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An application of the Cocktail method for the classification of the hydrophytic vegetation at Lake Trasimeno (Central Italy).

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Abstract:
Aim of this paper is to apply the Cocktail method, using formal definitions, to a vegetation data set from Lake Trasimeno in Central Italy. Lake Trasimeno is the fourth largest lake of Italy and a highly valuable ecosystem. It is included in the Natura 2000 Network as a Site of Community Importance and a Special Protection Area. In this framework, by applying a new methodology for the Italian scene, the authors intend also to summarize and increase the knowledge about hydrophytic vegetation of this important conservation site. For the vegetation classification, 171 phytosociologic relevés, 147 of which unpublished, were analyzed and assigned to 26 communities from the classes *Charetea*, *Lemnetea* and *Potametea.* Results suggest a great phytocoenotic diversity. Nevertheless this diversity should not be considered as an index of good water quality. It is most likely a result of the trophic conditions of the lake, which are strongly affected by the intense human activities in the surrounding areas, inducing a continuous alteration of the habitats. In fact, all the investigated communities are typical for mesotrophic or eutrophic waters. Some associations are newly reported for Lake Trasimeno, in particular those belonging to the *Charetea* class.

Key words: *Charetea*, Cocktail method, formal definition, hydrophytic vegetation, Italy, Lake Trasimeno, *Lemnetea*, *Potametea*, Umbria.

Riassunto:
L'obiettivo di questo lavoro è quello di applicare il metodo Cocktail, usando definizioni formali, ad un set di dati vegetazionali provenienti dal Lago Trasimeno in Italia centrale. Il Lago Trasimeno è il quarto lago italiano e rappresenta un ecosistema di elevato valore naturalistico. Esso è inserito nella Rete Natura 2000 come Sito di Interesse Comunitario e Zona di Protezione Speciale. Attraverso l'applicazione di una metodologia mai finora applicata nello scenario italiano, gli autori intendono anche sintetizzare ed accrescere le conoscenze relative alla vegetazione idrofitica di un sito rilevante dal punto di vista conservazionistico. Per la classificazione della vegetazione sono stati analizzati 171 rilievi fitosociologici, di cui 147 inediti, ed attribuiti a 26 distinte comunità incluse nelle classi *Charetea*, *Lemnetea* e *Potametea.* I risultati ottenuti suggeriscono una grande diversità fitocenotica. Tuttavia, questa diversità non dovrebbe essere interpretata come un indice di buona qualità delle acque; essa è piuttosto il risultato dello stato trofico del lago, profondamente influenzato dalle attività umane nei territori attigui, che inducono una continua alterazione degli habitat. Infatti, tutte le comunità indagate sono tipiche di acque mesotrofiche ed eutrofiche. Nel presente lavoro sono anche riportate associazioni mai segnalate prima per il Lago Trasimeno, in particolare alcune comunità della classe *Charetea.*

Parole chiave: *Charetea*, definizione formale, Italia, Lago Trasimeno, *Lemnetea*, metodo Cocktail, *Potametea*, Umbria, vegetazione idrofitica.

Introduction

The Annex I of the 92/43/EEC Directive includes several habitats represented by aquatic plant communities. For the Italian territory, Biondi *et al.* (2009) report aquatic macrophytic habitats in all the biogeographic regions and almost all the Italian administrative regions. At the same time, many macrophyte species are used for the bio-indication of lake and river trophic status (Ceschin *et al*., 2010; Kohler & Schneider, 2003; Schneider, 2007) and are given great relevance in the European Water Framework Directive (2000/60/EC). For these reasons, the interest about aquatic vegetation rised remarkably during the last decade, progressively taking into account even neglected types such as those belonging to *Charetea* class.

The Lake Trasimeno represents an important natural and economic resource for central Italy, providing a number of ecosystem services ranging from food (mainly fish) to water and tourism and acting as a carbon sink thanks to the large reed beds along its shore. Great attention is therefore directed to its ecological status and spatial/temporal dynamics. Up to now many scientific studies were done about flora, vegetation and ecology of this large shallow lake (e.g Granetti, 1965; Di Giovanni, 1960, 1974; Moretti, 1982; Pedrotti & Orsomando, 1982; Liberman Cruz, 1986; Orsomando & Pedrotti, 1985, 1986; Buchwald, 1994; Ludovisi & Gaino, 2010; Venanzoni & Gigante, 2000; Venanzoni *et al*. 2006; Gigante *et al*., 2011; Reale *et al*., 2011). However, none of these studies offered an exhaustive, representative overview on the aquatic vegetation.

One of the purposes of this study is to summarize and implement the knowledge about hydrophytic vegetation at the Lake Trasimeno, starting from published and unpublished data in the prospect of a larger review of the aquatic communities from central Italy.

The typically simple structure and poor floristic composition of the aquatic vegetation types offered a good chance for one of the first experimental applications of the Cocktail Method (Bruelheide, 2000) in Southern Europe.

Study area

Lake Trasimeno is located in central Italy, in the North-Western part of Umbria Region at an average altitude of 257 m. It is included in a Natural Regional Park and two Natura 2000 sites (SCI IT5210018 and SPA IT5210070).

Based on climatic data recorded in Monte del Lago climatic station (259 m; data from a period of 30 years), according to the bioclimatic index proposed by Rivas-Martínez *et al.* (1999), the study area belongs to the Mediterranean pluviseasonal-oceanic bioclimate, upper mesomediterrranean low subhumid belt (Gigante & Venanzoni, 2007).

From a lithological perspective, the area is characterized by Oligo-Miocenic marls in the eastern part, and by Plio-Quaternary sands and clays in the west sectors (Deffenu & Dragoni, 1978).

Lake Trasimeno is the fourth biggest lake in Italy with a surface of about 121.5 km^2 and a perimeter of about 53 km (Burzigotti *et al*., 2003). It is a large shallow lake with an average depth of 4.3 m and significant seasonal and yearly fluctuations of the water table. The total catchment area is 384 km^2 and the water retention time is over 24 years, with a consequent high evaporation rate (155x106 m^2/year) (De Bartolomeo *et al.* 2004). The water level is subject to great variation due to its total dependence on rains, lacking relevant tributaries. It was artificially increased at the end of the 1950s (Gambini 1995), having as a consequence a large submersion of the flat shores and a progressive remarkable retreat of the reed beds (Gigante *et al.* 2011; Reale *et al*., 2011). The lacustrine ecosystem is marred by several environmental problems, mostly deriving from the heavy anthropic impact, especially related to the intensive land use in the basin mainly represented by agriculture and pig farms (Mennella & Vizzari, 2008).

The water reaction is alkaline with pH values ranging between 8 and 10. The eutrophication level of the lake is close to the limit between mesotrophic and eutrophic and strictly depends on the annual rain rate (Ludovisi & Gaino, 2010). All these characteristics, combined with the increasing eutrophication level due to human activities, make Lake Trasimeno an extremely vulnerable ecosystem.

Materials and method

The analyzed data set includes 171 phytosociological relevés of the hydrophytic vegetation, carried out at Lake Trasimeno by applying the Braun-Blanquet method (1979). The greater part of the relevés (147) are unpublished. In order to obtain a complete framework including all the hydrophytic vegetation types ever observed at the lake, we added to the set also data from existing literature and included 24 published relevés (Liberman Cruz, 1986; Buchwald, 1994; Venanzoni & Gigante, 2000). The relevés reported by Granetti (1965) could not be used since the Author applied the cover scale proposed by Pignatti & Mengarda (1962); for this reason they cannot be compared with the others.

The data were classified using a computer expert system that included formal definitions created by the Cocktail method modified according to Kočí *et al.* (2003). The computer expert system was created specifically for the purposes of this study, using a data set of 3,056 relevés including data about different vegetation types from several localities in central Italy. This data set was stored in "anArchive" (www.anarchive.it), a database managed by the University of Perugia and including data from several local and national projects (Venanzoni *et al.*, 2011).

The Cocktail method is designed to simulate the Braun-Blanquet approach. It is largely based on expert knowledge, reflecting both the field experience of the authors and the reports from literature. It aims at creating formalized definitions of vegetation units by providing unequivocal criteria (Bruelheide, 2000; Bruelheide & Chytrý, 2000). The formal definitions are created using logical operators (AND, OR and AND NOT), combining species cover values and species groups. Sociological species groups and diagnostic species of the associations are determined using a fidelity measure (*phi* coefficient of association: Sokal & Rohlf, 1995; Chytrý *et al.*, 2002). A large diversified data set is necessary to obtain definitions with a large validity and to calculate species fidelities. For this reason, in this study the formal definitions were created using a larger data set including different vegetation types.

All the analyses were performed using the program Juice 7.0 (Tichý, 2002).

The specimens collected in the field were determined using Tutin *et al.* (1964-1980, 1993) and Pignatti (1982). The species *Lemna minuta* Kunth was identified according to Landolt (1980). All the species of the family *Characeae* were determined according to Bazzichelli & Abdelahad (2009). Species nomenclature was updated according to Conti *et al.* (2005), Holub (1997) and the International Code of Botanical Nomenclature (McNeill *et al.*, 2007). The

nomenclature of *syntaxa* is in accordance with the International Code of Phytosociological Nomenclature (Weber *et al*., 2000) and largely matches with Izco (2002) and Chytrý (2011).

Results

The processed relevés were assigned to 26 communities, split up among *Charetea, Lemnetea* and *Potametea* classes.

All the relevés fitted to the formal definitions of the expert system created by using the data set from central Italy. No relevé remained unclassified.

In the following, the 26 identified vegetation types are shortly described and characterized. For all the vegetation units the following information are reported: formal definition, diagnostic species, constant species based on the complete data set of 3,056 relevés and a short description including references from literature. The *phi* value and the relative frequency are reported respectively for each diagnostic species and each constant species.

CHARETEA Fukarek ex Krausch 1964

CHARETUM GLOBULARIS Zutshi ex Šumberová, Hrivnák, Rydlo & Ot'ahel'ova in Chytrý 2011 (Tab. 1)
(Syn.: *Charetum fragilis* Corillion 1957, *Charetum fragilis* Fijałkowski 1960, *Charetum globularis* Zutshi 1975)
Formal definition*:* *Chara globularis* cover> 25% NOT *Potamogeton perfoliatus* cover > 50% NOT *Typha latifolia* cover > 50%
Diagnostic species: *Chara globularis* (*phi* value 0.706)
Constant species: *Chara globularis* (100%), *Stuckenia pectinata* (67%)

This association is dominated by *Chara globularis*, a stonewort species that occurs in mesotrophic to eutrophic shallow water bodies rich in calcium and phosphorus and often in turbid wind-exposed lakes (Pełechaty *et al*., 2004; Bazzichelli & Abdelahad, 2009).

Species of the genus *Chara,* indicated as *Chara sp.,* were reported for Lake Trasimeno by several Authors, generally emphasizing their restricted distribution (Granetti, 1965; Di Giovanni, 1960; Orsomando & Catorci, 1991). Communities dominated by *Chara globularis* have been noticed for the first time in the year 2007 and indicated in an environmental report (Cecchetti & Lazzerini, 2007). At present this vegetation type occupies a large surface in the S-eastern part of the lake, creating dense meadows in interpenetration with *Potametum pectinati* and in contact with *Najadetum marinae*. Probably the increased distribution of this vegetation type is related to the increase in organic deposits that is characterizing the SE sector of the lake (Gigante *et al.*, 2011).

CHARETUM INTERMEDIAE (Corillion 1957) Fijałkowski 1960 (Tab. 1)
Formal definition: *Chara intermedia* cover > 25% NOT *Stuckenia pectinata* cover > 50%
Diagnostic species: *Chara intermedia* (*phi* value 0.887)
Constant species: *Chara intermedia* (100%), *Stuckenia pectinata* (100%)

This community occurs in shallow mesotrophic to eutrophic basins and can be interpreted as an indication of nutrient-rich waters and humic acids. It is often accompanied by other stonewort species such as *Chara globularis, C. delicatula* and *Nitellopsis obtusa,* (Gąbka *et al*., 2007). The association *Charetum intermediae* is here reported for the first time at Lake Trasimeno. The species *C. intermedia* might have been confused in the past with the very similar *C. hispida,* reported by Lazzerini & Cecchetti (2007) who suggested the presence of the association *Charetum hispidae*. The only relevé here reported was made in the S-eastern part of the lake, in contact with *Charetum globularis* and *Potametum pectinati*, in an area characterized by large deposits of organic sludge.

CHARETUM DELICATULAE Doll 1989 (Tab. 1)
Formal definition: *Chara delicatula* cover > 25% NOT *Persicaria amphibia* cover > 50%
Diagnostic species: *Chara delicatula* (*phi* value 0.504), *Nitellopsis obtusa* (phi value 0.473), *Chara tomentosa* (*phi* value 0.328)
Constant species: *Chara delicatula* (100%)

Chara delicatula usually forms monospecific or very species-poor stands and requires mesotrophic to eutrophic waters. Sometimes the species grows among helophytes and emergent vegetation (Pełechaty *et al.*, 2004). At Lake Trasimeno this community was found along the shores, in an artificial pond at an average depth of 50 cm, in contact with helophytic vegetation such as *Phragmitetum australis*, *Eleocharitetum palustris* and *Persicaria amphibia* community, showing an affinity with temporarily flooded areas. This association is here reported for the first time at Lake Trasimeno.

NITELLETUM HYALINAE Losev in Golub, Losev &

Tab. 1 - *Charetea* Fukarek ex Krausch 1964

	1	2	3	4	5	6	7	8	9	10	
Date (year)	2009	2009	2009	2009	2009	2011	2011	2011	2009	2010	P
Total cover (%)	100	100	100	100	40	100	100	100	100	60	r
Area (m²)	100	100	100	100	100	4	4	4	100	1	e
Relevé number (Anarchive)	1179	1181	1180	1184	1197	4607	4610	4612	1177	1669	s
Charact. sp. of *Charetum globularis*											
Chara globularis de Candolle	5	4	5	5	3	.	.	.	.	.	5
Charact. sp. of *Charetum delicatulae*											
Chara delicatula C. Agardh	.	.	.	.	.	5	5	5	.	2b	3
Charact. sp. of *Charetum intermediae*											
Chara intermedia A. Braun	.	.	.	.	.	.	.	.	5	.	1
Charact. sp. of *Nitelletum hyalinae*											
Nitella hyalina (de Candolle) C. Agard	.	.	.	.	.	.	.	.	.	3	1
Other species											
Stuckenia pectinata (L.) Börner	3	5	2b	2a	.	.	.	.	2b	.	5
Persicaria amphibia (L.) Delarbre	.	.	.	.	.	1	+	+	.	.	3
Ceratophyllum demersum L.	.	.	.	2b	2a	.	.	.	.	.	2
Vallisneria spiralis L.	.	.	.	2a	.	.	.	.	.	1	2
Myriophyllum spicatum L.	.	.	.	.	2a	.	.	.	.	.	1
Potamogeton perfoliatus L.	.	.	.	1	.	.	.	.	.	.	1
Potamogeton pusillus L.	.	.	.	.	.	.	.	.	.	1	1
Najas marina L. ssp. marina	.	.	.	.	2a	.	.	.	.	.	1
Najas minor All.	.	.	.	.	.	.	.	.	.	+	1
Ranunculus tricophyllus Chaix	.	.	.	.	.	2a	.	.	.		1
Lycopus europaeus L.	.	.	.	.	.	+	.	.	.	.	1
Alisma lanceolatum With.	.	.	.	.	.	.	r	.	.	.	1

Mirkin 1991 (Tab. 1)
Formal definition: *Nitella hyalina* cover > 25% NOT *Potamogeton perfoliatus* cover > 25%
Diagnostic species: *Nitella hyalina* (*phi* value 0.831), *Najas minor* (*phi* value 0.389), *Chara delicatula* (*phi* value 0.359)
Constant species: *Nitella hyalina* (100%), *Najas minor* (100%), *Najas marina* (67%), *Chara delicatula* (67%)

The phytocoenoses dominated by *Nitella hyalina* are typical of mesotrophic, shallow and still water bodies rich in calcium (Corillion, 1946, 1975). This community shows a pioneer character occurring in Lake Trasimeno in a few monospecific or species-poor stands near the shores, at a depth lower than 50 cm, characterized by high transparency and absence of organic sediments. *Nitelletum hyalinae* was observed at Lake Trasimeno by Cecchetti & Lazzerini (2007).

LEMNETEA MINORIS Bolós & Masclans 1955

LEMNETUM TRISULCAE den Hartog 1963 (Tab. 2)
Formal definition: *Lemna trisulca* cover > 25% NOT *Callitriche stagnalis* cover > 50% NOT *Salvinia natans* cover > 25%.
Diagnostic species: *Lemna trisulca* (*phi* value 0.462)
Constant species: *Lemna trisulca* (100%)

This species-poor association dominated by *Lemna trisulca* usually occurs in mesotrophic to eutrophic water bodies, but with high transparency. *Lemna trisulca* is a meso-pleustophytic species floating below the water surface and sometimes it can be covered by acro-pleustophytic or natant species. Only one relevé deriving from the literature was assigned to this association. It was previously referred by Liberman Cruz (1986) to *Lemno-Spirodeletum polyrhizae*, probably due to the presences of *Lemna minor* and *Spyrodela polyrhiza.* However this attribution is not justified by the formal definition obtained with the Cocktail method. *Lemnetum trisulcae* is not so common in central Italy and its presence was previously reported in Umbria Region only for the Lake Piediluco (Venanzoni & Gigante, 2000).

This association was no longer found at Lake Trasimeno during the last decade, despite the species *Lemna trisulca* is still present.

LEMNETUM MINORIS Soó 1927 (Tab. 2)
Formal definition: *Lemna minor* cover > 50%
Diagnostic species: *Lemna minor* (*phi* value 0.358)
Constant species: *Lemna minor* (100%)

Lemna minor is a cosmopolitan species with a great ecological amplitude as concerns nutrients content and water temperature. Sometimes the dominant species is accompanied by others pleustonic species such as *Lemna gibba, Spirodela polyrhiza* and *Azolla filiculoides.* More frequently, this association is monospecific and occurs in fresh and calm waters (Pirone *et al*., 1997; Šumberová, 2011a). These

Tab. 2 - *Lemno-Spirodeletum polyrhizae* Koch 1954, *Lemnetum gibbae* Miyawaki & J. Tüxen 1960, *Lemnetum minoris* Soó 1927, *Lemnetum trisulcae* den Hartog 1963, *Lemnetum minuto-gibbae Liberman* Cruz, Pedrotti & Venanzoni 1988

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Date (year)	2010	2009	1986	1986	1986	1986	1986	2003	2010	2003	2009	2010	2010	2003	2003	1986	2010	2010	2010	2010	2010	2010	2010	P
Total cover (%)	100	100	100	100	100	80	95	90	100	60	98	100	100	100	100	80	100	100	100	100	100	100	100	r
Area (m²)	4	4	1	1	1	1	1	1	2	1	9	3	1	15	1,5	1	4	4	4	4	4	3	3	e
Relevé number (Anarchive)	2705	1192	2896	2897	2895	2894	2893	1774	1695	1848	1195	2701	1747	1846	1847	2892	1349	2704	2695	1391	2697	2702	2699	s
Charact. sp. of *Lemno-Spirodeletum polyrhizae*																								
Spirodela polyrhiza (L.) Schleid.	5	5	5	4	5	4	5	5	1	2b	1	1	1	.	.	+	.	1	.	.	+	.	.	16
Charact. sp. of *Lemnetum gibbae*																								
Lemna gibba L.	+	.	.	.	.	.	.	.	5	3	5	4	5	.	.	.	+	+	1	1	1	2b	1	13
Charact. sp. of *Lemnetum minoris*																								
Lemna minor L.	.	.	+	2a	1	+	+	.	.	1	.	.	.	5	5	+	.	.	.	.	.	.	.	9
Charact. sp. of *Lemnetum trisulcae*																								
Lemna trisulca L.	1	.	.	.	.	+	+	.	2a	.	.	.	.	.	.	4	.	.	.	.	.	.	.	5
Charact. sp. of *Lemnetum minuto-gibbae*																								
Lemna minuta Kunth	.	2b	.	.	.	.	.	.	.	.	.	2a	2a	.	.	.	5	4	5	5	5	4	5	10
Charact. sp. of the upper units																								
Azolla filiculoides Lam.	.	.	+	1	+	1	+	+	.	.	.	.	2	.	.	+	1	2a	+	.	+	+	.	13
Hydrocharis morsus-ranae L.	.	.	+	.	.	.	.	3	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	5
Utricularia australis R. Br.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Other species																								
Phragmites australis (Cav.) Steud.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	+	.	.	.	1	3
Myriophyllum spicatum L.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	2
Agrostis stolonifera L.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	+	2
Bolboschoenus maritimus (L.) Palla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	2
Vallisneria spiralis L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	1
Paspalum distichum L. ssp. distichum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Alisma plantago-aquatica l.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Samolus valerandi L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1
Ranunculus sceleratus L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1
Sparganium erectum L. ssp. erectum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1

conditions are frequent at Lake Trasimeno inside the wet docks, along canals and in the clearings of the reed beds.

In the past this community was reported by several Authors for Lake Trasimeno (Granetti, 1965; Orsomando & Catorci, 1991; Orsomando, 1995; Venanzoni *et al.*, 2006). It is still well represented along the shores of the lake. Its maximum growth is in June and July, giving way in August and September to other communities, more resistant to drought, dominated by *Lemna gibba* and *Azolla filiculoides.*

LEMNO-SPIRODELETUM POLYRHIZAE Koch 1954 (Tab. 2)
Formal definition: *Spirodela polyrhiza* cover > 25% NOT *Salvinia natans* cover > 25%
Diagnostic species: *Spirodela polyrhiza* (*phi* value 0.467)
Constant species: *Spirodela polyrhiza* (100%), *Azolla filiculoides* (60%)

This association is described in literature as a community of eutrophic and hypertrophic waters where the dominant species *Spirodela polyrhiza* is frequently accompanied by *Lemna minor* (Rivas-Martínez, 1982; Šumberová, 2011a). At Lake Trasimeno *Lemnetum minoris* is commonly characterized by the presence of *Lemna minor* and *Azolla filiculoides* and sometimes by *Lemna minuta*, an exotic species native to South America and rapidly expanding in Europe, recently reported for the first time in Umbria Region and Lake Trasimeno by Gigante *et al.* (2010). In the past, *Lemno-Spirodeletum* was many times observed at Lake Trasimeno by several Authors (Liberman Cruz, 1986; Pedrotti & Orsomando, 1982; Orsomando & Catorci, 1991; Orsomando, 1995; Venanzoni & Gigante, 2000; Venanzoni *et al.*, 2006), but now it appears in decline due to the disappearance of flooded niches behind and into the reeds bed.

LEMNETUM GIBBAE Miyawaki & J. Tüxen 1960 (Tab. 2)
Formal definition: *Lemna gibba* cover > 25% NOT *Azolla filiculoides* cover > 50%
Diagnostic species: *Lemna gibba* (*phi* value 0.515)
Constant species: *Lemna gibba* (100%), *Spirodela polyrhiza* (56%)

This vegetation type occurs in eutrophic to hypertrophic water bodies in broad light. It is largely tolerant to high concentrations of nitrogen, phosphorus, calcium and chlorides (Scoppola, 1982; Šumberová, 2011a). During the past the species *Lemna gibba* was considered not common at Lake Trasimeno by several Authors (Liberman Cruz, 1986; Granetti, 1965; Orsomando & Catorci, 1991, Orsomando, 1995). Now the association *Lemnetum gibbae* is spreading around, probably due to the eutrophication level increase. This vegetation type is particularly developed in August and September, when eutrophication reaches its highest level. In this period *Lemna gibba* shows its evident gibbosity, a characteristic trait which makes the identification easier both for the species and the association. During spring and the first part of summer the gibbosity sometimes is absent and the species can be easily confused with *Lemna minor* (Landolt, 1980; Štěpánková *et al.*, 2010). For this reason, the actual extent of the association is probably underestimated.

LEMNETUM MINUTO-GIBBAE Liberman Cruz, Pedrotti & Venanzoni 1988 (Tab. 2)
Formal definition: *Lemna minuta* cover > 50%
Diagnostic species: *Lemna minuta* (*phi* value 0.830), *Lemna gibba* (*phi* value 0.511), *Azolla filiculoides* (*phi* value 32.3)
Constant species: *Lemna minuta* (100%), *Lemna gibba* (100), *Azolla filiculoides* (71%)

It is a floating plant community characterized by the dominance of *Lemna minuta*. This association was described for Lake Titicaca and other lakes in Bolivia as a vegetation type characterized by *L. minuta, L. gibba, L. valdiviana* and *Azolla filiculoides*, growing in still, nutrient/salt-rich water bodies (Liberman Cruz *et al.*, 1988; Molina *et al*., 2007). Communities dominated by *Lemna minuta* occur at Lake Trasimeno in several stands with a floristic composition very similar to that observed in the lakes of Bolivia, except for *L. valdiviana.* In the study area *L. minuta* is showing a strong competitiveness against *L. minor*, occupying the same niches and growing more rapidly.

SALVINIO NATANTIS-SPIRODELETUM POLYRHIZAE Slavnić 1956 (Tab. 3)
Formal definition: *Salvinia natans* cover > 25%
Diagnostic species: *Salvinia natans* (*phi* value 0.624), *Hydrocharis morsus-ranae* (*phi* value 0.394)
Constant species: *Salvinia natans* (100%), *Hydrocharis morsus-ranae* (82%), *Spirodela polyrhiza* (64%), *Azolla filiculoides* (64%), *Lemna trisulca* (55%)

This community is characterized by the dominance of the water fern *Salvinia natans* accompanied by other floating species such as *Spirodela polyrhiza*, *Azolla filiculoides* and *Lemna trisulca. Salvinia natans* is a largely tolerant species and occurs in mesotrophic to eutrophic water bodies (Scoppola, 1982). This association was indicated as one of the most common

Tab. 3 - *Ceratophyllo-Azolletum filiculoidis* Nedelcu 1967, *Salvinio natantis-Spirodeletum polyrhizae* Slavnić 1956, *Riccietum fluitantis* Slavnić 1956

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Date (year)	1986	2010	2010	2003	1986	1986	1986	1986	1986	1986	1986	1986	1986	1986	1986	1986	2003	1986	P
Total cover (%)	100	80	100	65	100	100	100	95	95	85	100	80	100	95	95	91	80	85	r
Area (m²)	1	1	4	4	1	1	1	1	1	1	1	1	1	1	1	1	18	1	e
Relevé number (Anarchive)	2900	1299	2703	1850	2898	2899	2890	2889	2888	2887	2885	2884	2882	2881	2880	2878	1849	2877	s
Charact. sp. of *Ceratophyllo-Azolletum filiculoidis*																			
Azolla filiculoides Lam.	5	4	5	3	5	5	.	+	+	+	.	+	+	2a	+	.	.	.	13
Ceratophyllum demersum L.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2
Charact. sp. of *Salvinio natantis-Spirodeletum polyrhizae*																			
Salvinia natans (L.) All	.	.	.	.	+	.	5	5	5	4	5	3	5	4	4	3	4	.	12
Charact. sp. of *Lemno minoris-Riccetum fluitantis*																			
Riccia fluitans L. emend. Lorb.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	4	5
Charact. sp. of the upper units																			
Lemna minor L.	+	.	.	.	+	+	+	+	+	+	+	+	+	+	.	.	2a	.	12
Spirodela polyrhiza (L.) Schleid.	1	1	.	2b	+	+	.	.	.	.	+	+	+	+	1	+	3	.	12
Hydrocharis morsus-ranae L.	.	.	.	.	.	.	.	+	+	+	.	.	+	+	+	1	.	.	7
Lemna trisulca L.	.	.	.	.	.	.	+	+	.	1	.	.	+	+	.	3	.	+	7
Utricularia australis R. Br.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	2a	.	.	3
Lemna minuta Kunth	.	2a	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Other species																			
Phragmites australis (Cav.) Steud.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1

at the Lake Trasimeno, in particular in the south-eastern sector (Pedrotti & Orsomando, 1982; Liberman Cruz, 1986; Orsomando & Catorci, 1991; Orsomando, 1995). These Authors report the association along all the lake shores in a belt between reed beds and fields. Currently the *Salvinio-Spirodeletum* seems to be in decline, probably due to habitat reduction.

CERATOPHYLLO-AZOLLETUM FILICULOIDIS Nedelcu 1967 (Tab. 3)

Formal definition: *Azolla filiculoides* cover > 25%

Diagnostic species: *Azolla filiculoides* (*phi* value 0.456)

Constant species: *Azolla filiculoides* (100%), *Spirodela polyrhiza* (56%)

This vegetation type, typical of eutrophic waters, is dominated by *Azolla filiculoides,* an exotic species native to America (Ninot *et al.*, 2000). This natant fern can form dense monospecific stands, or can be accompanied by few lemnid species such as *Spirodela polyrhiza* and *Lemna minor.* At Lake Trasimeno this community was often interpenetrated with *Lemno-Spirodeletum polyrhizae* (Liberman Cruz, 1986; Orsomando & Catorci, 1991). It occurs in canals, ponds and clearings of the reed bed. *Azolla filiculoides* is rather resistant to drought and in late summer can form dense layers covering the top of other pleustonic communities. Three relevés (Tab. 3 - Rell. 1, 5, 6), formerly referred to the association *Lemno-Spirodeletum polyrhizae* (Liberman Cruz, 1986), are here assigned to *Ceratophyllo-Azolletum filiculoidis*, considering the dominance of *Azolla filiculoides.*

RICCIETUM FLUITANTIS Slavnić 1956 (Tab. 3)

Formal definition: *Riccia fluitans* cover > 50%

Diagnostic species: *Riccia fluitans* (*phi* value 0.786), *Ricciocarpos natans* (*phi* value 0.706), *Lemna trisulca* (*phi* value 0.462)

Constant species: *Riccia fluitans* (100%), *Lemna trisulca* (100%)

This vegetation type is dominated by a floating liverwort, *Riccia fluitans*, which occurs in oligo-mesotrophic lentic or slow-flowing waters with high transparency (Pedrotti & Taffetani, 1982; Scoppola 1982). It is often accompanied by other floating species such as *Lemna trisulca* and *Utricularia australis* (Šumberová, 2011a). In Umbria Region this community is rare and has been reported only for the Lakes Trasimeno (Liberman Cruz, 1986) and Ventina (Venanzoni & Gigante, 2000). *Lemno minoris-Riccietum fluitantis* is by now completely disappeared from Lake Trasimeno, probably due to increased eutrophication level and habitat reduction. Šumberová and Chytrý (Šumberová, 2011a), after a nomenclatural revision, propose the name *Lemno minoris-Riccietum fluitantis* for this association.

UTRICULARIETUM AUSTRALIS Müller & Görs 1960 (Tab. 4)

Formal definition: *Utricularia australis* cover > 25% NOT *Hydrocharis morsus-ranae* cover > 25%

Diagnostic species: *Utricularia australis* (*phi* value 0.651)

Constant species: *Utricularia australis* (100%)

This is a community dominated by *Utricularia*

Tab. 4 - *Utricularietum australis* Müller & Görs 1960*, Hydrocharitetum morsus-ranae* Langendonck 1935

	1	2	3	4	5	6	
Date (year)	1998	1986	2009	2009	2003	1991	P
Total cover (%)	80	60	95	95	80	90	r
Area (m²)	2	1	20	21	6	20	e
Relevé number (Anarchive)	1358	2891	1194	1193	1775	2068	s
Charact. sp. of *Utriculiaretum australis*							
Utricularia australis R. Br.	5	3	4	3	.	.	4
Charact. sp. of *Hydrocharitetum morsus-ranae*							
Hydrocharis morsus-ranae L.	.	.	5	5	4	4	4
Charact. sp. of the upper units							
Lemna gibba L.	.	.	2b	2b	.	.	2
Salvinia natans (L.) All	.	+	.	.	.	2m	2
Utricularia minor L.	+	1	.	.	.	.	2
Lemna trisulca L.	.	+	.	+	.	.	2
Lemna minor L.	+	+	.	.	.	.	2
Ceratophyllum demersum L.	+	.	.	.	.	2b	2
Spirodela polyrhiza (L.) Schleid.	.	.	.	+	2a	.	1
Azolla filiculoides Lam.	.	.	.	.	1	.	1
Other species							
Paspalum distichum L. ssp. distichum	.	.	1	1	.	.	2
Myriophyllum spicatum L.	.	.	.	.	.	2a	1
Najas marina L. ssp. marina	1	.	.	.	.	.	1
Potamogeton lucens L.	+	.	.	.	.	.	1
Alisma plantago-aquatica L.	.	.	1	.	.	.	1

australis, which occurs in still and mesotrophic to eutrophic water bodies. Usually it is accompanied by pleustonic species such as *Lemna minor*, *Lemna trisulca* and *Riccia fluitans* (Brullo *et al*., 1994; Venanzoni & Gigante, 2000; Sburlino *et al*., 2004). This association was recognised at Lake Trasimeno only by Venanzoni & Gigante (2000) and Venanzoni et al. (2006). Several Authors reported about the species *Utricularia vulgaris* at Lake Trasimeno (Granetti, 1965; Liberman Cruz, 1986; Orsomando & Catorci, 1991). However, recent revisitations of this species showed that it should be correctly referred to *U. australis*; as a consequence, the only relevé reported by Liberman Cruz (1986) as *Lemno-Utricularietum* Soó 1947 was assigned by the Cocktail method to *Utricularietum australis* (Tab. 4 – Rel. 2).

HYDROCHARITETUM MORSUS-RANAE Langendonck 1935 (Tab. 4)

Formal definition: *Hydrocharis morsus-ranae* cover > 50%

Diagnostic species: *Hydrocharis morsus-ranae* (*phi* value 0.623), *Utricularia australis* (*phi* value 0.322)

Constant species: *Hydrocharis morsus-ranae* (100%)

This vegetation type is characterized by the dominance of *Hydrocharis morsus-ranae* accompanied by other floating *taxa* such as *Utricularia australis*, *Spirodela polyrhiza* and species of the genus *Lemna*. It occurs in mesotrophic to eutrophic, shallow and still waters. This association is known in central Italy and Umbria Region only for Lake Trasimeno (Granetti, 1965; Orsomando & Catorci, 1991; Orsomando, 1993, 1995). According both to literature and direct observations, currently its presence is decreasing due to the habitat changes, as noticed for other communities.

POTAMETEA Klika in Klika & Novák 1941

CERATOPHYLLUM DEMERSUM community (Tab. 5)

Formal definition: *Ceratophyllum demersum* cover > 25% NOT *Najas marina* cover > 25% NOT *Najas minor* cover > 50% NOT *Potamogeton perfoliatus* cover >25% *Vallisneria spiralis* cover > 50%

Diagnostic species: *Ceratophyllum demersum* (*phi* value 0.309)

Constant species: *Ceratophyllum demersum* (100%), *Myriophyllum spicatum* (54%)

The coenoses dominated by *Ceratophyllum demersum* typically colonize eutrophic and hypertrophic shallow waters, characterized by turbidity. They can tolerate anoxic conditions in summer and a high range of chemical and physical parameters (Ceschin & Salerno, 2008). Usually the association *Ceratophylletum demersi* is included in the *Lemnetea* class, being dominated by a floating species accompanied by other natant species such as *Hydrocharis morsus-ranae*, *Lemna minor* and *Spirodela polyrhiza* (Mucina *et al.*, 1993; Tomaselli *et al.,* 2006; Dubravka *et al*., 2008; Šumberová, 2011a). However, in the present case *Ceratophyllum demersum* is deep-rooted and always accompanied by species of the *Potametea* class such as *Myriophyllum spicatum, Najas marina* and *Stuckenia pectinata.* For this reason, we decided to treat this vegetation type only as a community and to assign it to the *Potametea* class (*Ceratophyllion demersi* alliance) as reported by some Authors (e.g. Venanzoni & Gigante, 2000; Tzonev *et al*., 2009). Macrophytic coenoses dominated by *Ceratophyllum demersum* have been frequently reported in central Italy (Ceschin & Salerno, 2008, Pirone *et al*., 1997; Avena & Scoppola, 1987; Iberite *et al*., 1995; Lastrucci *et al*., 2005). At Lake Trasimeno this community was referred to with different names: *Potamo-Ceratophylletum demersi* (Granetti, 1965); *Potamogetono-Ceratophylletum demersi* (Pedrotti & Orsomando, 1977, 1982; Orsomando & Catorci, 1991; Orsomando, 1993)*; Ceratophylletum demersi* (Buchwald, 1994; Venanzoni & Gigante, 2000; Venanzoni *et al.*, 2006; Lazzerini & Cecchetti, 2007).

POTAMETUM PECTINATI Carstensen ex Hilbig

Tab. 5 - *Ceratophyllum demersum* community

	1	2	3	4	5	6	7	8	
Date (year)	1991	2003	2003	2003	2009	1998	1998	2003	P
Total cover (%)	70	90	100	80	100	80	85	100	r
Area (m²)	24	6	100	1	25	10	9	1	e
Relevé number (Anarchive)	2070	1770	1769	1771	1199	1373	1375	1768	s
Charact. sp. of *Ceratophylletum demersi*									
Ceratophyllum demersum L.	3	5	4	3	5	4	5	5	8
Charact. sp. of the upper units									
Stuckenia pectinata (L.) Börner	2m	+	.	2a	2a	1	+	2a	7
Myriophyllum spicatum L.	2a	.	1	2a	2a	.	.	+	5
Vallisneria spiralis L.	2m	.	2a	1	.	1	.	3	5
Najas marina L. ssp. marina	.	+	2a	2a	2a	.	.	+	5
Elodea canadensis Michx.	.	.	2b	1	.	2a	.	+	3
Potamogeton perfoliatus L.	1	1	.	.	.	+	.	.	3
Najas minor All.	.	.	3	2a	.	.	.	.	2
Potamogeton crispus L.	1	.	.	.	.	.	.	+	2
Potamogeton lucens L.	.	.	.	.	.	.	+	.	1
Potamogeton natans l.	1	.	.	.	.	.	.	.	1
Other species									
Hydrocharis morsus-ranae L.	2b	.	+	.	.	.	.	.	2
Spirodela polyrhiza (L.) Schleid.	.	.	+	.	.	.	.	.	1

1971 (Tab. 6)

Formal definition: *Stuckenia pectinata* cover > 25% NOT *Potamogeton perfoliatus* cover > 25% NOT *Vallisneria spiralis* cover > 50% NOT *Chara globularis* cover > 25% NOT *Chara hispida* 50% NOT *Chara intermedia* cover > 50% NOT *Najas minor* cover > 50% NOT *Najas marina* cover > 25% NOT *Schoenoplectus lacustris* cover > 50% NOT *Chara vulgaris* cover > 50% NOT *Potamogeton polygonifolius* cover > 25%

Diagnostic species: *Stuckenia pectinata* (*phi* value 0.267)

Constant species: *Stuckenia pectinata* (100%)

This association is usually monospecific or composed by few species. The dominant species is *Stuckenia pectinata,* a submerged macrophyte that occurs in eutrophic and hypertrophic water bodies, often characterized by a high turbidity, anoxic conditions and sometimes high salt concentration. This association is an indicator of bad water quality due to organic pollution (Baldoni & Biondi, 1993; Ceschin *et al.*, 2010; Avena *et al.*, 1980). It is common in Italy and abundant at Lake Trasimeno (Venanzoni & Gigante, 2000; Venanzoni *et al.*, 2006; Lazzerini & Cecchetti, 2007) where it showed in the last decade a strong increase. It seems to have replaced the association *Potamo pectinati-Myriophylletum spicati,* which in the past was frequently indicated in the same area (Di Giovanni, 1960) but is nowadays completely absent.

POTAMETUM PERFOLIATI Miljan 1933 (Tab. 7)

Formal definition: *Potamogeton perfoliatus* cover > 25% NOT *Vallisneria spiralis* cover > 50% NOT *Myriophyllum spicatum* cover > 25% *Najas marina* cover > 25% NOT *Chara hispida* cover > 50%

Diagnostic species: *Potamogeton perfoliatus* (*phi* value 0.391)

Constant species: *Potamogeton perfoliatus* (100%), *Stuckenia pectinata* (58%)

This association occurs in mesotrophic to eutrophic, still or slow-flowing waters. The dominant species P*otamogeton perfoliatus* is sometimes accompanied by *Stuckenia pectinata, Myriophyllum spicatum, Najas marina* and *Najas minor.* Relevés dominated by *Potamogeton perfoliatus* or *Stuckenia pectinata* were formerly assigned by several Authors to the association *Potametum pectinato-perfoliati* (Passarge 1964) Den Hartog et Segal 1964 (e.g. Venanzoni & Gigante, 2000; Iberite *et al.*, 1995; Cecchetti & Lazzerini, 2007). According to Šumberová (2011b) *Potametum pectinato-perfoliati* is a synonym of *Potametum perfoliati*; we agree with this point of view and in the present study we refer *Potamogeton perfoliatus* or *Stuckenia pectinata* dominated communities to different associations. During the last decade the density of *Potametum perfoliati* increased, probably due to the change in trophic conditions.

POTAMETUM DENSO-NODOSI O. Bolós 1957 (Tab. 8)

[Syn. *Potametum nodosi* (Soó 1960) Segal 1964]

Formal definition: *Potamogeton nodosus* cover > 25% NOT *Myriophyllum verticillatum* cover > 25%

Diagnostic species: *Potamogeton nodosus* (*phi* value 0.478)

Constant species: *Potamogeton nodosus* (100%), *Myriophyllum spicatum* (55%)

This association occurs in shallow, flowing and lentic waters characterized by high turbidity and organic matter on the bottom. It is dominated by *Potamogeton nodosus*, a species with natant and submerged leaves (Šumberová, 2011b; Ninot *et al.* 2000). This association is quite abundant in Lake Trasimeno in proximity of the shores, at an average depth lower than 1 m. In former investigations, this plant community might have been referred to *Potametum natantis* Hild 1959, reported by Granetti (1965) and no longer found in the area.

POTAMO PERFOLIATI-VALLISNERIETUM SPIRALIS Losev & Golub in Golub, Losev & Mirkin 1991 (Tab. 9)

Formal definition: *Vallisneria spiralis* cover > 50% OR (*Vallisneria spiralis* cover > 25% NOT *Ceratophyllum demersum* cover > 50% NOT *Potamogeton nodosus* cover > 50% NOT *Potamogeton perfoliatus* cover

Tab. 6 - *Potametum pectinati* Carstensen ex Hilbig 1971

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Date (year)	2009	2009	2009	2010	2009	2009	2003	2003	2003	2003	2009	2009	2009	2003	2003	2003	P
Total cover (%)	90	100	95	100	90	85	85	95	90	90	70	80	70	80	90	80	r
Area (m²)	400	100	64	1	25	3	6	1	50	6	64	64	25	6	6	1	e
Relevé number (Anarchive)	1188	1182	1178	1667	1096	1095	1830	1821	1829	1824	1183	1198	1088	1823	1822	1820	s
Charact. sp. of *Potametum pectinati*																	
Stuckenia pectinata (L.) Börner	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	16
Charact. sp. of the upper units																	
Ceratophyllum demersum L.	.	.	1	1	.	1	.	.	.	.	1	2a	.	.	.	2a	6
Myriophyllum spicatum L.	2a	.	.	1	.	.	.	+	.	.	.	2a	.	.	.	3	5
Vallisneria spiralis L.	.	.	.	.	.	.	.	2a	.	2a	.	2b	.	+	.	2a	5
Potamogeton pusillus L.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	1	.	4
Najas marina L. ssp. marina	.	.	.	.	.	.	.	.	.	+	.	2a	.	+	+	.	4
Potamogeton perfoliatus L.	2b	.	.	.	.	.	.	.	.	+	.	.	.	.	1	.	3
Potamogeton lucens L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	2
Persicaria amphibia (L.) Delarbre	.	.	.	.	2a	.	.	.	.	.	.	.	.	.	.	.	1
Potamogeton crispus L.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1
Other species																	
Elodea canadensis Michx.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	+	2
Chara globularis Thuillier	.	2a	.	.	.	.	.	.	.	.	2a	.	.	.	.	.	2
Chara intermedia A. Braun	.	.	2a	.	.	.	.	.	.	.	.	1	.	.	.	.	2
Lemna gibba L.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1
Hydrocharis morsus-ranae L.	.	.	.	.	2a	.	.	.	.	.	.	.	.	.	.	.	1

Tab. 7 - *Potametum perfoliati* Miljan 1933

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Date (year)	2003	2003	2003	2003	2003	2009	2003	1998	2003	2003	2003	2003	2009	2009	2003	2003	2009	2003	P
Total cover (%)	85	70	90	85	85	95	65	85	75	75	85	75	65	60	95	40	40	70	r
Area (m²)	1	50	1	4	6	100	75	12	1	1	1	1	15	300	120	6	40	100	e
Relevé number (Anarchive)	1836	1834	1837	1841	1838	1212	1835	1372	1842	1839	1843	1833	1187	1186	1827	1832	1211	1831	s
Charact. sp. of *Potametum perfoliati*																			
Potamogeton perfoliatus L.	5	4	5	5	5	5	4	4	4	4	4	4	4	4	3	3	3	3	18
Charact. sp. of the upper units																			
Stuckenia pectinata (L.) Börner	1	1	.	.	.	.	3	2a	3	3	2b	1	3	2b	4	+	.	.	12
Najas marina L. ssp. marina	1	.	.	.	1	.	1	.	.	.	1	2a	.	.	+	.	.	1	7
Vallisneria spiralis L.	.	.	.	.	.	.	+	+	.	3	2a	.	.	.	.	+	.	3	6
Myriophyllum spicatum L.	.	.	.	.	.	.	.	+	.	1	.	.	2a	2a	+	.	.	1	6
Najas minor All.	+	1	.	.	1	.	.	.	.	.	+	2b	.	.	.	.	.	.	5
Potamogeton pusillus L.	.	2a	.	.	.	.	+	.	.	.	.	1	.	.	.	1	.	.	4
Ceratophyllum demersum L.	2a	.	.	.	.	.	.	2a	.	.	.	.	.	.	.	.	.	+	3
Potamogeton crispus L.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Potamogeton natans L.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
Other species																			
Elodea canadensis Michx.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1

> 25% NOT *Lemna minor* cover > 50% NOT *Myriophyllum spicatum* cover > 25%)

Diagnostic species: *Vallisneria* spiralis (*phi* value 0.472)

Constant species: *Vallisneria spiralis* (100%), *Myriophyllum spicatum* (72%)

This community is dominated by *Vallisneria spiralis,* a species with a wide ecological amplitude, which can occur in mesotrophic to eutrophic conditions. The dominant species is often accompanied by other macrophytes such as *Myriophyllum spicatum*, *Potamogeton perfoliatus*, *Stuckenia pectinata* and *Najas marina* (Hutorowicz 2006; Ninot *et al*,. 2000). At Lake Trasimeno this association, formerly reported by Venanzoni *et al.* (2006) as *Potamo-Vallisnerietum* Br.-Bl. 1931, occurs in shallow waters inside harbours, canals and near landing stages.

NAJADETUM MARINAE Fukarek 1961 (Tab. 10)

Formal definition: *Najas marina* cover > 50% OR (*Najas marina* cover > 25% NOT *Najas minor* cover > 25% NOT *Myriophyllum spicatum* cover > 25% *Stuckenia pectinata* cover > 25% NOT *Chara globularis* cover > 25% NOT *Potamogeton natans* cover > 50%)

Diagnostic species: *Najas marina* (*phi* value 0.279)

Constant species: *Najas marina* (100%)

This community dominated by *Najas marina* grows

Tab. 8 - *Potametum denso-nodosi* O. Bolós 1957

	1	2	3	4	5	6	7	8	9	10	
Date (year)	2010	2003	2003	2003	2010	2010	2003	2009	2003	2003	P
Total cover (%)	100	85	75	70	60	80	80	35	75	50	r
Area (m²)	9	1	8	1	4	4	50	8	8	4	e
Relevé number (Anarchive)	1724	1803	1807	1806	1722	1723	1805	1191	1767	1804	s
Charact. sp. of *Potametum denso-nodosi*											
Potamogeton nodosus Poir.	5	5	4	4	4	4	4	3	3	3	10
Charact. sp. of the upper units											
Najas marina L. ssp. marina	.	.	1	+	1	.	+	.	1	+	6
Stuckenia pectinata (L.) Börner	.	2a	+	.	.	1	.	.	+	+	5
Ceratophyllum demersum L.	+	2a	.	.	.	1	2a	.	.	.	4
Myriophyllum spicatum L.	1	1	.	.	1	.	.	.	.	3	4
Potamogeton pusillus L.	.	.	2a	.	.	.	.	.	2a	2a	3
Vallisneria spiralis L.	2a	.	.	.	.	.	3	.	.	2a	3
Najas minor All.	.	.	.	.	+	+	.	.	.	.	2
Potamogeton crispus L.	1	.	.	.	.	.	.	.	.	2a	2
Callitriche palustris L.	.	.	1	.	.	.	.	.	1	.	2
Potamogeton perfoliatus L.	.	.	.	.	.	1	.	.	.	.	1
Potamogeton lucens L.	.	+	.	.	.	.	.	.	.	.	1
Other species											
Elodea canadensis Michx.	.	.	.	1	.	.	.	.	.	+	2
Spirodela polyrhiza (L.) Schleid.	.	1	.	+	.	.	.	.	.	.	2
Lemna minor L.	.	.	.	+	.	.	.	.	.	+	2
Nitella hyalina (de Candolle) C. Agardh	.	.	.	.	1	.	.	.	.	.	1
Azolla filiculoides Lam.	.	+	.	.	.	.	.	.	.	.	1

Tab. 9 - *Potamo perfoliati-Vallisnerietum spiralis* Losev & Golub in Golub, Losev & Mirkin 1991

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Date (year)	2003	2003	2003	2003	2003	2003	2009	2010	2010	2003	2003	2003	2003	2003	2003	P
Total cover (%)	90	90	95	90	90	95	90	100	100	90	100	70	100	85	50	r
Area (m²)	3	3	1	6	15	1	25	3	4	1	50	1	100	6	1	e
Relevé number (Anarchive)	1815	1809	1808	1810	1812	1811	1185	1718	1699	1816	1813	1818	1826	1814	1817	s
Charact. sp. of *Potamo-Vallisnerietum spiralis*																
Vallisneria spiralis L.	5	5	5	5	5	5	5	5	5	5	5	4	4	4	3	15
Charact. sp. of the upper units																
Myriophyllum spicatum L.	.	+	1	.	2a	.	2a	1	1	.	1	2b	3	2a	.	10
Stuckenia pectinata (L.) Börner	+	+	3	+	.	1	.	.	.	1	.	2b	4	2a	.	9
Najas marina L. ssp. marina	+	.	.	.	.	+	.	.	.	2a	2a	.	1	1	2a	7
Ceratophyllum demersum L.	+	.	.	+	.	.	.	.	.	3	.	.	3	+	2a	6
Najas minor All.	.	.	.	1	.	2a	.	.	.	3	3	.	1	.	2a	6
Potamogeton perfoliatus L.	.	.	+	.	.	+	2a	.	.	.	.	.	.	3	.	4
Potamogeton pusillus L.	.	.	.	1	.	2a	.	.	.	.	.	.	.	.	.	2
Potamogeton nodosus Poir.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	1
Potamogeton crispus L.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1
Other species																
Elodea canadensis Michx.	.	.	2a	.	.	.	.	.	.	.	.	.	2a	.	.	2
Spirodela polyrhiza (L.) Schleid.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	2
Lemna minor L.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1
Phragmites australis (Cav.) Steud.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	1

in still water bodies such as lakes, pools and artificial ponds. It occurs in mesotrophic to eutrophic water, rich in calcium and salt. The dominant species is often accompanied by others with similar ecology such as *Najas minor, Stuckenia pectinata, Potamogeton perfoliatus* and *Myriophyllum spicatum.* This phytocoenosis was reported for Lake Trasimeno by Pedrotti & Orsomando (1977), Venanzoni & Gigante (2000), Venanzoni *et al.* (2006) and Lazzerini & Cecchetti (2007). This community is particularly frequent in the S-Eastern part of the lake. Its expansion is facilitated by the eutrophic conditions and the abundance of organic matter on the bottom.

NAJADETUM MINORIS Ubrizsy 1961 (Tab. 11)
Formal definition: *Najas minor* cover > 50% OR (*Najas minor* cover > 25% NOT *Najas marina* cover > 50% NOT *Ceratophyllum demersum* cover > 50% NOT *Vallisneria spiralis* cover > 25% NOT *Potamogeton natans* cover > 50%)
Diagnostic species: *Najas minor* (*phi* value 0.389), *Najas marina* (*phi* value 0.252)

Tab. 10 - *Najadetum marinae* Fukarek 1961

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Date (year)	2003	2003	2003	2003	2003	2003	2003	2003	2009	2009	2009	2009	2003	2010	2003	2003	2003	2009	2009	2009	2010	2009	P
Total cover (%)	75	80	85	100	100	45	65	70	70	100	80	100	85	100	70	80	85	95	98	95	100	95	r
Area (m²)	1	6	9	6	9	8	9	1	100	64	4	100	4	1	6	3	6	64	100	100	1	100	e
Relevé number (Anarchive)	1789	1788	1801	1781	1780	1782	1787	1786	1201	1204	1202	1205	1772	1666	1777	1779	1778	1207	1206	1208	1665	1209	s
Charact. sp. of *Najadetum marinae*																							
Najas marina L. ssp. marina	4	5	4	5	5	3	4	4	4	5	4	5	3	5	4	3	5	5	5	5	5	5	22
Charact. sp. of the upper units																							
Ceratophyllum demersum L.	3	+	.	.	.	2a	.	2a	1	.	.	.	3	1	.	.	2a	1	.	+	.	1	11
Stuckenia pectinata (L.) Börner	.	.	.	1	2a	.	.	2a	2a	.	3	.	.	2a	.	2a	2a	.	.	1	1	2a	11
Najas minor All.	+	2a	3	2a	3	.	.	.	.	.	.	.	+	.	3	1	3	.	.	.	.	.	9
Potamogeton perfoliatus L.	+	.	1	.	+	.	.	3	.	.	1	.	+	.	1	.	.	.	.	.	.	.	7
Myriophyllum spicatum L.	1	.	.	+	.	1	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	6
Potamogeton pusillus L.	.	.	2a	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	3
Potamogeton lucens L.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2
Potamogeton crispus L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1
Vallisneria spiralis L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Other species																							
Chara globularis Thuillier	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	2

Constant species: *Najas minor* (100%), *Najas marina* (91%), *Stuckenia pectinata* (55%)

This community is dominated by *Najas minor* and grows in mesotrophic or eutrophic, calcium-rich waters, often with high concentration in chlorides (Šumberová, 2011b; Neacşu *et al.*, 2010). The dominant species is similar to *Najas marina*, both from a morphological and ecological point of view. *Najadetum minoris*, in fact, is often interpenetrated with *Najadetum marinae,* creating a mosaic. The dominant species is usually accompanied by *Najas marina*, *Stuckenia pectinata*, *Myriophyllum spicatum* and *Potamogeton perfoliatus. Najadetum minoris* is reported in the present paper for the first time for Lake Trasimeno. It occurs prevalently in the S-Eastern part of the lake, however it is less abundant than *Najadetum marinae.*

POTAMETUM LUCENTIS Hueck 1931 (Tab. 12)
Formal definition: *Potamogeton lucens* cover > 25 NOT *Najas minor* cover > 50 NOT *Potamogeton perfoliatus* cover > 25% NOT *Stuckenia pectinata* cover > 25%
Diagnostic species: *Potamogeton lucens* (*phi* value 0.645)
Constant species: *Potamogeton lucens* (100%)

It is a species-poor phytocenosis dominated by *Potamogeton lucens,* a submerged macrophyte. It occurs in clear mesotrophic or naturally eutrophic water bodies, also with abundant organic sediments on the bottom (Buchwald, 1994). This association was reported for Lake Trasimeno with reference to the subassociation *nymphaeetosum albae* Granetti 1965 (Granetti, 1965; Pedrotti & Orsomando, 1977; Orsomando & Catorci, 1991), which is differentiated by some species of the alliance *Nymphaeion.* Currently the association *Potamentum lucentis* is not common, while the subassociation *nymphaeetosum* has completely disappeared due to the local extinction or reduction of several species, including *Nymphaea alba.*

POTAMETUM PUSILLI Soó 1927 (Tab. 12)
Formal definition: *Potamogeton pusillus* cover > 50%
Diagnostic species: *Potamogeton pusillus* (*phi* value 0.561), *Nymphaea alba* (*phi* value 0.342)
Constant species: *Potamogeton pusillus* (100%), *Nymphaea alba* (60%)

This vegetation type refers to a species-poor, sometimes monospecific association, which occurs in shallow mesotrophic or eutrophic water. Communities dominated by *Potamogeton pusillus* are reported for central Italy only by Lastrucci (2008) and Biondi *et al.* (1997, 2004). At Lake Trasimeno this association is very rare and grows in stands characterized by clear waters, stony or rocky substrata, at an average depth lower than 50 cm.

POTAMO PECTINATI-MYRIOPHYLLETUM SPICATI Rivas Goday 1964 (Tab. 12)
Formal definition: *Myriophyllum spicatum* cover > 25% NOT *Stuckenia pectinata* cover > 25% NOT *Potamogeton nodosus* cover > 25%
Diagnostic species: *Myriophyllum spicatum* (*phi* value 0.300)
Constant species: *Myriophyllum spicatum* (100%), *Stuckenia pectinata* (51%)

This vegetation type is very common in water bodies characterized by a high concentration of organic sediments (Barko & Smart, 1986; Ceschin & Salerno, 2008). The dominant species *Myriophyllum spicatum*,

Tab. 11 - *Najadetum minoris* Ubrizsy 1961

	1	2	3	4	5	6	7	8	9	10	11	
Date (year)	2003	2003	2003	2003	2003	2003	2003	2003	2003	2003	2003	P
Total cover (%)	85	95	90	95	80	100	100	70	40	50	30	r
Area (m²)	6	6	1	6	3	4	50	1	4	1	2	e
Relevé number (Anarchive)	1791	1798	1790	1792	1793	1802	1825	1796	1797	1776	1795	s
Charact. sp. of *Najadetum minoris*												
Najas minor All.	5	5	5	5	5	5	4	4	3	3	3	11
Charact. sp. of the upper units												
Najas marina L. ssp. marina	1	2a	2b	1	+	+	3	.	1	2a	.	9
Stuckenia pectinata (L.) Börner	2a	4	.	.	+	+	4	1	.	2a	2a	8
Potamogeton perfoliatus L.	1	+	.	+	+	+	.	+	.	.	.	6
Potamogeton pusillus L.	.	.	2b	3	.	.	3	1	2a	.	1	6
Myriophyllum spicatum L.	.	+	+	.	.	.	3	.	.	2a	.	4
Ceratophyllum demersum L.	1	3	.	.	.	.	2a	.	.	2a	.	4
Vallisneria spiralis L.	.	1	.	.	.	.	1	.	.	1	.	3
Potamogeton lucens L.	.	.	.	.	3	3	.	.	.	.	.	2
Potamogeton crispus L.	.	.	.	.	.	.	1	.	.	.	.	1
Other species												
Elodea canadensis Michx.	.	.	.	.	.	.	.	.	.	1	.	1

Tab. 12 - *Potametum lucentis* Hueck 1931, *Potametum pusilli* Soó 1927, *Potamo pectinati-Myriophylletum spicati* Rivas Goday 1964

	1	2	3	4	5	6	
Date (year)	2003	2003	2010	2010	2009	2003	P
Total cover (%)	85	90	70	70	80	75	r
Area (m²)	6	20	0,5	2	1000	15	e
Relevé number (Anarchive)	1799	1800	1664	1725	1189	1819	s
Charact. sp. of *Potametum lucentis*							
Potamogeton lucens L.	5	5	.	.	1	.	3
Charact. sp. of *Potametum pusilli*							
Potamogeton pusillus L.	.	.	4	4	.	.	2
Charact. sp. of *Potamo pectinati-Myriophylletum spicati*							
Myriophyllum spicatum L.	.	.	.	.	4	3	2
Charact. sp. of the upper units							
Najas marina L. ssp. marina	+	1	+	.	3	1	5
Najas minor All.	+	2b	.	.	2b	+	4
Potamogeton perfoliatus L.	+	+	.	.	1	.	3
Stuckenia pectinata (L.) Börner	+	.	.	.	2b	2a	3
Potamogeton nodosus Poir.	.	.	.	+	.	.	1
Vallisneria spiralis L.	.	.	.	.	.	3	1
Other species							
Nitella hyalina (de Candolle) C. Agardh	.	.	.	2a	r	.	2

is tolerant to a broad range of chemical and physical conditions. Usually this species is accompanied by *Stuckenia pectinata, Najas marina* and *Ceratophyllum demersum*. This plant community was very common in Lake Trasimeno during the past; in fact, *Myriophyllum spicatum* was indicated by Di Giovanni (1960) and Granetti (1965) as the second most common species of the lake and one of the most prominent sources of problems for fishing. Nowadays it only occurs sporadically and in restricted stands.

PERSICARIA AMPHIBIA community (Tab. 13)
Formal definition: *Persicaria amphibia* cover > 25%
Diagnostic species: *Persicaria amphibia* (*phi* value 0.309)
Constant species: *Persicaria amphibia* (100%)

This vegetation type is usually a species-poor community dominated by the aquatic form (*ecophene*) of *Persicaria amphibia*. In accordance with other Authors (e.g. Klosowski & Tomaszewicz, 1986; Sburlino *et al.*, 2008) we decided to treat the aquatic stands of *Persicaria amphibia* as an independent aspect, distinct from *Polygonetum natantis* Soó 1927, which refers to the terrestrial or dried up stands. Phytocoenoses dominated by *Persicaria amphibia* aquatic *ecophene* have been reported from central Italy at Lake Bolsena (Iberite *et al.*, 1995), in Valdichiana (Lastrucci *et al.*, 2010a) and in River Arno (Lastrucci *et al.*, 2010b). At Lake Trasimeno it is here recorded for the first time. It was found only in a small pond along the lake's shore. The dominant species was accompanied by *Ranunculus tricophyllus*.

RANUNCULUS TRICHOPHYLLUS community (Tab. 13)
Formal definition: *Ranunculus trichophyllus* cover > 25% NOT *Eleocharis palustris* cover > 50% NOT *Callitriche obtusangula* cover > 25%
Diagnostic species: *Ranunculus trichophyllus* (*phi* value 0.389)
Constant species: *Ranunculus trichophyllus* (100%)

Ranuncuulus trichophyllus is an aquatic plant which occurs in oligo-mesotrophic to eutrophic waters. At lake Trasimeno it forms species-poor coenoses characterized, besides the dominant species, by the presence of *Persicaria amphibia* (aquatic form) and sometimes *Ranunculus peltatus* subsp. *baudotii*. It occurs only in a canal (La Valle) and in a created

Tab. 13 - *Persicaria amphibia* aq. ecoph. community, *Ranunculus trichophyllus* community

	1	2	3	4	5	6	7	8	
Date (year)	2010	2011	2010	2011	2010	2010	2011	2011	P
Total cover (%)	80	90	80	80	100	90	80	95	r
Area (m²)	2,25	4	4	4	2,25	2,25	4	4	e
Relevé number (Anarchive)	1316	4608	1318	4611	1320	1319	4606	4609	s
Persicaria amphibia aq. ecoph. community									
Persicaria amphibia (L.) Delarbre	5	5	4	4	2b	2b	1	.	7
Ranunculus trichophyllus community									
Ranunculus trichophyllus Chaix	1	2a	2a	.	5	5	4	5	7
Ranunculus peltatus Schrank subsp. baudotii (Godr.) Meikle ex C.D.K. Cook	.	.	.	.	.	.	2a	+	2
Other species									
Lycopus europaeus L.	.	+	.	.	.	+	r	r	4
Chara delicatula C. Agardh	.	1	3	.	2a	.	2a	.	4
Phragmites australis (Cav.) Steud.	.	.	.	r	.	+	.	.	2
Stachys palustris L.	.	+	.	1	.	.	.		2
Alisma plantago-aquatica L.	.	.	+	.	.	.	.	.	1
Juncus articulatus L. subsp. articulatus	.	.	.	.	+	.	.	.	1
Eleocharis palustris (L.) Roem. et Schult.	.	.	2a	.	.	.	.	.	1
Typha angustifolia L.	.	.	+	.	.	.	.	.	1

pond near the lake's shore. We decided to treat these coenosis only at the community level, because its species composition doesn't match with the association *Ranunculetum trichophylli* Soó 1927.

Discussion

The application of a computer expert system to a vegetation data set from central Italy produced satisfactory results and allowed the classification of all the relevés in an unequivocal way. Due to the extreme species poverty of the treated associations, the created formal definitions do not contain species groups, but only species cover or combination of covers of different species. For each plant community, the species with the highest *phi* coefficient value are the most significant and discriminating, and can be considered real diagnostic *taxa* (Bruelheide & Chytrý, 2000).

Usually the Cocktail method requires a large starting data set and should include as many different vegetation types as possible to obtain definitions with general validity and species groups with high statistical value. These conditions are essential for calculating the *phi* coefficient values of associations (Chytrý, 2011). For this reason, in the present work a data set of 3,056 relevés including aquatic, wetland, meadow, grassland, shrub and forest vegetation, was considered. This large data set can be considered sufficient to create definitions for hydrophytic associations. The typical floristic poorness and the strong dominance of one or few species make aquatic communities a suitable object for applying the Cocktail method, emphasizing the concept of diagnostic species. However, this implies that the syntaxonomic variability of these vegetation types is always rather restricted and limited to already described communities, without any space for local differential *taxa*.

The present work allowed to investigate and summarize the hydrophytic vegetation of Lake Trasimeno, by adding a large set of unpublished data to the already existing information. The results suggest a great phytocoenotic diversity. Nevertheless this diversity is not to be considered as an indication of good water quality, since it is a direct consequence of the increased trophic level of the waters, as a result of the intensive human activities which induce a constant habitat alteration.

All the investigated communities are typical of mesotrophic or eutrophic water and several of them profit from water turbidity and organic deposit on the bottom, such as the associations *Charetum globularis, Charetum intermediae, Potametum pectinati, Potametum denso-nodosi* and *Ceratophyllum demersum* community.

Rare and more interesting phytocoenoses like *Ranunculus trichophyllus* community, *Hydrocharitetum morsus-ranae* and *Utricularietum australis* were found only in particular situations, such as constructed ponds mainly fed by rainwater or artificial canals, not directly connected with the lacustrine water body although included in the same ecosystem.

It should be noted that several macrophytic species and communities reported in the past by many Authors have now totally disappeared or are strongly reduced. A striking example is the association *Myriophyllo*

verticillati-Nupharetum lutei (Granetti, 1965; Orsomando & Catorci, 1991; Orsomando, 1993), which completely disappeared from the lake together with the species *Nuphar lutea* and *Myriophyllum verticillatum*. All the coenoses related to very shallow and still water, such as the lemnid-dominated communities, are in decline due to the disappearance of proper niches, above all those located in the reed bed clearings or between the reeds and the surrounding landscape.

Syntaxonomical scheme

Charetea Fukarek ex Krausch 1964
- *Charetalia hispidae* Sauer ex Krausch 1964
  - *Charion globularis* Krausch 1964
    - *Charetum globularis* Zutshi ex Šumberová, Hrivnák, Rydlo & Ot'ahel'ova in Chytrý 2011
    - *Charetum intermediae* (Corillion 1957) Fijałkowski 1960
    - *Charetum delicatulae* Doll 1989
  - *Nitelletalia flexilis* Krause 1969
    - *Nitellion flexilis* Krause 1969
      - *Nitelletum hyalinae* Losev in Golub, Losev & Mirkin 1991

Lemnetea O. Bolós & Masclans 1955
- *Lemnetalia minoris* O. Bolós & Masclans 1955
  - *Lemnion minoris* O. Bolós & Masclans 1955
    - *Lemnetum trisulcae* den Hartog 1963
    - *Lemnetum minoris* Soó 1927
    - *Lemno-Spirodeletum polyrhizae* Koch 1954
    - *Lemnetum gibbae* Miyawaki & J. Tüxen 1960
    - *Lemnetum minuto-gibbae* Liberman Cruz, Pedrotti & Venanzoni 1988
    - *Salvinio natantis-Spirodeletum polyrhizae* Slavnić 1956
    - *Ceratophyllo-Azolletum filiculoidis* Nedelcu 1967
    - *Riccietum fluitantis* Slavnić 1956
  - *Utricularion vulgaris* Passarge 1964
    - *Utricularietum australis* Müller & Görs 1960
  - *Hydrocharition morsus-ranae* (Passarge 1964) Westhoff & den Held 1969
    - *Hydrocharitetum morsus-ranae* Langendonck 1935

Potametea Klika in Klika & Novák 1941
- *Potametalia* Koch 1926
  - *Nymphaeion albae* Oberdorfer 1957
    - *Persicaria amphibia* (aquatic ecophene) community
  - *Potamion* Miljan 1933
    - *Potametum pectinati* Carstensen ex Hilbig 1971
    - *Potametum perfoliati* Miljan 1933
    - *Potametum lucentis* Hueck 1931
    - *Potametum pusilli* Soó 1927
    - *Potametum denso-nodosi* O. Bolós 1957
    - *Potamo pectinati-Myriophylletum spicati* Rivas Goday 1964
    - *Najadetum marinae* Fukarek 1961
    - *Najadetum minoris* Ubrizsy 1961
    - *Ceratophyllum demersum* community
    - *Potamo perfoliati-Vallisnerietum spiralis* Losev & Golub in Golub, Losev & Mirkin 1991
  - *Ranunculion aquatilis* Passarge 1964
    - *Ranunculus trichophyllus* community

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Addenda

Dates, localities, geographic and geologic references of the relevés

Tab. 1

Rel. 1: 30-07-2009; La Valle; lat: 43.0983333; lon: 12.1778667; clay. Rel. 2: 23-09-2009; La Valle; lat: 43.0995000; lon: 12.1798833; slime-clay. Rel. 3: 30-07-2009; La Valle; lat: 43.1018500; lon: 12.1780667; clay. Rel. 4: 30-07-2009; La Valle; lat: 43.1039000; lon: 12.1819167; clay. Rel. 5: 14-07-2009; Between Polvese Island and S. Arcangelo; lat: 43.1140667; lon: 12.1472833; slime-clay. Rel. 6: 19-04-2011; La Valle (artificial pond); lat: 43.0909500; lon: 12.1860167; clay. Rel. 7: 19-04-2011; La Valle (artificial pond); lat: 43.0909500; lon: 12.1860167; clay. Rel. 8: 19-04-2011; La Valle (artificial pond); lat: 43.0906500; lon: 12.1861500; clay. Rel. 9: 30-07-2009; La Valle (artificial pond); lat: 43.0967667; lon: 12.1791167; clay. Rel. 10: 04-08-2010; La Valle (artificial pond); lat: 43.1854500; lon: 12.0769167; claystone.

Tab. 2

Rel. 1: 05-08-2010; La Valle (artificial canal); lat: 43.1063500; lon: 12.1876500; cement covered by organic sediments. Rel. 2: 09-06-2009; Passignano sul Trasimeno; lat: 43.1900833; lon: 12.1084167; sand-slime. Rel. 3-4-5-6-7-16: 26-09-1986; unspecified; lat: unspecified; lon: unspecified; unspecified; bibl. reference: Liberman Cruz, 1986. Rel. 8: Summer 2003; Borghetto; lat: unspecified; lon: unspecified; unspecified. Rel. 9: 05-08-2010; La Valle (artificial canal); lat: 43.1058833; lon: 12.864000; cement covered by organic sediments. Rel. 10-14-15: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified. Rel. 11: 06-07-2009; La Valle (artificial canal); lat: 43.1058833; lon: 12.864000; cement covered by organic sediments. Rel. 12: 11-06-2010; Polvese Island; lat: 43.1166167; lon: 12.1490333; sand-slime. Rel. 13: 10-09-2010; S. Feliciano; lat: 43.1138333; lon: 12.1709500; clay. Rel. 17: 22-07-2010; Tuoro sul Trasimeno; lat: 43.1947833; lon: 12.0814833; sand-slime. Rel. 18: 08-07-2010; Passignano sul Trasimeno; lat: 43.1901333; lon: 12.1086167; sand-slime. Rel. 19-20: 23-07-2010; Castiglione del Lago (artificial pound); lat: 43.1378500; lon: 12.0409167; sand. Rel. 21: 20-07-2010; Castiglione del Lago (artificial pound); lat: 43.130911; lon: 12.1648167; slime. Rel. 22: 20-07-2010; S. Arcandelo; lat: 43.0911333; lon: 12.648167; slime. Rel. 23: 11-06-2010; Polvese Island; lat: 43.1165667; lon: 12.1490333; sand-slime.

Tab. 3

Rel. 1-5-6-7-8-9-10-11-12-13-14-15-16-18: 26-09-1986; unspecified; lat: unspecified; lon: unspecified; unspecified; bibl. reference: Liberman Cruz, 1986. Rel. 2: 25-06-2010; Porto di Panicarola-Mirabella; lat: 43.1901333; lon: 12.1085333; sand-slime. Rel. 3: 08-07-2010; Passignano sul Trasimeno; lat: 43.1901333; lon: 12.1066167; sand-slime. Rel. 4-17: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified.

Tab. 4

Rel. 1: July 1998; unspecified; lat: unspecified; lon: unspecified; unspecified; bibl. reference: Venanzoni & Gigante 2000. Rel. 2: 26-09-1986; unspecified; lat: unspecified; lon: unspecified; unspecified; bibl. reference: Liberman Cruz, 1986. Rel. 3-4: 06-07-2009; La Valle (artificial canal); lat: 43.1058833; lon: 12.1864000; cement covered by organic sediments. Rel. 5: Summer 2003; Borghetto; lat: unspecified; lon: unspecified; unspecified. Rel. 6: 29-07-1991; Tuoro sul Trasimeno; lat: unspecified; lon: unspecified; unspecified; bibl. reference: Buchwald 1994.

Tab. 5

Rel. 1: 29-07-1991; Tuoro sul Trasimeno; lat: unspecified; lon: unspecified; unspecified; bibl. reference: Buchwald 1994. Rel. 2-3-4-8: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified. Rel. 5: 23-09-2009; La Valle; lat: 43.1046167; lon: 12.1830833; clay-slime. Rel. 6-7: July 1998; unspecified; lat: unspecified;

lon: unspecified; unspecified; bibl. reference: Venanzoni & Gigante 2000.

Tab. 6
Rel. 1: 3006-2010; Borghetto; lat: 43.1889167; lon: 12.0494333; sand. Rel. 2: 30-07-2010; La Valle; lat: 43.0976833; lon: 12.1778667; clay. Rel. 3: 30-07-2010; La Valle; lat: 43.0963500; lon: 12.1778667; clay. Rel. 4: 04-08-2010; Passignano; lat: 43.1928333; lon: 12.0983833; sand-slime. Rel. 5: 06-07-2009; La Valle; lat: 43.0976833; lon: 12.1867667; clay. Rel. 6: 30-06-2009; Passignano; lat: 43.1900333; lon: 12.1084000; sand-slime. Rel. 7-8-9-10-14-15-16: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified. Rel.11: 06-07-2009; La Valle; lat: 43.0976833; lon: 12.1867667; clay. Rel. 12: 23-09-2009; La Valle; lat: 43.1039667; lon: 12.1824667; clay. Rel. 13: 14-07-2009; S. Feliciano; lat: 43.1252333; lon: 12.1535167; clay.

Tab. 7
Rel. 1-2-3-4-5-7-9-10-11-12-15-16-18: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified. Rel. 6: 14-07-2009; Castiglione del Lago; lat: 43.1375667; lon: 12.0412000; sand-clay. Rel. 13: 30-06-2009; Borghetto; lat: 43.1844500; lon: 12.0360500; sand-slime. Rel. 14: 30-06-2009; Borghetto; lat: 43.1892667; lon: 12.0499167; sand-slime. Rel. 17: 14-07-2009; Castiglione del Lago; lat: 43.1451500; lon: 12.0325333; sand-clay.

Tab. 8
Rel. 1: 03-09-2010; Castiglione del Lago; lat: 43.1237667; lon: 12.0570667; sand-clay. Rel. 2-3-4-7-9-10. Rel. 5: 03-09-2010; Castiglione del Lago; lat: 43.1214500; lon: 12.0480500; clay. Rel. 6: 03-09-2010; Castiglione del Lago; lat: 43.1217833; lon: 12.0479167; clay. Rel. 8: 13-07-2009; Castiglione del Lago; lat: 43.1828333; lon: 12.0236833; clay.

Tab. 9
Rel. 1-2-3-4-5-6-10-11-12-13-14-15: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified. Rel. 7: 14-07-2009; S. Arcangelo; lat: unspecified; lon: unspecified; clay. Rel. 8: 03-09-2010; Castiglione del Lago; lat: 43.1221833; lon: 12.0486833; slime-clay. Rel. 9: 27-08-2010; Borghetto; lat: 43.1221833; lon: 12.0486833; sand-slime with claystone.

Tab. 10
Rel. 1-2-3-4-5-6-7-8-13-15-16-17: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified. Rel. 9: 23-09-2009; La Valle; lat: 43.0960500; lon: 12.1801667; slime-clay. Rel. 10: 30-07-2009; La Valle; lat: 43.0950333; lon: 12.1823833; clay. Rel. 11: 30-06-2009; Borghetto; lat: 43.1844500; lon: 12.0360500; slime-clay. Rel. 10-12: 30-07-2009; La Valle; lat: 43.0952333; lon: 12.1812500; clay. Rel. 10-14: 04-08-2010; Passignano; lat: 43.1928333; lon: 12.0983833; sand-slime. Rel. 18: 30-07-2009; La Valle; lat: 43.0955167; lon: 12.1801667; clay. Rel. 19: 03-07-2009; La Valle; lat: 43.0955733; lon: 12.1825167; clay. Rel. 20: 06-07-2009; La Valle; lat: 43.0952333; lon: 12.1801833; clay. Rel. 21: 04-08-2010; Punta Navaccia; lat: 43.1865833; lon: 12.1186833; sand. Rel. 22: 06-07-2009; La Valle; lat: 43.0967000; lon: 12.1823167; clay.

Tab. 11
Rel. 1-2-3-4-5-6-7-8-9-10-11 Date: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified.

Tab. 12
Rel. 1-2-6: Summer 2003; unspecified; lat: unspecified; lon: unspecified; unspecified. Rel. 3: 04-08-2010; Punta Navaccia; lat: 43.1865833; lon: 12.1186833; sand. Rel. 4: 03-09-2010; Castiglione del Lag; lat: 43.239333; lon: 12.0577500; sand-slime. Rel. 5: 03-07-2009; Poggio di Braccio; lat: 43.0780167; lon: 12.1261500; sand.

Tab. 13
Rel. 1: 28-06-2010; S. Savino; lat: 43.0907500; lon: 12.1867667; slime-clay. Rel. 2: 19-04-2011; Between S. Arcangelo and S. Feliciano (artificial pound); lat: 43.1064333; lon: 12.1867667; clay. Rel. 3: 28-06-2010; S. Savino; lat: 43.0905667; lon: 12.1863667; slime-clay. Rel. 4: 19-04-2011; S. Arcangelo (artificial pound); lat: 43.0907167; lon: 12.1869000; clay. Rel. 5: 28-06-2010; S. Savino; lat: 43.0905833; lon: 12.1863833; slime-clay. Rel. 6: 28-06-2010; S. Savino; lat: 43.0905667; lon: 12.1863667; slime-clay. Rel. 7: 19-04-2011; S. Arcangelo (artificial pound); lat: 43.0909500; lon: 12.1860333; clay. Rel. 8: 19-04-2011; S. Arcangelo (artificial pound); lat: 43.0910500; lon: 12.1860833; clay.