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HYGROPHILOUS VEGETATION AND HABITATS OF CONSERVATION INTEREST IN THE AREA OF THE LAKE PORTA (TUSCANY, CENTRAL ITALY)

Abstract - *Hygrophilous vegetation and habitats of conservation interest in the area of the Lake Porta (Tuscany, Central Italy).* The vegetation of the Lake Porta and the surrounding wetlands and water courses has been investigated according to the phytosociological method through 73 original relevés. The identified plant communities belong to the following classes: *Charetea fragilis*, *Lemnetea minoris*, *Potametea pectinati*, *Isoëto-Nanojuncetea*, *Phragmito australis-Magnocaricetea elatae*, *Alnetea glutinosae*. In the canals surrounding the lake, it has been noted the invasion by *Myriophyllum aquaticum*, an alien species from South America, forming very dense stands, penetrating inside the native hydrophytic plant communities and surviving even in dry habitats. However the survey shows the occurrence of a number of native communities and of several habitats of conservation interest as well.

Key words - alien species, conservation, hydrophytes, phytosociology, vegetation.

Riassunto - *Vegetazione igrofila ed habitat di interesse conservazionistico nell'area del lago di Porta (Toscana, Italia Centrale).* La vegetazione del lago di Porta e delle aree umide circostanti è stata indagata dal punto di vista fitosociologico con la realizzazione di 73 rilevamenti originali. Le cenosi rilevate sono state inquadrate nelle seguenti classi: *Charetea fragilis*, *Lemnetea minoris*, *Potametea pectinati*, *Isoëto-Nanojuncetea*, *Phragmito australis-Magnocaricetea elatae*, *Alnetea glutinosae*. Nei canali che circondano il lago si evidenzia invasione da parte di *Myriophyllum aquaticum*, una specie esotica di origine sudamericana, che forma popolamenti molto estesi nei corsi d'acqua studiati, riuscendo a penetrare anche all'interno delle fitocenosi idrofitiche autoctone e sopravvivendo anche in ambienti asciutti. L'indagine evidenzia comunque la presenza nell'area di studio di cenosi autoctone di elevato pregio naturalistico e di diversi habitat di interesse conservazionistico.

Parole chiave - conservazione, fitosociologia, piante acquatiche, specie esotiche, vegetazione.

Introduction

The wetlands exhibit a highly specialized flora and vegetation but are habitats subject to several threats, such as land reclamation, eutrophication, and banalization of the landscape (see also Bedford *et al.*, 2001; Dudgeon *et al.*, 2006). In addition we have to consider the invasion of non-native species or the expansion of native ones, to which these environments are particularly vulnerable (Zedler & Kercher, 2004). In fact, the ability of most invasive species to form dense and monospecific stands can lead to significant changes in the habitat structure, determining dramatic impacts not only on flora and vegetation but also on native communities of animals (Boylen *et al.*, 1999; Stiers *et al.*, 2011).

Myriophyllum aquaticum (Vell.) Verdc. is a species native to South America, widely used for aquaria or water gardens, which is actually considered invasive in many countries (Dutarte, 2004).

The first observation of this species in Italy was reported by Minutillo & Moraldo (1993) for the river Garigliano in the administrative provinces of Latina and Caserta. In recent times, the presence of this plant in the waterways surrounding the area of Lake Porta, in the provinces of Massa Carrara and Lucca, has been reported (Lastrucci *et al.*, 2006; Castelli *et al.*, 2010; Peruzzi *et al.*, 2016). Subsequently, the species was found in Lombardy and Veneto (Celesti-Grapow *et al.*, 2010) and, more recently, in Emilia-Romagna, Friuli Venezia Giulia and Marche (Gubellini *et al.*, 2014; Acta Plantarum, 2015). The Lake Porta (Fig. 1) covers around 159 hectares and is the northernmost remnant wetland of the retrodunal lakes of Versilia, in north-western Tuscany (Tomei *et al.*, 2001). Since 1998, the lake has been protected by mean the institution of a Natural Protected Area of Local Interest (ANPIL, see Regione Toscana, 1995). In 2003, it was also recognised as a Special Protection Area (SPA), in accordance with the Council Directive 79/409/EEC.

The Lake Porta is surrounded by several flooded depressions, artificial lakes, ditches and canals which are characterised by different degrees of anthropization. This area is located in the vicinity of mining and residential zones which lead to a high degree of anthropic impact as already evidenced by Sani & Lombardi (2005).

From a botanical point of view, the area is relatively little known and the available literature is primarily floristic (Pellegrini, 1942; Tomei & Bartelletti, 1977; Tomei *et al.*, 1997).

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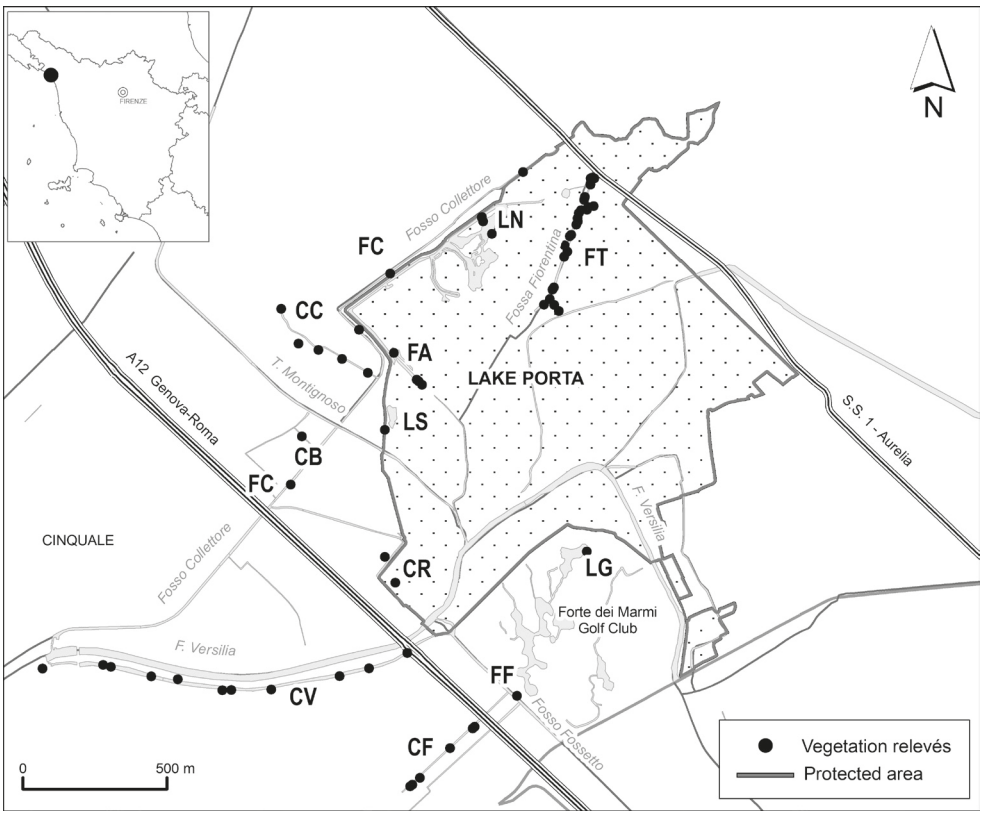

Fig. 1 - Study area. Location of sample sites and boundary of the protected area.

Vegetational and floristic records occur in Tomei & Garbari (1981) while a list of plant communities, without the support of phytosociological relevés, is reported by Tomei *et al.* (1998), Tomei *et al.* (2001), and Sani & Lombardi (2005). The floristic data indicate the presence of species of high importance included in the Italian and Tuscan attention list (Conti *et al*., 1997; Tuscan Region, 2000; Rossi *et al*., 2013); however, some species such as *Menyanthes trifoliata, Sagittaria sagittifolia, Hottonia palustris* and *Nymphoides peltata* are no longer found in the area (Vietina & Ardara, 2001).
The aim of this paper is to provide an update of the vegetation knowledge of Lake Porta and of surrounding areas which are currently invaded by *M. aquaticum,* in view of future works aimed to the management of this species.

Materials and methods

The study of the vegetation was carried out in accordance with the phytosociological method (Braun-Blanquet, 1932; Biondi, 2011). A total of 73 relevés was performed and the identified communities were organised at the association rank mainly according to Chytrý (2011), Landucci *et al.* (2013) and the other references reported specifically in the text. The syntaxonomic scheme follows mainly Lastrucci *et al.* (2014) and the nomenclature to the alliance level follows Biondi & Blasi (2013) and Biondi *et al.* (2014). Plant names follow mostly Conti *et al.* (2005; 2007) and Bazzichelli & Abdelahad (2009) and subsequent updates about native and alien *taxa* (e.g. Kaplan, 2008; Iberite *et al*., 2011).
The sampling sites are indicated in the tables by the following tags: FT ('Fossa Fiorentina' canal and neighbouring streams and wetlands); FC ('Fosso Collettore' canal); FF ('Fosso Fossetto' canal); FA (canal within the marshland of Lake Porta); LN (north pond of Lake Porta); LS (south pond of Lake Porta); CB (canal along Bregoscia Street); CC (tributary of the 'Fosso Collettore'); CF (tributary of the 'Fosso Fossetto'); CR (canal near 'Le Rene'); CV (canal on the left side of the Versilia river); LG (lake inside the Golf Club).

Results and discussion

Twenty-one vegetation types, here described as true associations or simply "community with" have been identified together with two association's variants. These vegetation types belong to the following classes: *Charetea fragilis* (Tab. 1), *Lemnetea minoris* (Tab. 2),

Tab. 1 - Vegetation of the class *Charetea fragilis*.

Rel. number	1
Cover (%)	100
Area (sqm)	10
Locality	CV
Charact. ass. *Charetum vulgaris*	
Chara vulgaris L.	5
Other aquatic species	
Stuckenia pectinata (L.) Börner	2
Myriophyllum verticillatum L.	+
Ceratophyllum demersum L.	r
Other species	
Phragmites australis (Cav.) Trin. ex Steud.	2
Paspalum distichum L.	1
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	1

Tab. 2 - Vegetation of the class *Lemnetea minoris*.

Rel. number	1	2	3	4	5
Cover (%)	100	100	40	100	100
Area (sqm)	1	1	4	4	4
Locality	FT	LS	CV	CF	CV
Charact. ass. *Lemnetum minuto-gibbae*					
Lemna minuta Kunth	5	5	.	.	.
Charact. ass. *Ceratophylletum demersi*					
Ceratophyllum demersum L.	.	.	3	5	4
Other aquatic species					
Stuckenia pectinata (L.) Börner	.	.	2	.	1
Myriophyllum aquaticum (Vell.) Verdc.	1	.	.	.	1
Chara vulgaris L.	.	.	.	.	3
Other species					
Juncus subnodulosus Schrank	.	.	.	1	.

Potametea pectinati (Tab. 3, 4, 5, 6), *Isoëto-Nanojuncetea* (Tab. 7), *Phragmito australis-Magnocaricetea elatae* (Tab. 8, 9, 10), and *Alnetea glutinosae* (Tab. 11).

Aquatic vegetation

The vegetation dominated by native hydrophytes was found mainly along the canals surrounding the lake, especially along the Fossa Fiorentina canal, and the canal that passes through the Golf Club and then runs parallel to the river Versilia. To a lesser extent, hydrophytic plant communities were also observed in the open areas of the lake and in some ponds within the Golf Club.

In the canals of the southern part of the study area several hydrophytic associations were found:

Charetum vulgaris Corillion 1957 (Tab. 1), a pioneer vegetation typical of slightly alkaline soils and shallow or medium-deep meso-eutrophic waters (Hrivnák *et al.*, 2005), was found in only one water course, on the left side of the Versilia river.

Ceratophylletum demersi Corillion 1957 (Tab. 2, rel. 3-5), already reported within the study area (Tomei *et al.*, 1998), was observed in some waterways around the lake, forming large mats floating in the intermediate layers of the water column. The association is quite widespread in the Central Italy, where it was found in different types of wetlands ranging from lakes to streams, preferentially in eu-hypertrophic waters (e.g. Sburlino *et al.*, 2004; Ceschin & Salerno, 2008; Landucci *et al.*, 2011; Lastrucci *et al.*, 2012).

Potametum pectinati Carstensen ex Hilbig 1971 (Tab. 3, rel. 1-2) was found mainly in the tract of the canal that runs on the left bank along the river Versilia. This association, fairly widespread in Central Italy (Ceschin & Salerno, 2008; Landucci *et al.*, 2011; Lastrucci *et al.*, 2012), develops even in water at high salt concentrations. This could explain why the phytocoenosis has been also found in the stretch of the canal closer to the sea, similarly to what was reported for other Italian rivers (e.g. Ceschin & Salerno, 2008).

Myriophylletum verticillati Gaudet ex Šumberová in Chytrý 2011. (Tab. 3, rel. 3-5) was found in some canals of the study area, where it formed dense stands, often in contact on one side with coenoses such as *Potametum pectinati*, *Charetum vulgaris,* and *Ceratophylletum demersi*, and on the other side with plant communities dominated by species with floating leaves, belonging to the alliance *Nymphaeion albae*. From a syndynamic point of view, this association precedes the formation of communities of floating-leaf species, which, in the study area, are represented by *Nuphar lutea* and/or

Tab. 3 - Vegetation of the alliance *Potamion pectinati* (I).

Rel. number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cover (%)	100	100	100	100	100	100	100	100	80	50	80	70	80	85
Area (sqm)	4	4	16	16	4	4	4	4	1	4	4	4	4	4
Locality	CV	CV	FF	FF	CV	FT	FT	FT	FT	FT	FT	FT	FT	FT
Charact. ass.*Potametum pectinati*														
Stuckenia pectinata (L.) Börner	4	5	1	1	.	.	.	.	.	.	.	.	.	.
Charact. ass.*Myriophylletum verticillati*														
Myriophyllum verticillatum L.	.	1	4	5	5	.	.	.	.	.	.	.	.	.
Charact. ass.*Potametum crispi*														
Potamogeton crispus L.	.	.	.	.	.	5	5	5	4	3	4	2	2	2
diff. of the variant with *Myriophyllum aquaticum*														
Myriophyllum aquaticum (Vell.) Verdc.	.	.	.	.	.	.	.	.	.	1	+	4	5	4
Charact. of other units of *Potametea* class														
Callitriche stagnalis Scop.	.	.	.	.	.	1	.	.	.	.	2	.	.	.
Veronica beccabunga L. aquatic ecophene	.	.	.	.	.	+	+	.	+	.	.	.	.	.
Helosciadium nodiflorum (L.) W. D. J. Koch aquatic ecophene	.	.	.	.	.	+	+	.	.	.	.	.	.	.
Callitriche cophocarpa Sendtn.	.	.	.	.	.	.	.	.	3	.	.	.	.	.
Veronica anagallis-aquatica L. subsp. anagallis-aquatica aquatic ecophene	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Other aquatic species														
Ceratophyllum demersum L.	1	1	3	1	.	.	.	.	.	.	.	.	.	.
Chara vulgaris L.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
Other species														
Sparganium erectum L.	.	.	.	.	.	.	1	1	+	.	1	.	.	.
Carex acutiformis Ehrh.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Equisetum palustre L.	.	.	.	.	.	.	.	.	.	.	.	.	.	+

Tab. 4 - Vegetation of the alliance *Potamion pectinati* (II): *Myriophyllum aquaticum* community. A = acquatic; T = terrestrial

Rel. number	1	2	3	4	5	6	7	8	9	10	11	12
Cover (%)	85	100	100	95	90	75	85	100	40	85	85	80
Area (sqm)	10	4	10	4	4	10	4	4	1	2	2	2
Locality	FT	FT	FT	CV	CC	FC	FC	FC	CB	FT	FT	FT
Habitat type	A	A	A	A	A	A	A	A	T	T	T	T
Myriophyllum aquaticum community												
Myriophyllum aquaticum (Vell.) Verdc.	5	5	5	5	5	4	5	5	2	4	4	3
Charact. of upper units												
Potamogeton crispus L.	r	.	+	.	.	.	.	.	.	.	.	.
Stuckenia pectinata (L.) Börner	.	.	.	1	.	.	.	.	.	.	.	.
Other aquatic species												
Lemna minuta Kunth	1	2	2	.	.	.	.	.	.	.	.	.
Chara vulgaris L.	.	.	.	1	.	.	.	.	.	.	.	.
Ceratophyllum demersum L.	.	.	.	+	.	.	.	.	.	.	.	.
Other species												
Dactylis glomerata L.	.	.	.	.	.	.	.	.	+	2	1	1
Veronica beccabunga L.	.	+	r	.	.	.	.	.	.	+	+	.
Rubus ulmifolius Schott	.	.	.	.	.	.	.	.	.	1	1	2
Holcus lanatus L.	.	.	.	.	.	.	.	.	.	1	1	1
Galium aparine L.	.	.	.	.	.	.	.	.	.	+	1	+
Rumex crispus L.	.	.	.	.	.	.	.	.	+	.	1	+
Paspalum distichum L.	.	.	.	.	.	1	.	.	2	.	.	.
Nasturtium officinale R. Br. subsp. officinale	.	.	.	.	.	.	.	.	.	.	1	2
Calystegia sepium (L.) R. Br. subsp. sepium	.	.	.	.	.	.	.	.	.	.	+	2
Potentilla reptans L.	.	.	.	.	.	.	.	.	.	+	2	.
Bromus sterilis L.	.	.	.	.	.	.	.	.	.	1	1	.
Carex riparia Curtis	.	.	.	.	.	1	.	.	.	.	.	1
Veronica anagallis-aquatica L. subsp. anagallis-aquatica	.	.	.	.	.	.	1	.	.	.	.	+
Veronica persica Poir.	.	.	.	.	.	.	.	.	.	1	.	r
Helosciadium nodiflorum (L.) W. D. J. Koch	.	.	.	.	+	.	.	.	+	.	.	.
Carex pendula Huds.	.	.	.	.	.	.	.	.	.	+	+	.
Periploca graeca L.	.	.	.	.	.	.	.	.	.	.	+	+
Urtica dioica L. subsp. dioica	.	.	.	.	.	.	.	.	.	+	.	+
Agrostis stolonifera L.	.	.	.	.	.	.	.	.	.	.	2	.
Rumex conglomeratus Murray	.	.	.	.	.	.	.	.	1	.	.	.
Trifolium repens L.	.	.	.	.	.	.	.	.	1	.	.	.
Phragmites australis (Cav.) Trin. ex Steud.	.	.	.	.	1	.	.	.	.	.	.	.
Lolium perenne L.	.	.	.	.	.	.	.	.	1	.	.	.
Lythrum salicaria L.	.	.	.	.	.	.	.	.	+	.	.	.
Equisetum palustre L.	.	.	.	.	.	.	.	.	.	.	.	+
Iris pseudacorus L.	.	.	.	.	+	.	.	.	.	.	.	.
Carex acutiformis Ehrh.	.	.	.	.	.	.	.	.	.	+	.	.
Cardamine hirsuta L.	.	.	.	.	.	.	.	.	.	.	.	+
Carex hirta L.	.	.	.	.	.	.	.	.	.	+	.	.
Cyperus longus L.	.	.	.	.	.	+	.	.	.	.	.	.
Equisetum arvense L. subsp. arvense	.	.	.	.	.	.	.	.	.	+	.	.
Equisetum telmateia Ehrh.	.	.	.	.	.	.	.	.	.	+	.	.
Geranium dissectum L.	.	.	.	.	.	.	.	.	.	.	+	.
Poa annua L.	.	.	.	.	.	.	.	.	+	.	.	.
Persicaria lapathifolia (L.) Delarbre subsp. lapathifolia	.	.	.	.	.	.	.	.	.	r	.	.
Trifolium pratense L.	.	.	.	.	+	.	.	.	.	.	.	.

Tab. 5 - Vegetation of the alliance *Nymphaeion albae*

Rel. number	1	2	3	4	5	6	7	8	9
Cover (%)	100	100	100	90	80	85	100	90	90
Area (sqm)	4	4	4	4	4	10	16	4	16
Locality	CV	CV	CV	CF	CF	LN	LG	CV	CV
Charact. ass. *Nymphaeo albae-Nupharetum luteae*									
Nymphaea alba L.	5	5	5	5	5	5	.	3	1
Nuphar lutea (L.) Sm.	.	.	.	.	.	.	5	3	5
Charact. of other units of *Potametea* class									
Myriophyllum verticillatum L.	1	1	1	+	.	.	.	2	1
Stuckenia pectinata (L.) Börner	+	+	.	.	.	.	.	.	.
Other aquatic species									
Ceratophyllum demersum L.	.	.	r	+	.	.	.	.	.
Chara vulgaris L.	+	.	.	.	.	.	.	.	.
Other species									
Paspalum distichum L.	.	.	.	.	.	.	.	+	+
Arundo donax L.	.	.	.	.	.	.	.	+	+
Phragmites australis (Cav.) Trin. ex Steud.	.	.	.	.	+	.	.	.	.

Nymphaea alba. The syntaxonomical autonomy of the association *Myriophylletum verticillati* is now consolidated (Klosowski & Tomaszewicz, 1989; Ceschin & Salerno, 2008; Šumberová *et al*., 2011), although the floristic composition and the ecological characteristics of its habitat are similar to those of some *Nymphaeion* communities (Klosowski & Tomaszewicz, 1989). Therefore, especially in the past, the association has been included in the *Nymphaeion* alliance (e.g. Brullo *et al*., 1994; Marchiori & Sburlino, 1997) and sometime *Myriophyllum verticillatum* communities have been interpreted as *facies* of *Nymphaeion* associations such as *Nymphaeo albae-Nupharetum luteae* Nowiński 1927 nom. mut. propos. Šumberová in Chytrý 2011 (e.g. Meriaux & Wattez, 1983; Buchwald, 1994). In this work, we place the association in the alliance *Potamion*, in agreement with the recent proposals of Golub *et al*., (1991), Brzeg & Wojterska (2001), Ceschin & Salerno (2008) and Šumberová (2011).

The association *Nymphaeo albae-Nupharetum luteae* (Tab. 5), was present in the study area with a *facies* dominated by only *Nymphaea alba,* one with only *Nuphar lutea* and another with the concurrent presence of the two species, similarly to what Sburlino *et al.* (2008) reported for the North-eastern Italy.

It is worth noting that communities dominated by cultivar of *Nymphaea* with yellow flowers were observed in a canal adjacent to the Golf Club.

Dense stands dominated by *Potamogeton crispus* were found mainly in the Fossa Fiorentina canal (Tab. 3 rel. 6-14). These communities have been here classified in the *Potametum crispi* Soó 1927, which is typical of both lentic and lotic, eutrophic to hypertrophic waters (Šumberová, 2011). In some of our relevés, a variant of *Potametum crispi,* dominated by *Myriophyllum aquaticum,* was identified (Tab. 3, rel. 10-14). This non-native species in the study area showed a high ability of invading other plant communities, forming dense and poor-in-species stands, similarly to what reported in other European invaded areas (e.g. Ferreira & Moreira, 1995; Stiers *et al*., 2011). The *Myriophyllum aquaticum* variant might subsequently evolve into monophytic coenoses of *M. aquaticum*.

In the Fossa Fiorentina and some small tributaries a vegetation dominated by *Callitriche cophocarpa* and attributable to the association *Lemno-Callitrichetum cophocarpae* (Mierwald, 1988) Passarge 1992 (Tab. 6, rel. 1-6) was found; this association developed also in small depressions located flanking the canal, where the water remains until the first summer months and

Tab. 6 - Vegetation of the alliance *Ranunculion aquatilis*

Rel. number	1	2	3	4	5	6	7	8
Cover (%)	100	80	45	10	55	100	95	60
Area (smq)	2	4	4	4	2	2	2	4
Locality	FT	CC	FC	CC	FT	FT	FT	FT
Charact. ass. *Lemno-Callitrichetum cophocarpae*								
Callitriche cophocarpa Sendtn.	5	5	2	2	3	2	.	.
Diff. of variant with *Myriophyllum aquaticum*								
Myriophyllum aquaticum (Vell.) Verdc.	.	.	+	.	2	5	5	3
Callitriche stagnalis and *Myriophyllum aquaticum* community								
Callitriche stagnalis Scop.	.	.	.	.	.	.	1	2
Charact. of other units of *Potametea* class								
Potamogeton crispus L.	1	.	.	.	.	.	.	.
Other species								
Agrostis stolonifera L.	1	+	.	.	.	2	+	.
Helosciadium nodiflorum (L.) W. D. J. Koch	1	2	+	+	.	.	.	.
Veronica anagallis-aquatica L. subsp. anagallis-aquatica	+	+	.	.	+	+	.	.
Ranunculus sceleratus L.	.	.	.	.	1	2	.	.
Alisma lanceolatum With.	.	.	.	.	.	.	+	.
Alisma plantago-aquatica L.	.	.	+	.	.	.	.	.
Carex pendula Huds.	.	.	.	.	1	.	.	.
Equisetum arvense L. subsp. arvense	.	+	.	.	.	.	.	.
Equisetum palustre L.	.	.	.	.	.	.	1	.
Glyceria notata Chevall.	.	.	.	.	.	+	.	.
Iris pseudacorus L.	.	1	.	.	.	.	.	.
Lysimachia vulgaris L.	.	.	.	.	1	.	.	.
Ranunculus repens L.	.	.	.	.	.	.	+	.
Rumex crispus L.	.	.	+	.	.	.	.	.

then dries out slowly. *Lemno-Callitrichetum* is typical of the quiet and clear calcareous, moderately eutrophic waters, warming in the summer and characterized by a muddy bottom (Passarge, 1992; Sburlino *et al*., 2008). The presence of *Callitriche cophocarpa* was already known for the area in issue (Tomei *et al*., 1998) whereas its syntaxonomic characterization was still missing. As in the case of *Potametum crispi,* the *Lemno-Callitrichetum* exhibited a variant with *M. aquaticum* interpretable as an initial stage of invasion (Tab. 6, rel. 5-6). A similar situation was observed for the *Callitriche stagnalis* communities (Tab. 6, rel. 7-8), where only stands dominated by *M. aquaticum* have been identified.

In the situations more heavily invaded, *Myriophyllum aquaticum* formed very dense and poor-in-species stands (Tab. 4, rel. 1-8) characterised by emergent shoots forming a bright green, homogeneous layer covering the surface of the water body. (Tab. 4, rel. 1-8) On the basis of our observations in the study area the ideal conditions for *M. aquaticum* appear to be areas with very slow flow, a variable turbidity value, and a silty-muddy substrate. These conditions are consistent with those observed in other invaded European areas (e.g. Hussner & Lösch, 2005). Moreover, *M. aquaticum* showed the ability to survive outside the water course (Tab. 4, rel. 9-12), and to develop in semi-terrestrial conditions (lateral depressions with water stagnation) or even in completely terrestrial conditions (banks and embankments). These features might become a critical factor for future management of this invasive species. Accordingly, the monitoring and eventually the control should not be limited to the water bodies, but should involve the surrounding areas too. It is important to note, fortunately, that *Myriophyllum aquaticum* was not yet observed within the open waters of the Lake Porta.

Moreover, communities characterised by the presence of the alien *Lemna minuta* Kunth were found again in the Fossa Fiorentina and in damp depressions that flank this canal (Tab. 2, rel. 1-2). In the Fossa Fiorentina *L. minuta*, native to areas of temperate and subtropical America (Banfi & Galasso, 2010), seems to prefer the spaces between the stems of *Myriophyllum aquaticum*, where the flow is lower, as reported also by Hussner & Lösch (2005) for the River Erft (Germany). This species is considered invasive in Italy and in many parts of Europe and Asia (Iberite *et al*., 2011), and communities dominated by *Lemna minuta* were reported for several Italian sites, e.g. in natural pools

Tab. 7 - Vegetation of the class *Isoëto-Nanojuncetea.*

Rel. number	1	2
Cover (%)	100	65
Area (sqm)	1	1
Locality	LN	FA
Cyperus fuscus community		
Cyperus fuscus L.	5	4
Charact. of upper units		
Ranunculus sardous Crantz	.	+
Other species		
Phragmites australis (Cav.) Trin. ex Steud.	1	+
Cirsium vulgare (Savi) Ten.	2	.
Ranunculus sceleratus L.	.	1
Juncus articulatus L.	1	.
Helosciadium nodiflorum (L.) W. D. J. Koch	+	.
Carex riparia Curtis	.	+
Cyperus eragrostis Lam.	+	.
Eupatorium cannabinum L. subsp. cannabinum	.	+
Lycopus europaeus L.	+	.
Persicaria lapathifolia (L.) Delarbre subsp. lapathifolia	+	.
Veronica beccabunga L.	+	.
Alnus glutinosa (L.) Gaertn. (pl.)	r	.
Hypericum tetrapterum Fr.	r	.

"Cave Faschetta" (Piedmont, Northern Italy, Iamonico *et al.* 2012), in pools or ditches in Rome (Lazio, Central Italy, Iberite *et al.* 2008), or in the Lake Trasimeno (Umbria, Central Italy, Landucci *et al.* 2011). Landucci *et al.* (2011) classified the communities with *L. minuta* as *Lemnetum minuto-gibbae* Liberman Cruz, Pedrotti & Venanzoni 1988, to which also the relevés of Lake Porta were here referred.

To be mentioned the occurrence of *Pistia stratiotes* L. in the study area (although not sampled in the relevés); this species often shows an invasive behaviour (see Brundu *et al.*, 2012), and thus its presence in the study area should be carefully monitored.

Hygrophilous therophytic vegetation

Communities dominated by *Cyperus fuscus* (Tab. 7) were observed throughout the paths alongside the lake or in small, muddy patches emerging in the summer at the edge of helophytic vegetation.

It is known that the pioneer attitudes of *Cyperus fuscus* lead it to rapidly colonize areas temporarily devoid of plants and to take advantage from human activities such as banks remodelling (see Venanzoni & Gigante, 2000). This characteristic is confirmed also in the study area, where its stands were subject to many disturbance factors. According to Šumberová & Hrivnák (2013), *Cyperus fuscus*, is a characteristic and dominant species of the *Cyperetum micheliani* Horvatić 1931, an association typical of the natural and artificial wetlands characterized by a strong degree of disturbance and rapid desiccation. The Lake Porta's communities could be considered as an impoverished form of this association.

Swampy helophytic vegetation

The vegetation dominated by helophytes was found along the banks of the canals, in the marshy areas of Lake Porta, in variously flooded depressions and in the clearings of the swampy woods.

In the marshy areas of Lake Porta, the dominant type of vegetation resulted the *Phragmitetum australis* Savic 1926 nom. mut. propos. Šumberová *et al.* in Chytrý 2011 (Tab. 8, rel. 1-5), which covered large areas of the lake's basin and is interrupted only by a few open zones. This association was already considered as expanding by Tomei & Garbari (1981) and Tomei *et al.* (1998), supplanting other helophyte communities such as those dominated by *Cladium mariscus* (Sani & Lombardi, 2005). The association grew in situations of prolonged submersion, forming dense pauci-or even monospecific stands. In more dried conditions, the association was characterized by an increase of nitrophilous species, as already noted by Gigante *et al.* (2013) for the Lake Trasimeno in Umbria.

In such ecological conditions, the association *Iridetum pseudacori* Eggler ex Brzeg & Wojterska 2001 (Tab. 8, rel. 6-7) develops too. This association finds its optimum on substrates which are subjected to prolonged submersion in winter and which dry up in summer (Landucci *et al.*, 2013).

The association *Caricetum acutiformis* Eggler 1933 (Tab. 9, rel. 1) was found in a small marshy area located at the edge of a black alder wood along the Fossa Fiorentina canal. The association develops typically on swampy areas with meso-eutrophic, from basic to slightly acidic waters (Landucci *et al.*, 2013).

The association *Caricetum ripariae* Máthé & Kovács 1959 (Tab. 9, rel. 2-3) was found at the edge of marshy woods and along ditches and canals, tolerating a degree of disturbance caused by the management of the banks. In the study area, this association was already mentioned by Tomei *et al.* (1998).

In some areas of Lake Porta's marshland, on the edge of the *Phragmitetum* and to a water-depth of a few centimetres, a vegetation dominated by *Carex elata* was found (Tab. 9, rel. 4-5). This was here classified as *Caricetum elatae* Koch in 1926. This association was already known for the study area (Tomei *et al.*, 1998). The *Caricetum elatae* develops typically in meso-eutrophic waters rich in carbonates characterized by a strong variation of the water level (Landucci *et al.*, 2013). In the study area, some of *Carex elata* stands exhibited an advanced dynamical stage testified by

Tab. 8 - Vegetation of the alliance *Phragmition communis.*

Rel. number	1	2	3	4	5	6	7
Cover (%)	100	100	100	100	100	100	80
Area (sqm)	10	16	20	20	10	10	8
Locality	FT	CC	LN	LN	FA	FT	CR
Charact. ass. *Phragmitetum australis*							
Phragmites australis (Cav.) Trin. ex Steud.	5	5	5	5	5	.	.
Charact. ass. *Iridetum pseudacori*							
Iris pseudacorus L.	+	.	.	.	.	5	5
Charact. of upper units							
Carex riparia Curtis	+	2	.	.	1	1	.
Lysimachia vulgaris L.	.	1	.	.	.	+	.
Carex acutiformis Ehrh.	+	.	.	.	.	+	.
Lythrum salicaria L.	.	.	.	.	1	.	.
Other species							
Calystegia sepium (L.) R. Br. subsp. sepium	1	.	.	.	+	.	.
Lonicera japonica Thunb.	.	.	.	.	2	.	+
Rubus ulmifolius Schott	1	.	.	.	.	.	+
Populus canescens (Aiton) Sm.	1	.	.	.	.	.	.
Equisetum arvense L. subsp. arvense	.	.	.	.	+	.	.
Bidens frondosus L.	.	.	.	.	+	.	.
Carex pendula Huds.	.	.	.	.	.	.	+
Eupatorium cannabinum L. subsp. cannabinum	.	.	.	.	+	.	.
Galium aparine L.	.	.	.	.	.	+	.
Hedera helix L. subsp. helix	.	.	.	.	.	.	+
Humulus lupulus L.	.	.	.	.	+	.	.
Poa trivialis L.	.	.	.	.	.	+	.
Solanum dulcamara L.	.	.	.	.	+	.	.
Stachys palustris L.	.	.	.	.	+	.	.
Urtica dioica L. subsp. dioica	.	.	.	.	.	+	.

the occurrence of woody species such as black alder or black poplar, which suggest a further evolution in a riparian forest.

The vegetation of the order *Nasturtio-Glycerietalia* (Tab. 10) was found in moderately rheophilus environments subjected to wide water-level fluctuations. In the study area, it was represented by three associations: *Helosciadietum nodiflori* Maire 1924 (Tab. 10 rel. 1-2), *Nasturtietum officinalis* Gilli 1971 (Tab. 10, rel. 3-4), and *Sparganietum erecti* Roll 1938 (Tab. 10, rel. 5). The first two associations have been found in shallow waters along the banks of the canals that surround the lake, sometime in spatial contact. For the study area, only the *Helosciadietum* had been reported (Tomei *et al.*, 1998, sub *Apietum nodiflori* Br. Bl. 1931). These communities have been found to be in spatial contact also in other wetlands of Central Italy (Landucci *et al.*, 2013).

The association *Sparganietum erecti* was found in some canals, in conditions of greater depth than those observed for the two phytocoenoses previously described. It is an association intermediate between *Glycerio-Sparganion* and *Phragmition* and it is quite common in Central Italy (Buchwald, 1994). It develops mostly in stagnant or slightly running water, tolerating strong fluctuations of the water level (Buchwald, 1994; Lastrucci *et al.*, 2010).

Tab. 9 - Vegetation of the order *Magnocaricetalia elatae.*

Rel. number	1	2	3	4	5	6
Cover (%)	100	100	90	90	95	95
Area (sqm)	8	4	10	4	10	4
Locality	FT	FT	FT	FA	FA	CC
Charact. ass. *Caricetum acutiformis*						
Carex acutiformis Ehrh.	5	.	.	.	.	.
Charact. ass. *Caricetum ripariae*						
Carex riparia Curtis	2	5	5	2	+	.
Charact. ass. *Caricetum elatae*						
Carex elata All.	.	.	.	4	4	.
Charact. ass. *Cyperetum longi*						
Cyperus longus L. subsp. longus	.	.	.	.	.	4
Charact. of upper units						
Lythrum salicaria L.	+	.	.	+	.	+
Iris pseudacorus L.	+	+	.	.	.	2
Lysimachia vulgaris L.	.	.	.	.	+	1
Galium elongatum C. Presl	.	.	.	.	.	2
Phragmites australis (Cav.) Trin. ex Steud.	.	.	.	.	3	.
Galium palustre L.	.	.	.	1	.	.
Schoenoplectus lacustris (L.) Palla	.	.	.	.	.	+
Teucrium scordium L. subsp. scordium	.	.	.	+	.	.
Other species						
Rubus ulmifolius Schott	+	2	1	.	.	.
Lonicera japonica Thunb.	+	2	1	.	.	.
Calystegia sepium (L.) R. Br. subsp. sepium	.	.	.	1	+	1
Alnus glutinosa (L.) Gaertn.	.	.	.	3	1	.
Populus nigra L.	.	.	.	1	2	.
Eupatorium cannabinum L. subsp. cannabinum	.	.	.	1	1	.
Periploca graeca L.	.	.	.	1	+	.
Cyperus fuscus L.	.	.	.	r	+	.
Urtica dioica L. subsp. dioica	.	+	.	+	.	.
Carex pendula Huds.	.	.	1	.	.	.
Ranunculus repens L.	.	.	.	.	.	1
Solanum dulcamara L.	.	.	.	.	.	1
Galium aparine L.	+	.	.	.	.	.
Symphyotrichum squamatum (Spreng.) G.L. Nesom	.	.	.	+	.	.
Hypericum tetrapterum Fr.	.	.	.	.	+	.
Dactylis glomerata L.	.	.	.	.	.	+
Ranunculus sardous Crantz	.	.	.	.	+	.
Ranunculus sceleratus L.	.	.	.	.	+	.
Agrostis stolonifera L.	.	.	.	.	.	+
Equisetum palustre L.	.	.	.	.	.	+
Arum italicum Mill.	.	+	.	.	.	.
Myriophyllum aquaticum (Vell.) Verdc.	.	+	.	.	.	.
Hedera helix L. subsp. helix	.	.	+	.	.	.

Tab. 10 - Vegetation of the order *Nasturtio officinalis-Glycerietalia fluitantis.*

Rel. number	1	2	3	4	5
Cover (%)	70	90	80	80	90
Area (sqm)	4	4	4	4	4
Locality	CF	FT	CF	CF	FT
Charact. ass. *Helosciadietum nodiflori*					
Helosciadium nodiflorum (L.) W. D. J. Koch	4	2	.	.	.
Charact. ass. *Nasturtietum officinalis*					
Nasturtium officinale R. Br. subsp. officinale	1	.	4	3	.
Charact. ass. *Sparganietum erecti*					
Sparganium erectum L.	.	1	.	.	4
Charact. of upper units					
Veronica anagallis-aquatica L. subsp. anagallis-aquatica	.	4	.	2	2
Phragmites australis (Cav.) Trin. ex Steud.	1	.	2	2	.
Alisma plantago-aquatica L.	.	.	.	+	.
Carex riparia Curtis	.	.	+	.	.
Other species					
Potamogeton crispus L.	.	1	.	.	.
Lemna minuta Kunth	.	.	.	.	1
Juncus subnodulosus Schrank	.	.	.	1	.
Elymus caninus (L.) L. subsp. caninus	r	.	.	.	.

Swamp woodlands

Woods dominated by *Alnus glutinosa* (Tab. 11) have been detected in several marshy areas surrounding the lake Porta. This kind of vegetation was already mentioned for the study area (see Tomei *et al*., 1998; Tomei *et al*., 2001, sub *Alnetum glutinosa*e (Janas, 1932) Meijer Drees 1936). In condition of low disturbance and of prolonged flooding, these woods were found to be rich in helophytes such as *Phragmites australis*, *Iris pseudacorus, Carex riparia* and *Carex acutiformis*. On the contrary a higher degree of disturbance and a lower permanence of water changed their floristic composition favouring the presence of hygro-nitrophilous species; the presence of numerous non-native species (*Ligustrum lucidum*, *L. sinensis*, *Euonymus japonicus*, *Lonicera japonica*) can be explained with the proximity of human settlements where the presence of gardens facilitated the spread of ornamental species in the natural surrounding areas. The few available data do not allow us to propose a syntaxonomical classification at the association rank according to the recent revision of Sburlino *et al.* (2011), mainly due to the mixture in our relevés of several species differentiating distinct black alder marsh associations. It is, however, important to confirm the presence in the study area of these lowland swamp woods, representing a rarefied and fragmented type of vegetation in Italy (Biondi & Blasi, 2013).

Additional plant communities reported in literature but not observed in this survey

The following plant communities, which are currently reported in the phytosociological literature (Tomei *et al*., 1998 and Sani & Lombardi, 2005) for the study area were not found in our study:

– acquatic vegetation: communities with *Potamogeton berchtoldii* and *Lemna trisulca*; comm. with *Elodea canadensis*; comm. with *Zannichellia palustris* and *Callitriche cophocarpa*; comm. with *Potamogeton pusillus*; *Potamo pectinati-Myriophylletum spicati* Rivas Goday 1964 (sub *Myriophylletum spicati* Soó 1927); *Lemnetum trisulcae* den Hartog 1963 (sub *Lemnetum trisulcae* Knapp & Stoffer 1962)
– helophytic vegetation: communities with *Schoenoplectus tabernaemontani*; comm. with *Equisetum palustre*
– woods*: Populetum albae* (Br. Bl. 1931) Tchou 1947

Tab. 11 - Vegetation of the class *Alnetea glutinosae.*

Rel. number	1	2	3	4
Cover (%)	90	100	100	100
Area (sqm)	150	80	100	100
Locality	FT	CC	CR	CR
Tree and shrub layer				
Alnus glutinosa (L.) Gaertn.	5	5	5	5
Sambucus nigra L.	.	.	1	1
Laurus nobilis L.	.	+	1	.
Ligustrum sinense Lour.	.	.	+	+
Ficus carica L.	.	.	2	1
Populus canescens (Aiton) Sm.	.	1	.	.
Populus nigra L.	.	.	1	.
Salix alba L.	.	.	1	.
Platanus hispanica Mill. ex Münchh.	.	1	.	.
Cornus sanguinea L.	.	.	.	1
Acer negundo L.	.	1	.	.
Euonymus japonicus L. f.	.	.	1	.
Emerus major Mill. subsp. major	.	+	.	.
Ligustrum lucidum W.T. Aiton	+	.	.	.
Ligustrum vulgare L.	.	.	.	+
Prunus sp.	.	.	+	.
Lianas and herbaceous species				
Hygrophilous species				
Iris pseudacorus L.	1	+	.	+
Carex riparia Curtis	3	1	.	.
Carex acutiformis Ehrh.	2	.	.	.
Phragmites australis (Cav.) Trin. ex Steud.	+	.	.	.
Other				
Hedera helix L. subsp. helix	+	2	4	3
Rubus ulmifolius Schott	2	+	3	5
Carex pendula Huds.	+	3	1	+
Lonicera japonica Thunb.	1	.	3	3
Equisetum arvense L. subsp. arvense	.	1	1	.
Arum italicum Mill.	+	+	.	.
Carex remota L.	.	3	.	.
Urtica dioica L. subsp. dioica	.	1	.	.
Calystegia sepium (L.) R. Br. subsp. sepium	.	2	.	.
Clematis vitalba L.	.	1	.	.
Potentilla indica (Jacks.) Th. Wolf	.	1	.	.
Humulus lupulus L.	.	.	1	.
Poa trivialis L.	.	1	.	.
Ranunculus repens L.	.	1	.	.
Galium aparine L.	.	+	.	.
Potentilla reptans L.	.	+	.	.
Ranunculus lanuginosus L.	.	+	.	.
Stellaria aquatica (L.) Scop.	.	+	.	.
Vitis sp.	.	+	.	.

Conservation issues

The survey on the vegetation of Lake Porta and the surrounding wetlands has highlighted the presence of five habitats of community importance according with the Directive 92/43/EEC (see Biondi *et al.*, 2009; Biondi *et al.*, 2012). The Habitat 3150 occurs in stagnant waters, both in the lake and in the surrounding ponds and canals; the Habitat 3260 occurs in the slow running waters of some canals; in particular some aspects with *Callitriche* (especially *Callitriche cophocarpa*) seem occur in areas characterized by a relatively low human disturbance; Habitat 3140 is represented only by the communities of *Chara vulgaris.*

Almost all the aquatic communities are subject to invasion by *Myriophyllum aquaticum*, an issue that could lead in future to a homogenization and trivialization of these habitats. According to Bolpagni (2013), it is possible to consider a plant community dominated by alien species as a habitat of conservation concern when it allows to preserve important ecosystem functions or constitutes a *refugium* for endangered species. For the study area, our data does not allow us to evaluate all the different components of the ecosystem's functions. Nonetheless the invasion of *Myriophyllum aquaticum* seems to impoverish or modify the native plant communities, drastically lowering the quality of the habitat itself. Similarly, a low conservation value is to be assigned to the aspects belonging to the Habitat 3150, consisting in the *Lemna minuta* communities.

Habitat 3130 appears poorly represented. It is characterised by small, pioneer communities of *Cyperus fuscus* which, at least for the moment, seem to be less affected by the invasion of non-native species. These should nonetheless to be closely monitored, owing to the *Myriophyllum aquaticum*'s ability to expand itself even in terrestrial areas.

The forest habitat type in the study area consists of swampy woods dominated by black alder, referred to the priority Habitat 91E0. In areas with lower disturbance, this habitat appears in its most typical form, while in the areas closer to urbanized zones, an impoverishment of the hygrophilous flora and the presence of alien species occur.

It is also worth mentioning the presence of a regionally important habitat, in accordance with Tuscan Regional Law LR 56/2000, such as the helophytic communities referred to the alliance *Glycerio-Sparganion*. Especially for communities dominated by small-sized species such as *Helosciadium nodiflorum* or *Nasturtium officinale*, the risk of invasion by *M. aquaticum* exists and, while waiting for the removal of this species, proper monitoring would be necessary to prevent the habitat's loss or trivialization.

SYNTAXONOMIC SCHEME

CHARETEA FRAGILIS F. Fukarek ex Krausch 1964
CHARETALIA HISPIDAE Sauer ex Krausch 1964
Charion vulgaris (Krause ex Krause & Lang 1977) Krause 1981
Charetum vulgaris Corillion 1957

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
UTRICULARIETALIA MINORIS Den Hartog & Segal 1964
Ceratophyllion demersi Den Hartog & Segal ex Passarge 1996
Ceratophylletum demersi Corillion 1957

POTAMETEA PECTINATI Klika in Klika & Novák 1941
POTAMETALIA PECTINATI Koch 1926
Potamion pectinati (W. Koch 1926) Libbert 1931
Myriophylletum verticillati Gaudet ex Šumberová in Chytrý 2011
Potametum pectinati Carstensen ex Hilbig 1971
Potametum crispi Soó 1927
var. a *Myriophyllum aquaticum*
Myriophyllm aquaticum community
Nymphaeion albae Oberdorfer 1957
Nymphaeo albae-Nupharetum luteae Nowiñski 1927 nom. mut. propos. Šumberová in Chytrý 2011
Ranunculion aquatilis Passarge 1964
Lemno-Callitrichetum cophocarpae (Mierwald 1988) Passarge 1992
var. a *Myriophyllum aquaticum*
Callitriche stagnalis and *Myriophyllum aquaticum* community
ISOËTO-NANOJUNCETEA Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946
NANOCYPERETALIA FLAVESCENTIS Klika 1935
Nanocyperion flavescentis Koch ex Libbert 1932
Cyperus fuscus community

PHRAGMITO AUSTRALIS-MAGNOCARICETEA ELATAE Klika in Klika & Novák 1941
PHRAGMITETALIA AUSTRALIS Koch 1926
Phragmition communis Koch 1926
Phragmitetum australis Savič 1926 nom. mut. propos. Šumberová *et al.* in Chytrý 2011
Iridetum pseudacori Eggler ex Brzeg et Wojterska 2001
MAGNOCARICETALIA ELATAE Pignatti 1953
Magnocaricion elatae Koch 1926
Caricetum elatae Koch 1926
Caricetum acutiformis Eggler 1933
Caricion gracilis Neuhäusl 1959
Caricetum ripariae Máthé et Kovács 1959

Cyperetum longi Micevski 1957
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
Helosciadietum nodiflori Maire 1924
Nasturtietum officinalis Gilli 1971

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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