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Contribution to the knowledge of aquatic vegetation of montane and submontane areas of Northern Apennines (Italy)

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Abstract

The importance of wetlands for biodiversity conservation is widely recognized. Their relevance is crucial in the identification of habitat types included in the Habitats Directive 92/43/EEC and in the application of the following conservation measures. Yet, several montane and submontane areas are poorly investigated from the phytosociological point of view. Here we studied aquatic communities of the Tuscan-Romagna Apennines in Italy using 52 vegetation plots dominated by hydrophytes collected in wetlands of natural and artificial origin. We analysed our data using a cluster analysis and identified 12 vegetation types that we classified as three vegetation classes *Charetea intermediae*, *Lemnetea* and *Potamogetonetea*, and two habitat types of conservation importance, as the hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. (Natura 2000 code 3140) and the natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* (Natura 2000 code 3150). Our study highlights the diversity of aquatic habitats in montane and submontane areas of the Northern Apennines where water bodies are generally small and scattered. This study further highlights the important role of natural freshwater ecosystems for vegetation, but also the notable role of partly or entirely artificial water bodies in maintaining aquatic communities.

Keywords

conservation, freshwater ecosystem, habitat, hydrophyte, phytosociology, syntaxonomy, vegetation

Introduction

Aquatic habitats are highly relevant for plant diversity conservation, especially considering the worldwide degradation of natural aquatic ecosystems and their species richness decline (Hrivnák et al. 2014). Wetlands are crucial for the conservation of biodiversity, as they provide suitable habitats for numerous threatened plant and animal species (Zhang et al. 2012). Despite that, due to man-driven pressures and threats, they are among the most threatened habitats in the world (Dudgeon et al. 2006). In Europe, including Italy, freshwater ecosystems include a high proportion of threatened habitats in an unfavourable conservation status due to fragmentation, surface reduction, floristic impoverishment, and alien species invasion (Janssen et al. 2016; Zivkovic et al. 2017; Gigante et al. 2018; Gennai et al. 2020; Lazzaro et al. 2020; EEA 2020; Viciani et al. 2020). Moreover, several wetland plant communities of conservation importance are not included in the Habitats Directive, nor in other protection lists, despite being

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extremely rare in the Mediterranean Basin (Gigante et al. 2013; Benavént-Gonzales et al. 2014; Lastrucci et al. 2014, 2017; Angiolini et al. 2017). In Italy, there is a contrasting pattern of frequency of wetlands between Alps and Apennines. While the Alps are relatively rich in wetlands, the Apennines are rather poor in freshwater ecosystems. The latter ones are also often fragmented and floristically impoverished, due the progressive loss of hygrophilous boreal species along the north-south gradient (Angiolini et al. 2019). Moreover, especially at relatively low elevations, many Apennine wetlands result in being widely associated with anthropogenic activities, being partially or totally of artificial origin (Gerdol and Tomaselli 1993).

In this context, phytosociological investigations of freshwater plant communities are essential for determining habitat types, typical species, and, finally, prioritisation of conservation (Biondi et al. 2012; European Commission 2013; Viciani et al. 2014, 2016; Gigante et al. 2016, 2018; Bonari et al. 2021). In the northern and central Apennines the literature available focused mostly on montane wetlands (Gerdol and Tomaselli 1993; Tardella and Di Agostino 2020, and references therein), and on montane fluvial systems (Arrigoni and Papini 2003; Foggi et al. 2011). On the contrary, only a few, local studies have been carried out on the wetland communities of the eastern part of the mountains between Tuscany and Romagna (Lastrucci et al. 2005, 2006), some of which did not use the phytosociological approach (e.g. Raffaelli 1971), or without published relevés (e.g., Buldrini et al. 2017). With the aim of filling the mentioned gap of knowledge, we investigated aquatic vegetation of small submontane and montane wetlands of natural and artificial origin in Tuscan-Romagna Apennines.

Materials and methods

Study area

The study area lies in the north-eastern Apennines between Tuscany and Emilia-Romagna regions (Central Italy, Fig.1). The area encompasses 45 wetlands sites, ranging from 535 m a.s.l. to 1,470 m a.s.l., mainly located in Tuscany in the Foreste Casentinesi National Park and some other Special Areas of Conservation of the Natura 2000 network. These wetlands of natural and artificial origin are of different sizes and include lakes, small ponds, and pools. They are mostly located in forest areas. Depending on elevation, the climate is generally submontane/montane, with moderate temperatures and moderate to heavy rainfall. At higher elevations, a temperate oceanic bioclimate is found, while there is a temperate oceanic-sub-Mediterranean bioclimate at lower elevations (Pesaresi et al. 2017). As to geological substrates, there are four main geological formations in the area: three on

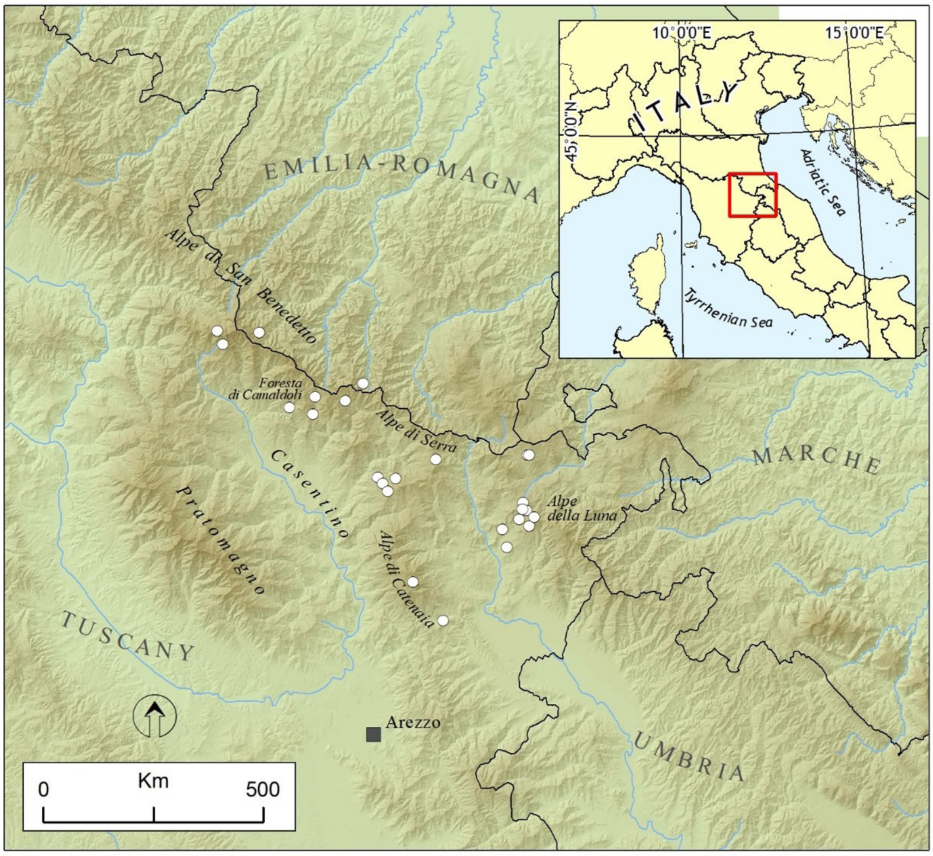

Figure 1. Study area and its position in respect to Italy (inset in the upper right corner). White circles are the sampled sites (N = 23).

the Tyrrhenian-facing slopes, with two types of siliceous sandstones ("Macigno of Mugello" and "Macigno of Chianti"), encompassing different percentages of limestone and silty schists, and some solid limestone outcrops ("Alberese"), and one on the Adriatic-facing slopes ("Marnoso-Arenacea"), with widespread sandstone-marly flysch formations. Other less extensive geological formations are also present, such as the peculiar ultramafic outcrops of High Tiber Valley (Carmignani et al. 2013).

Data set and data analysis

Our dataset is composed of all the published (N = 6) and unpublished (N = 46) relevés dominated by hydrophytes from the area. It includes 23 sampling localities. The published data include small wetlands in the high Marecchia Valley (Lastrucci et al. 2005; N = 4) and on ultramafic soils in the upper Tiber Valley (Lastrucci et al. 2006; N = 2). The new data were collected between 2005-2019 following the phytosociological method (Braun Blanquet 1932). Further site information is available in Appendix.

We analysed a matrix of 52 relevés × 38 species using a cluster analysis in R environment (R Core Team 2020). We used the chord distance of the function vegdist of vegan package (Oksanen et al. 2020) and median linkage of the function hclust of R.

Plant species names mainly follow the Portal to the Flora of Italy (2021), while the syntaxonomic nomenclature of classes, orders and alliances, including the names derived from the genus *Potamogeton*, follows Mucina et al. (2016). Association names follow Chytrý (2011). The names of the syntaxa agree with the 4th edition of the ICPN (Theurillat et al. 2021).

Results and discussion

The dendrogram resulting from the cluster analysis (Fig. 2) allowed us to identify 12 different communities. From a syntaxonomic view point they can be classified as three different classes corresponding to *Charetea intermediae*, *Lemnetea* and *Potamogetonetea*. We elaborate in more detail these communities below.

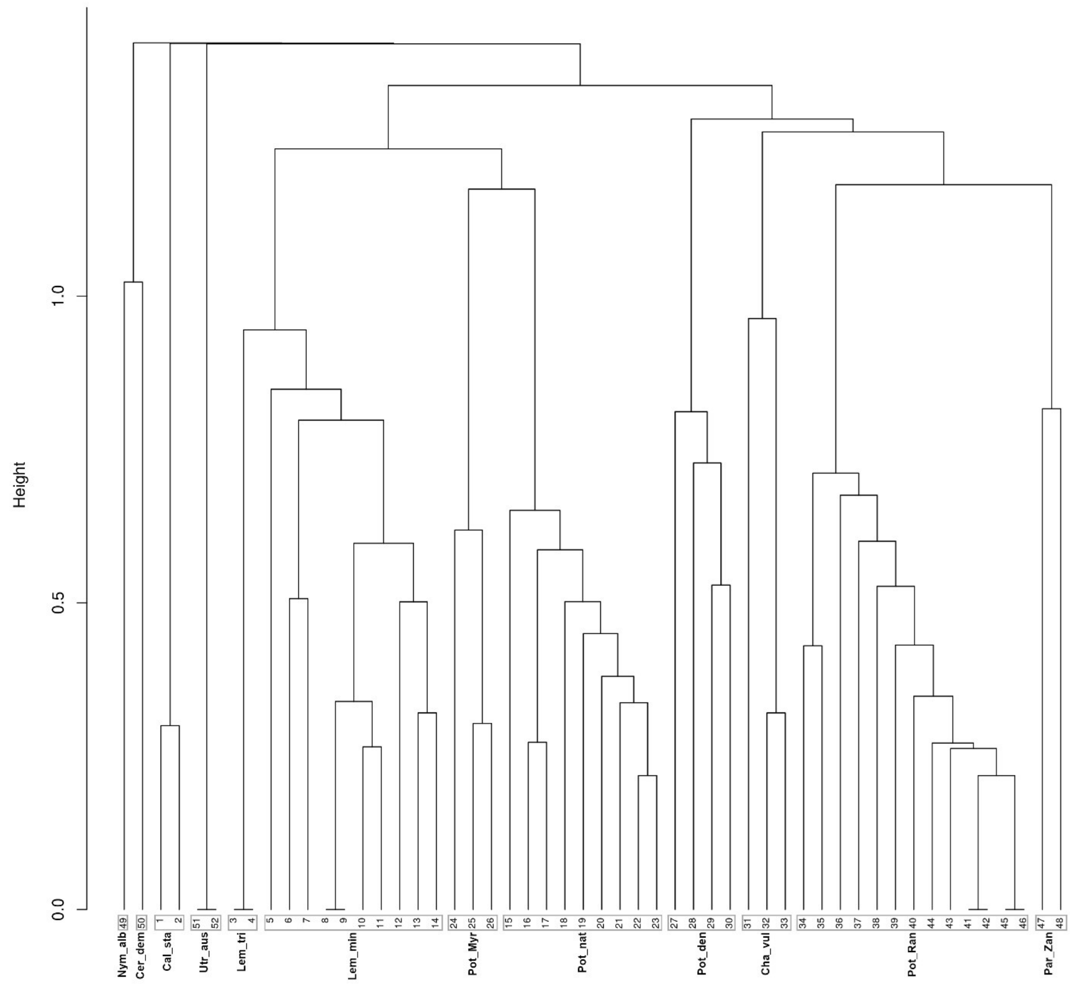

Figure 2. Cluster dendrogram of our data encompassing 52 relevés of aquatic vegetation of montane and submontane areas of Northern Apennines (Italy).

Aquatic vegetation communities

CHARETUM VULGARIS Corillion 1957 (Table 1, rels 1–3; Cha_vul, rels 31–33 in Fig. 2)

The communities dominated by *Chara vulgaris* occur in stagnating and slow running, eutrophic, shallow and medium deep waters (Hrivnák 2002; Hrivnák et al. 2005) and can be classified to the association *Charetum vulgaris*. Due to the broad ecological amplitude of the dominant species, the association can be found in very different habitat types (Šumberová et al. 2011), including disturbed and polluted ones, sometimes even subject to desiccation. In the study area, we found mainly the typically species-poor expressions of this association, developing in clear and relatively shallow water bodies. However, we also report a variant co-dominated by *Zannichellia palustris* (rel. 2 in Table 1) where advanced drying up conditions are present. Here, the presence of small helophytes and other hygrophilous species underlines a transition towards other vegetation types.

LEMNETUM MINORIS Soó 1927 (Table 2, rels 1–10; Lem_min, rels 5–14 in Fig. 2)

Lemna minor-dominated communities can be classified to the association *Lemnetum minoris*. These communities are rather common in Europe, including Italy, developing in several habitat types, due the broad ecological range of *L. minor*. This community often forms mono- or paucispecific stands (Sburlino et al. 2004; Šumberová 2011a; Caldarella et al. 2021). Several authors (e.g. Rivas-Martínez et al. 2001; Makra 2005; Hrivnák and Csiky 2009; Šumberová 2011a) classify this vegetation type to the association *Lemnetum minoris* Soó 1927 (syn. *Lemnetum minoris* Oberd. ex Th. Müller et Görs 1960), reporting it from different types of eutrophic water bodies except very large ones, where the species might be disturbed by the actions of the waves (Šumberová 2011a; Zervas et al. 2020). Nevertheless, given the wide sociological and ecological value of the dominant species, other authors consider the communities of *L. minor* only as a basal phytocoenon (Scoppola 1982; Pott 1992; Sburlino et al. 2004). *L. minor* tends to form rather poor communities, often mixing up with the communities of the class *Potamogetonetea*. Some of our relevés (rels. 4–6) can be seen as transitional aspects towards the association *Potamogetonetum natantis*. This is in agreement with previous Tuscan vegetation studies (Lastrucci et al. 2010, 2012).

Table 1. *Charetea intermediae* F. Fukarek 1961.

Rel. n.	1	2	3
Site reference	A	C	C
Relevé area (m²)	10	4	2
Total cover (%)	100	100	90
Number of species	1	2	9
Number in the dendrogram	33	32	31
Charetum vulgaris			
Chara vulgaris L.	5	5	3
Other species			
Ranunculus trichophyllus Chaix	.	1	.
Zannichellia palustris L.	.	.	3
Veronica beccabunga L.	.	.	2
Alisma plantago-aquatica L.	.	.	1
Equisetum palustre L.	.	.	1
Ranunculus repens L.	.	.	1
Juncus inflexus L.	.	.	+
Mentha aquatica L. subsp. *aquatica*	.	.	+

LEMNETUM TRISULCAE den Hartog 1963 (Table 2, rels 11–12; Lem_tri, rels 3–4 in Fig. 2)

The association *Lemnetum trisulcae* was found in a small pond (Lastrucci et al. 2005, sub *Lemnetum trisulcae* Knapp et Stöffer 1962). The association *Lemnetum trisulcae* is typical of mesotrophic to eutrophic still water bodies, especially in alluvial pools with clear water (Šumberová 2011a).

In the study area, in agreement with literature, the community develops under the water surface covered by a floating layer of *Lemna minor* (Buchwald 1994; Šumberová 2011a). This association is particularly important from the conservation viewpoint as *Lemna trisulca* is a rare species in the study area. The sampled locality represents the only site known in the Arezzo province (Viciani et al. 2021).

UTRICULARIETUM AUSTRALIS Müller et Görs 1960 (Table 2, rels 13–14; Utr_aus, rels 51–52 in Fig. 2)

The association *Utricularietum australis* is typical of mesotrophic to naturally eutrophic water bodies such as small fishponds, alluvial pools and oxbows. The community can be found also on newly established wetlands (Šumberová 2011a). This is confirmed also in the study area, where the association *Utricularietum australis* was found in a rather recently restored wetland. At the site, the species *Utricularia australis* has progressively become more abundant over the last ten years. We sampled rather dense stands during our survey. Interestingly, the species was recorded also in a nearby wetland (Peruzzi et al. 2017), where, however, the species does not form an autonomous community as it competes with a layer of other hydrophytes, especially *Lemna minor* and *Potamogeton natans*.

CERATOPHYLLETUM DEMERSI Corillion 1957 (Table 2, rel. 15; Cer_dem, rel. 50 in Fig. 2)

The association *Ceratophylletum demersi* was reported in a small lake on ultramafic substrates (Lastrucci et al. 2006), where it occupies the central and deeper areas of the lake, forming dense mats along the entire water column, due the ability of the dominant species to grow under poor light condition (Zervas et al. 2020). In the study area, the stands of the association *Ceratophylletum demersi* are situated in contact with the communities of *Nymphaea alba* which, on the contrary, occupy areas with shallow waters. The presence of *Ceratophyllum demersum* at this site, however, has reduced over the time, probably due to the abandonment of human management or the presence of alien animal species observed during our field surveys (e.g., the red swamp crayfish).

Table 2. *Lemnetea* O. de Bolòs et Masclans 1955.

Rel. n.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Site reference	Pr	G	G	G	G	G	T	T	MC	G	Pi	Pi	LI	LI	LPe
Relevé area (m²)	1	5	4	4	2	2	4	4	4	4	1	1	4	4	10
Total cover (%)	20	100	95	100	100	100	95	80	100	100	100	100	100	90	90
Number of species	6	5	5	2	2	3	2	3	2	1	2	2	1	1	1
Number in the dendrogram	5	6	7	8	9	10	11	12	13	14	3	4	51	52	50
Lemnetum minoris															
Lemna minor L.	2	5	5	4	4	5	5	4	5	5	3	3	.	.	.
Lemnetum trisulcae															
Lemna trisulca L.	.	.	.	.	.	.	.	.	.	.	4	4	.	.	.
Utricularietum australis															
Utricularia australis R. Br.	.	.	.	.	.	+	.	.	.	.	.	.	5	5	.
Ceratophylletum demersi															
Ceratophyllum demersum L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Other species															
Potamogeton natans L.	.	.	.	3	3	2	1	1	.	.	.	.	.	.	.
Ranunculus trichophyllus Chaix	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.
Galium palustre L. subsp. *palustre*	.	2	+	.	.	.	.	.	.	.	.	.	.	.	.
Phragmites australis (Cav.) Trin. ex Steud.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.
Equisetum arvense L.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Juncus articulatus L.	+														
Equisetum palustre L.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Nasturtium officinale R.Br. subsp. *officinale*	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus repens L.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Veronica beccabunga L.	+														
Carex remota L.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.

NYMPHAEETUM ALBAE Vollmar 1947 (Table 3, rel. 1; Nym_alb, rel. 49 in Fig. 2)

According to several authors (Šumberová 2011b; Zervas et al. 2020), Nymphaea alba dominated stands can be classified to the association *Nymphaeetum albae* Vollmar 1947, typical of mesotrophic to eutrophic oxbows and alluvial pools. During vegetation succession, it replaces submerged vegetation and contributes to the terrestrialisation of shallow water bodies (Šumberová 2011b). This association was reported (sub Myriophyllo verticillati-Nupharetum lutei Koch 1928) in a small lake on ultramafic substrates (Lastrucci et al. 2006). This community has dramatically reduced over time.

POTAMOGETONETUM NATANTIS Hild 1959 (Table 3, rels 2–10; Pot_nat, rels 15–23 in Fig. 2)

Our relevés can be classified to the association *Potamogetonetum natantis*, typical of mostly mesotrophic, but also oligotrophic or eutrophic water bodies with 20–100 cm deep, still or slowly moving waters (Šumberová 2011b). *Potamogeton natans* seems to be the more widespread rhizophyte with emergent leaves in the study area. It tends to form pauci- or monospecific stands, often occupying the entire surface of small pools or ponds. *P. natans* dominated communities seem to be rather common also in other wetlands of central Apennines (Buchwald 1994).

POTAMOGETONETUM DENSO-NODOSI O. Bolòs 1957 (Table 3, rels 11–14; Pot_den, rels 27–30 in Fig. 2)

Potamogeton nodosus is able to form stands in stagnant or slow running waters and in markedly fast-moving conditions (Ceschin and Salerno 2008; Landucci et al. 2011; Mereu et al. 2012; Lastrucci et al. 2012, 2014). Comparing with *P. natans* communities, this species forms stands in deeper and larger water bodies in the study area, producing both submerged and floating communities. We classified our data to the association *Potamogetonetum denso-nodosi*, reported for several habitat types such as eutrophic low-running waters of rivers, channels, reservoir, pits and ponds with fine-textured or also gravelly beds covered by organic matter (Ninot et al. 2000; Info Flora 2021).

POTAMOGETONO PECTINATI-MYRIOPHYLLETUM SPICATI Rivas Goday 1964 (Table 3, rels 15–17; Pot_Myr, rels 24–26 in Fig. 2)

In the study area, the association P*otamogetono pectinati-Myriophylletum spicati* was found at only one site. The association is in contact with the association *Potamogetonetum natantis* Hild 1959, which occurs in deeper water. This association (syn. *Myriophylletum spicati* Soó 1927 nom. nud.) can develop in different wetland types tolerating turbidity, drying and human disturbance (Šumberová 2011b; Zervas et al. 2020).

PARVO-POTAMOGETONO-ZANNICHELLIETUM PEDICELLATAE Soó 1947 (Table 3, rels 18–19; Par_Zan, rels 47–48 in Fig. 2)

The association *Parvo-Potamogetono-Zannichellietum pedicellatae* (syn. *Zannichellietum palustris* Lang 1967) includes monodominant stands of *Zannichellia palustris* or mixed stands of this species with narrow-leaved *Potamogeton* s.l. species such as *Stuckenia pectinata* or *Potamogeton pusillus* (Šumberová 2011b). We found this as-

Table 3. *Potamogetonetea* Klika in Klika et Novák 1941.

Rel. n.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Site reference	LPe	Cam	Pi	Pi	PS	T	T	Me	Mv	T	LV	Cast	Cast	Cast	Me	Me	Me	Poz	Poz	Be	Cam	ErN	To	T	LPi	Be	PS	St	Prt	Prt	Mv	PS	PStr	PStr
Relevé area (m²)	10	4	2	1	4	1.5	1.5	16	16	3	4	10	10	6	9	4	4	4	4	6	4	1	1	4	1	4	4	16	4	4	2	4	4	2
Total cover (%)	100	50	80	50	100	95	90	80	80	95	70	80	80	80	100	100	100	100	100	100	100	60	70	100	95	80	100	85	100	90	80	100	100	100
Number of species	3	5	4	4	4	6	2	3	2	1	5	4	5	5	2	3	1	5	3	5	2	2	4	4	3	3	2	2	2	2	1	1	3	2
Number in the dendrogram	49	15	16	17	18	19	20	21	22	23	27	28	29	30	24	25	26	47	48	34	35	36	37	38	39	40	44	43	41	42	45	46	1	2
Nymphaeetum albae																																		
Nymphaea alba L.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogetonetum natantis																																		
Potamogeton natans L.		5	4	3	5	5	5	5	5	5	.	.	.	.	3	+	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Potamogetonetum denso-nodosi																																		
Potamogeton nodosus Poir.	.	.	.	.	.	.	.	.	.	.	4	4	4	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogetono pectinati-Myriophylletum spicati																																		
Myriophyllum spicatum L.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	4	5	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Parvo-Potamogetono-Zannichellietum pedicellatae																																		
Zannichellia palustris L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogetono crispi-Ranunculetum trichophylli																																		
Ranunculus trichophyllus Chaix	.	1	1	1	1	+	1	.	.	.	.	2	.	1	.	.	.	3	.	5	4	3	4	5	5	5	5	5	5	5	5	5	.	.
Callitriche stagnalis community																																		
Callitriche stagnalis Scop.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5
Other species of Potamogetonetea and subordinated syntaxa																																		
Najas major All.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Callitriche palustris L.	.	.	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton crispus L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Other species																																		
Mentha aquatica L. subsp. *aquatica*	.	.	.	.	.	+	.	.	.	.	.	+	+	.	.	+	.	.	.	.	.	.	+	.	.	1	.	.	+	+	.	.	.	.
Juncus articulatus L.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	+	.	+	.	.	+	.	1	.	.	.	.	.	.	.	.	.
Lemna minor L.	.	+	.	.	1	.	.	.	+	.	.	.	.	.	.	.	.	+	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Alisma plantago-aquatica L.	.	.	.	.	.	r	.	.	.	.	+	.	.	.	.	.	.	.	.	1	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Eleocharis palustris (L.) Roem. et Schult. subsp. *palustris*	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	+	.	.	2	.	.	+	.	.	.	.	.	.	.	.
Chara vulgaris L.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.
Glyceria notata Chevall.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.
Galium palustre L. subsp. *palustre*	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phragmites australis (Cav.) Trin. ex Steud.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alisma lanceolatum With.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Peplis portula L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+
Sparganium erectum L. s.l.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Equisetum palustre L.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Veronica beccabunga L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Agrostis stolonifera L.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cardamine amara L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
Chara sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Juncus effusus L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lycopus europaeus L.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ceratophyllum demersum L.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nasturtium officinale R.Br. subsp. *officinale*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

sociation in different habitat types, often in very shallow, eutrophic to hypertrophic and turbid waters, related to the nitrophilous character of *Z. palustris* (Ceschin and Salerno 2008). In the study area, *Z. palustris* stands are present only in small pools, developing in very shallow waters of a few centimeters in contact with *Ranunculus trichophyllus* vegetation or with the helophytes of the surrounding belts. According to several authors (e.g., Biondi and Blasi 2015; Mucina et al. 2016) vegetation with *Zannichellia* sp. pl. should be classified to syntaxa typical of mainly coastal meso-eutrophic brackish waters of the alliance *Zannichellion pedicillatae*. However, the alliance *Zannichellion pedicellatae* communities can reach inland areas as a result of pollution and eutrophication which, in our case, could be caused by the presence of livestock (Biondi and Blasi 2015; Preislerová et al. 2022).

POTAMOGETONO CRISPI-RANUNCULETUM TRICHOPHYLLI Imchenetzky 1926 (Table 3, rels 20–32; Pot_Ran, rels 34–46 in Fig. 2)

Ranunculus trichophyllus is one of the more common hydrophytes in the study area and can be found in several habitat types, such as in flowing and in standing waters (Lastrucci et al. 2014 and references therein). However, the species seems to prefer small shallow ponds visited by livestock and are subject to strong summer drying. The species often forms rather dense, species-poor stands, belonging to the association *Potamogetono crispi-Ranunculetum trichophylli* (syn. *Ranunculetum trichophylli* Soó 1927), typical of oligo-mesotrophic to eutrophic waters and tolerates high levels of turbidity (Šumberová 2011b). The association tolerates strong water level variations and can live for a short time even in complete emersion.

CALLITRICHE STAGNALIS community (Table 3, rels 33–34; Cal_sta, rels 1–2 in Fig. 2)

Callitriche stagnalis community occurs in small pools, subject to almost total drying in the summer season and disturbed by the trampling of wild and farmed animals, especially horses. The community is represented by species-poor stands in which *Callitriche stagnalis* has high cover values. The ecological features of this community suggest classifying it to the *Ranunculion aquatilis* alliance.

Conclusion and nature conservation implications

Several vegetation types identified in the study area can be referred to as habitats of conservation interest (Biondi et al. 2009, 2012). Though generally small and partially of artificial origin, the investigated wetlands are crucial to increase species and habitat diversity (Landi et al. 2009; Viciani et al. 2010, 2018) and to support a habitat network able to preserve the hygrophilous species assemblages of the mountain wetland systems of woody environments (Flinn et al. 2008; Angiolini et al. 2019).

The assignment of vegetation types to habitat types included in the Habitats Directive 92/43/EEC is not always straightforward. For example, species of the genus *Chara* can be found in different vegetation types. However, this does not assure the presence of the habitat Natura 2000 code 3140 "Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp." (Guarino et al. 2019). In our study, the investigated communities are ecologically and physiognomically referable to the class *Charetea intermediae*. Though extremely species-poor and fragmented, the *Chara vulgaris* communities present in a few clear pools can thus be referred to the habitat code 3140.

Almost all vegetation types belonging to the *Lemnetea* and *Potamogetonetea* classes we report here can be assigned to the habitat Natura 2000 code 3150 "Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*" (Fig. 3). Though the investigated water bodies are generally small, the assignment of the vegetation types to this

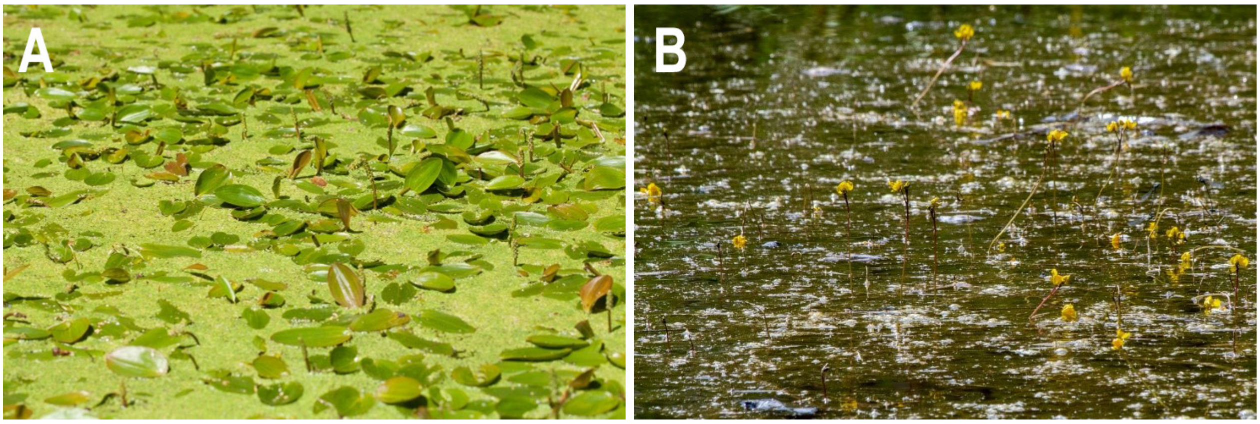

Figure 3. *Lemnetum minoris* Soó 1927 community with *Lemna minor* L. and *Potamogeton natans* L. (A) and *Utricularietum australis* Müller et Görs 1960 community with *Utricularia australis* R. Br. (B). Both communities can be referred to the habitat 3150 "Natural euthrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation" in the study area. Photo credit: (A) G. Bonari, 2016; (B) R. Sauli, 2019.

habitat is clear, for their ecological and floristical features. Accordingly, many of the dominant species of the investigated communities are listed among the diagnostic species of the habitat code 3150 (Biondi et al. 2009).

The interpretation of the communities with *Ranunculus trichophyllus* and *Callitriche stagnalis* for conservation purpose is critical. These species are listed among the diagnostic species of the habitat Natura 2000 code 3260 “Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation” (Biondi et al. 2009), but in ecological conditions of almost stagnant water, with a very reduced flow, it is rather common to find an admixture of species of the alliances *Ranunculion aquatilis* and *Potamogetonion*. Nevertheless, the classification of our communities to the habitat code 3260 appears inappropriate, because this habitat is rather related to running water with seasonal water fluctuations. As a matter of fact, to discriminate between habitats 3150 and 3260, the prevalence of the ecological criterion over the floristical one is generally preferred (Rivieccio et al. 2021).

Our study highlights the diversity of montane and submontane aquatic habitats of Northern Apennines. Interestingly, this diversity is hosted in natural and non-natural wetlands thus suggesting that conservation of azonal aquatic vegetation, when carefully planned and at favourable environmental conditions, can be, to some extent, pursued also by means of (semi-)artificial wetlands.

Syntaxonomic scheme

CHARETEA INTERMEDIAE F. Fukarek 1961
CHARETALIA INTERMEDIAE Sauer 1937
Charion vulgaris (W. Krause et Lang 1977) W. Krause 1981
Charetum vulgaris Corillion 1957

LEMNETEA O. de Bolòs et Masclans 1955
LEMNETALIA MINORIS O. de Bolòs et Masclans 1955
Lemnion minoris O. de Bolòs et Masclans 1955
Lemnetum minoris Soó 1927
Lemnetum trisulcae den Hartog 1963
Utricularion vulgaris Passarge 1964
Utricularietum australis Müller et Görs 1960
Stratiotion Den Hartog et Segal 1964
Ceratophylletum demersi Corillion 1957

POTAMOGETONETEA Klika in Klika et Novák 1941
POTAMOGETONETALIA Koch 1926
Nymphaeion albae Oberd. 1957
Nymphaeetum albae Vollmar 1947
Potamogetonetum natantis Hild 1959
Potamogetonion Libbert 1931
Potamogetonetum denso-nodosi O. de Bolòs 1957
Potamogetono pectinati-Myriophylletum spicati Rivas Goday 1964
Zannichellion pedicellatae Schaminée, Lanjouw et Schipper ex Passarge 1996
Parvo-Potamogetono-Zannichellietum pedicellatae Soó 1947
Ranunculion aquatilis Passarge ex Theurillat in Theurillat et al. 2015
Potamogetono crispi-Ranunculetum trichophylli Imchenetzky 1926
Callitriche stagnalis community

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Appendix

Viciani et al. Contribution to the knowledge of aquatic vegetation of montane and submontane areas of Northern Apennines. Plant Sociology.

Site abbreviation	Site name	Lat (°) Long (°)	Elevation m a.s.l.	Wetland type	Reference to published data
A	Asqua	43.796964, 11.782587	727	Small lake	
Be	Beccia	43.708008, 11.916856	951	Small ponds	
C	Campigna	43.874481, 11.743633	1,166	Pond	
Cam	Camarelle	43.685020, 12.107370	954	Ponds	
Cast	Lago di Castelnuovo	43.646771, 12.081608	541	Lake	
ErN	Eremo Nuovo	43.819104, 11.887456	893	Small lake	
G	Gorga Nera	43.877920, 11.684562	1,29	Pond	
LI	Lago degli Idoli	43.864074, 11.691800	1,374	Small lake	
LPe	Lago delle Pescaie	43.573863, 11.988761	536	Lake	Relevés from Lastrucci et al. (2006)
LPi	Lago Pianacci	43.722407, 11.903239	628	Lake	
LV	Lago del Vinco	43.716096, 11.910387	801	Small lake	
MC	Monte Cavallo	43.674691, 12.100705	768	Ponds	
Me	Metaleto	43.789484, 11.815124	899	Small lake	
Mv	Monte Verde	43.676265, 12.122311	1,028	Small lake	
Pi	La Pianca	43.740200, 12.115532	1,03	Ponds	Relevés from Lastrucci et al. (2005)
Poz	Pozzolo	43.667496, 12.114135	910	Pond	
Pr	Pratelle	43.738875, 11.986408	969	Ponds	
Prt	Pratalino	43.720983, 11.928446	966	Small lake	
PS	Poggio Sambuco	43.691791, 12.106996	1,001	Small lake	
PStr	Pozza delle Strosce	43.614585, 11.948222	1,345	Small pond	
St	Stammerina	43.802265, 11.861270	1,11	Pond	
T	Laghetto Traversari	43.807336, 11.819495	1,077	Small lake	
To	Il Toro	43.719856, 11.951316	1,032	Pond	

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