, 10/07/2015, GBX=1606314, GBY=4857326; Rel. 13, Fossa Nuova, near Bonifica degli Studiati, 04/05/2016, GBX=1610508, GBY=4852355; Rel. 14, Fossa Nuova, near Bonifica degli Studiati, 04/05/2016, GBX=1610509, GBY=4852341; Rel. 15, Idrovora di Vecchiano, 04/05/2016, GBX=1608184, GBY=4852553; Rel. 16, Il Porto di Massaciuccoli, 04/05/2016, GBX=1609068, GBY=4854564.

Tab. 3: Rel. 1, Fosso Malfante, 29/07/2015, GBX=1606818, GBY=4855818.

Tab. 4: Rel. 1, Collettore Centrale, 29/07/2015, GBX=1605905, GBY=4856620; Rel. 2, Pit near Fosso Malfante, 10/09/2015, GBX=1604634, GBY=4856580; Rel. 3, Collettore Centrale, 29/07/2015, GBX=1605906, GBY=4856618, Rel. 4, Collettore Centrale, 29/07/2015, GBX=1605847, GBY=4856597; Rel. 5, Collettore Centrale, 29/07/2015, GBX=1605846, GBY=4856598; Rel. 6*, Collettore Centrale, 29/07/2015, GBX=1605848, GBY=4856598; Rel. 7, Pit near Fosso Malfante, 10/09/2015, GBX=1604637, GBY=4856580; Rel. 8, Fosso Centralino, 10/09/2015, GBX=1605599, GBY=4856233; Rel. 9, Collettore Centrale, 29/07/2015, GBX=1605850, GBY=4856601; Rel. 10, Fosso Centralino, 10/09/2015, GBX=1605598, GBY=4856228; Rel. 11, Collettore Centrale, 29/07/2015, GBX=1605853, GBY=4856603; Rel. 12, Fosso Burlamacca, 01/07/2015, GBX=1607568, GBY=4856035; Rel. 13, Nature trail near Porto, 01/07/2015, GBX=1608891, GBY=4854873; Rel. 14, La Piaggetta, 04/05/2016, GBX=1608041, GBY=4855461. Tab. 5: Rel. 1, Fosso Ferro di Cavallo, 10/07/2015, GBX=1606531, GBY=4857062; Rel. 2, Fosso Ferro di Cavallo, 10/07/2015, GBX=1606529, GBY=4857063; Rel. 3, Pit near Fosso Malfante, 29/07/2015, GBX=1604612, GBY=4856973; Rel. 4, Near Porto di Massaciuccoli, 01/07/2015, GBX=1608704, GBY=4854595.

Tab. 6: Rel. 1, Chiaro Grande near Padule del Nelli, 01/07/2015, GBX=1608463, GBY=4855181; Rel. 2, Fosso Burlamacca, 01/07/2015, GBX=1607764, GBY=4855935; Rel. 3, Fosso Ferro di Cavallo, 10/07/2015, GBX=1606724, GBY=4856843; Rel. 4, Channel near M. Cocco, 29/07/2015, GBX=1609436, GBY=4853820; Rel. 5, Canale Burlamacca, 10/07/2015, GBX=1605840, GBY=4856860; Rel. 6, Fosso Malfante, 29/07/2015, GBX=1607091, GBY=4855682; Rel. 7, Pit near Fosso Malfante, 10/09/2015, GBX=1604507, GBY=4856658; Rel. 8, La Piaggetta, 04/05/2016, GBX=1608010, GBY=4855443; Rel. 9, Fosso Malfante, 29/07/2015, GBX=1605944, GBY=4856249; Rel. 10, Fosso Malfante, 29/07/2015, GBX=1606260, GBY=4856014; Rel. 11, Fosso Burlamacca, 01/07/2015, GBX=1607240, GBY=4856168; Rel. 12, Canale delle Cave, 10/07/2015, GBX=1605288, GBY=4857117; Rel. 13, Near Cava Incrociata, 29/07/2015, GBX=1603544, GBY=4857571; Rel. 14, Fosso Pantaneto, 10/07/2015, GBX=1606484, GBY=4857399; Rel. 15, Canale Burlamacca, 10/07/2015, GBX=1605853, GBY=4856809; Rel. 16, Pit near Fosso Malfante, 29/07/2015, GBX=1604623, GBY=4857019; Rel. 17, Canale Burlamacca, 10/07/2015, GBX=1605851, GBY=4856809; Rel. 18, Collettore Centrale, 29/07/2015, GBX=1605906, GBY=4856622; Rel. 19, Pit near Fosso Malfante, 29/07/2015, GBX=1604987, GBY=4856841.

Tab. 7: Rel. 1, Near Porto di Massaciuccoli, 01/07/2015, GBX=1608714, GBY=4854620; Rel. 2, Near Porto di Massaciuccoli, 01/07/2015, GBX=1608725, GBY=4854585; Rel. 3, Near Porto di Massaciuccoli, 01/07/2015, GBX=1608744, GBY=4854587; Rel. 4, Chiaro Grande near Padule del Nelli, 01/07/2015, GBX=1608595, GBY=4854884; Rel. 5, Chiaro Grande near Bigongiari, 10/07/2015, GBX=1608744, GBY=4854288; Rel. 6, Chiaro Grande near Bigongiari, 04/05/2016, GBX=1608710, GBY=4854215; Rel. 7, Nature trail near Porto, 01/07/2015, GBX=1608693, GBY=4854826; Rel. 8, [from Petraglia (2013) (MAS1-SPH)], Near Porto di Massaciuccoli, 13/05/2012, GBX=1608771, GBY=4854601; Rel. 9, [from Petraglia (2013) (MAS2-SPH)], Near Porto di Massaciuccoli, 13/05/2012, GBX=1608782, GBY=4854592; Rel. 10, [from Petraglia (2013) (MAS3-SPH)], Near Porto di Massaciuccoli, 13/05/2012, GBX=1608787, GBY=4854587; Rel. 11, [from Petraglia (2013) (MAS4-SPH)], Near Porto di Massaciuccoli, 13/05/2012, GBX=1608774, GBY=4854588; Rel. 12, Near Fosso Burlamacca, 04/05/2016, GBX=1607781, GBY=4855731; Rel. 13, [from Petraglia (2013) (MAS7-SPH)], Near Porto di Massaciuccoli, 13/05/2012, GBX=1608784, GBY=4854571; Rel. 14, [from Petraglia (2013) (MAS5-SPH)], Near Porto di Massaciuccoli, 13/05/2012, GBX=1608792, GBY=4854580; Rel. 15, [From Petraglia (2013) (MAS6-SPH)], Near Porto di Massaciuccoli, 13/05/2012, GBX=1608783,

GBY=4854567; Rel. 16, Chiaro Grande near Bigongiari, 04/05/2016, GBX=1608708, GBY=4854211; Rel. 17, Chiaro Grande near Bigongiari, 04/05/2016, GBX=1608714, GBY=4854217; Rel. 18, Near Fosso Burlamacca, 04/05/2016, GBX=1607780, GBY=4855730.
Tab. 8: Rel. 1, Nature trail near Porto, 01/07/2015, GBX=1608956, GBY=4854636; Rel. 2, Nature trail near Porto, 01/07/2015, GBX=1608935, GBY=4854658; Rel. 3, Nature trail near Porto, 01/07/2015, GBX=1608811, GBY=4854714; Rel. 4, Channel near Fosso Burlamacca, 01/07/2015, GBX=1606756, GBY=4856324, GBX=1607098, GBY=4856253; Rel. 5, Fosso Burlamacca, 01/07/2015, GBX=1607098, GBY=4856253; Rel. 6, Near Cava Incrociata, 29/07/2015, GBX=1603833, GBY=4857602; Rel. 7, Fosso Malfante, 10/09/2015, GBX=1606135, GBY=4855970; Rel. 8, Fosso Burlamacca, 01/07/2015; Rel. 9, Fosso Pantaneto, 10/07/2015, GBX=1606223, GBY=4857292; Rel. 10, Fosso Le Quindici, 29/07/2015, GBX=1604252, GBY=4855262; Rel. 11, Fossa Nuova, near Bonifica degli Studiati, 04/05/2016, GBX=1610506, GBY=4852372; Rel. 12, Fossa Nuova, near Bonifica degli Studiati, 04/05/2016, GBX=1610512, GBY=4852347; Rel. 13, Idrovora di Vecchiano, 04/05/2016, GBX=1608174, GBY=4852540.
Tab. 9: Rel. 1, Fosso Pantaneto, 10/07/2015. GBX=1606481, GBY=4857399; Rel. 2, Idrovora di Vecchiano, 04/05/2016, GBX=1608190, GBY=4852550.
Tab. 10: Rel. 1, Fosso Malfante, 29/07/2015, GBX=1606817, GBY=4855820; Rel. 2, Fosso Le Quindici, 29/07/2015, GBX=1604441, GBY=4854867; Rel. 3, Fosso Malfante, 29/07/2015, GBX=1605941, GBY=4856250.
Tab. 11: Rel. 1, Fosso Le Quindici, 29/07/2015, GBX=1604070, GBY=4855565; Rel. 2, Fosso Pantaneto, 10/07/2015, GBX=1606473, GBY=4857409; Rel. 3, Pantaneto, 10/09/2015, GBX=1607301, GBY=4857855.
Tab. 12: Rel. 1, Chiaro Grande near Padule del Nelli, 01/07/2015, GBX=1608529, GBY=4855054; Rel. 2, Pressi Fosso Burlamacca, 04/05/2016, GBX=1607774, GBY=4855730.

[Localities reference system: GAUSS-BOAGA (ROMA 1940, Zone 1]