Vegetation of the "Altipiani di Colfiorito" wetlands (central Apennines, Italy)

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Abstract

The “Altipiani di Colfiorito” catchment basin in central Italy features a wetland system of great interest for conservation, composed of seven plains. Considering that most of the relevés conducted in the past refer to one plain and date back to the 1960s, the research aim was to widen and update the vegetation knowledge in the whole wetland system. Two hundred and thirty-nine phytosociological relevés were carried out using the Braun-Blanquet method. On the basis of cluster analysis of the species data set and phytosociological interpretation, 39 vegetation types were classified, most of which of high conservation interest in central Italy, referred to the Potamogetonetea (6 communities), Bidentetea (2), Phragmito-Magnocaricetea (21), Molini-Arrhenatheretea (9), and Epilobietea angustifolii (1) classes. The new subassociation Phalaridetum arundinaceae alopecuretosum bulbosi is also described. Twenty-two communities found in the past decades by other authors were confirmed, while 17 were new records for the study area. Ten communities were attributed to four habitats of community interest according to the 92/43/EEC Directive, coded as 3150, 3260, 3270, and 6510. Twenty-four communities were not confirmed (eight of Charetea, Lemnetea minoris, and Potamogetonetea, one of Bidentetea; seven of Phragmito-Magnocaricetea; three of Scheuchzerio-Caricetea fuscae, four of Molini-Arrhenatheretea and one of Isoëto-Nanojuncetea). Three habitats of community interest (3140, 3170*, and 7230) were not confirmed.

Keywords
central Italy, habitats of community interest, humid meadows, lacustrine habitat, marshland, nature conservation

Introduction

Wetlands represent important ecosystems at the European level (Landucci et al. 2015). The central Apennine (Italy) wetland systems of tectonic-karstic basins are important hotspots of plant and animal biodiversity (Ciaschetti et al. 2020), but management abandonment and such anthropic pressures as drainage, water extraction, tillage, and excavations have greatly reduced their extent and worsened their conservation status (Pedrotti 1965, 1996, 2019; Ballelli et al. 2010; Catorci et al. 2010).

The "Altipiani di Colfiorito" catchment basin hosts one of the most important wetlands of central Italy and is highly worthy of conservation because of its landscape, plant and animal biodiversity, and ecology (Orsomando and Catorci 1998; Renzini 1998; Tardella 2007). This area includes a wetland protected by the Ramsar Convention, an Important Bird Area, three Special Areas of Conservation, and a Special Protection Area of the Natura 2000 network, according to the 92/43/EEC Directive. Since 1995, part of this wetland system has been included in the Parco di Colfiorito, a Regional Park of Umbria.

Several authors (e.g. Pedrotti 1965, 1996, 2019; Ballelli et al. 2001; Brusaferto et al. 2008; Catorci et al. 2010; Lustrucci et al. 2017a, b, 2019a) pointed out the modifications of this wetland in the past decades, which have led to the reduction in extension, worsening of conservation status or local extinction of rare and endangered plant
communities, some of which deemed habitats of community interest (Biondi et al. 2010). Moreover, this wetland system includes the Habitat “C1.6a Temperate temporary waterbody” that, although is qualified for Least Concern in the European Red List of habitats and, thus, is not deemed threatened at the European level, in Italy has a declining trend in extent and quality (Janssen et al. 2016).

Most of the studies about the vegetation of this district have been conducted at the Palude di Colfiorito, in the central part of the catchment basin, since the 1960s by Pedrotti, who published the vegetation map (Pedrotti 1975) and the related phytosociological relevés (Pedrotti 2019), which date back to the years 1963-1968, along with some new relevés (Pedrotti 2019; Pedrotti and Murrija 2020). Some other relevés at the Palude di Colfiorito have been published by Pedrotti (1979), Buchwald (1992, 1994), and Lastrucci et al. (2017a). A few relevés are available for the other wetlands (Aleffi and Cortini Pedrotti 1995; Pedrotti 2019).

Considering that the plant sociology of plant communities in the whole system of the “Altipiani di Colfiorito” had never been exhaustively analysed and that most of the relevés conducted in the past refer to the only Palude di Colfiorito and date back to the 1960s, the research goal was to classify the plant communities that compose the vegetation of the wet environments, widening and updating the vegetation knowledge of the wetland system.

Methods

Study area

The study area, known as the “Altipiani di Colfiorito”, is located between Umbria and Marche in central Italy (Fig. 1) (coordinate range 42° 59.40’–43° 04.50’ N, 12° 50.30’–12° 55.80’ E), at altitudes ranging from 750 to 810 m a.s.l., and consists of seven plains, named the Palude di Colfiorito, Piano di Colfiorito, Piano di Popola e Cesi, Piano di Annifo, Piano di Arvello, Piano di Colle Croce, and Piano di Ricciano (Appendix I).

In terms of bioclimate, the study area is in the lower supratemperate bioclimatic belt, whose thermotype is lower supratemperate and the ombrotype is lower humid (Pesaresi et al. 2017); the mean annual temperature ranges from 11 to 13 °C and the mean annual precipitation from 1000 to 1100 mm (Orsomando et al. 2000).

The geological substratum is composed of limestones and the plains are covered by lake and marshy deposits, such as gravel, clay, silty clay, and peat (Materazzi and Pieruccini 2001). Soils are deep, hydromorphic, subacid, rich in organic matter, with silty clayey texture and scarce or absent skeleton (Giovagnotti et al. 2003).

The water supply is mainly provided by rainfall, which is maximum in autumn-winter-spring and minimum in summer, while only a small part derives from some torrent waterways and small springs. This rainfall trend determines significant water level fluctuations,

Land use history and anthropic pressure

The study area has a long land use history. Artificial underground drainage systems were built about two thousand years ago by the Romans and, more recently (1458-1464) by the Da Varano Dukes. The latter, called “Botte dei Varano”, caused the complete drainage of the Piano di Colfiorito that until then had hosted a lake (Mengozzi 1781; Pedrotti 2019). Between 1492 and 1631 numerous attempts were carried out to drain the Palude di Colfiorito, by excavating and progressively enlarging the swallow holes, digging canals and ditches, but they never succeeded in the complete reclamation of the basin (Sensi 1998; Pedrotti 2019). Even in the last century, the Palude di Colfiorito was subjected to numerous attempts of reclamation to widen the extent of croplands (Lippi-Boncambi 1940; Pedrotti and Pettorossi 1968, 1969; Pedrotti 2019).

Figure 1. Location of the “Altipiani di Colfiorito” (central Italy).
Photographic documentation of the Palude di Colfiorito shows that in the 1940s-early 1950s, this wetland was almost completely flooded during the rainy part of the year, appearing as a lacustrine area surrounded by a belt of Phragmites australis and Schoenoplectus lacustris, and was indeed called Lake of Colfiorito (Brusaferro et al. 2008; Catorci et al. 2010; Pedrotti 2019). The reed was contained by flame weeding to foster the presence of anatids for hunting purposes (Brusaferro et al. 2008). The extent of the coenoses of the Phragmition communis was changeable depending on the water amount and anthropic pressure, whereas, in the outer part of the basin, there was herbaceous vegetation (Pedrotti 2019). The free waters in the central part of the basin in the mid of the reed bed hosted hydrophytic communities characterized by Potamogeton lucens, Nymphaea alba, Persicaria amphibia, and Characeae (Pedrotti 2019).

Between 1964 and 1972, the vegetation of a peat bog, composed of Eriophorum latifolium, Carex panicea, and Juncus subnodulosus communities, along with Magnocaricion elatae communities and part of Ranunculion velatini hay-meadows, were destroyed to plant a poplar (Populus canadensis) cultivation, and then drained, tilled, and subjected to peat mining (Pedrotti 1965, 1977, 2019).

From the early 1970s, when hunting was prohibited and the periodical flame weeding ceased, to the end of the 20th century, the reed doubled its surface to the detriment of hydrophytic communities and Schoenoplectetum lacustris (Pedrotti 1975; Orsomando 2002; Catorci et al. 2010), while the vegetation of Trifolio-Hordeetalia reduced its extent (Pedrotti 2019).

In the early 1990s, the thresholds of the bulkheads in front of the three main swallow holes were raised, and gaps in the helophytic vegetation were opened near the borders of the basin (Pedrotti 1996). This intervention had the positive effect of limiting the frequency of desiccation events during summer. However, in the last 20 years, the Palude di Colfiorito underwent several times desiccation, probably because of the reduction of precipitation and the increase in evapotranspiration due to the spread of the reed bed (Brusaferro et al. 2008; Catorci et al. 2010).

Since the institution of the Colfiorito Regional Park, the anthropic pressure ceased; however, the reed bed spread, closing some canals and ditches, and accumulated a great amount of litter, causing negative impacts on the wetland ecosystem (Brusaferro et al. 2008; Catorci et al. 2010). The Nymphaecetum albae spread as well, and a shrub formation now covers the area formerly covered by the peat bog vegetation (Pedrotti 2019).

Recently, Lastrucci et al. (2019a) recorded at the Palude di Colfiorito a net 18.8% increase in the surface of the reed bed between 1988 and 2012 due to the expansion of the reeds in terrestrial habitats formerly covered by different types of natural vegetation. However, they reported a retreat of the reed bed from the waterfront and an increasing fragmentation associated with the reed dieback process (Lastrucci et al. 2017b, 2019a).

The privately-owned lands occupied by humid hay meadows around the marsh, as well as in the other plains, are traditionally mown twice during the year (late June/early July and late August). The use of fertilizers in the surrounding arable lands has been deemed as the main cause of water eutrophication in the Palude di Colfiorito, where the quality of water between 2004 and 2011 was frequently considered as poor or bad, with low oxygen concentrations during summer (Regione Umbria 2015).

Data collection

We conducted 239 phytosociological relevés (years 2005-2009) using the Braun-Blanquet phytosociological method (Braun-Blanquet 1964). The species nomenclature followed Bartolucci et al. (2018). For each relevé, we recorded the following data: collection date, locality, altitude (m a.s.l.), slope aspect (azimuth degrees), slope angle (vertical degrees), total vegetation cover (%), and cover-abundance values of the species, the latter assigned using the Braun-Blanquet scale (Braun-Blanquet 1964). Localities are indicated in the tables (Supplementary material 1: Tables S1-S19) using the following abbreviations: An, Piano di Anìno; Ar, Piano di Arvello; Cc, Piano di Colle Croce; Co, Piano di Colfiorito; PC, Palude di Colfiorito; P, Piano di Popola e di Cesì; R, Piano di Ricciano. The dates of relevés are listed in Appendix II.

Data elaboration

We transformed Braun-Blanquet cover-abundance classes into percent values using the average cover values of Braun-Blanquet classes:

- + (< 1%), 0.5 %;
- 1 (1–5%), 3 %;
- 2 (5–25%), 15%;
- 3 (25–50%), 37.5%;
- 4 (50–75%), 62.5%;
- 5 (75–100%), 87.5%

r (rare species) were attributed 0.1%. We performed cluster analysis on the Hellinger-transformed “relevé-by-species cover” matrix, using the vegan R-package, version 3.4.1, as well as the vegdist function of the vegan R-package, version 2.4-3 (Oksanen et al. 2017). To perform the Hellinger transformation, we used the decostand function of vegan.

For the taxonomic placement of the vegetation types, we referred to Chytrý (2011), Landucci et al. (2013, 2015, 2020), Biondi and Blasi (2016), Mucina et al. (2016),
Venanzoni et al. (2018), and Ciaschetti et al. (2020). The nomenclature of alliances and higher syntaxonomic ranks was taken from Mucina et al. (2016). For nomenclature at the association level, we referred mainly to Chytrý (2011) and Landucci et al. (2020).

Finally, we compared the plant communities found in our survey with those found by other authors in the past in the study area and assessed their status as habitats of community interest sensu 92/43/EEC Directive following the Italian interpretation manual of the 92/43/EEC Directive habitats (Biondi et al. 2010).

Results
The cluster analysis of the phytosociological relevés showed the following nineteen main groups (Fig. 2), some of which were further divided into sub-clusters depending on their floristic characteristics: rooting hydrophytic communities dominated by *Myriophyllum spicatum*, *Persicaria amphibia*, *M. verticillatum*, *Nymphaea alba* (group 1, Suppl. material 1: Table S1) or *Callitrichaceae stagnalis* (group 2, Suppl. material 1: Table S2); rooting hydrophytic communities with a dominance of *Ranunculus trichophyllus*, and helophytic vegetation with a dominance of *Glyceria notata* (group 3, Suppl. material 1: Table S3); helophytic communities dominated by *Berula erecta*, *Catabrosa aquatica*, *Veronica anagallis-aquatica*, *Nasturtium officinale* or *Helosciadium nodiflorum* (group 4, Suppl. material 1: Table S4, Eleocharis palustris* (group 5, Suppl. material 1: Table S5), *Schoenoplectus lacustris*, *Limniris pseudacorus*, *Typha latifolia*, Carex hirta, *Glyceria maxima* (group 6, Suppl. material 1: Table S6), *Carex vesicaria* (group 7, Suppl. material 1: Table S7), *Juncus inflexus* subsp. *inflexus* (group 8, Suppl. material 1: Table S8); *Sambucus ebulus*-dominated perennial nitrophilous vegetation (group 9, Suppl. material 1: Table S9); helophytic communities characterized by *Carex riparia*, *Cyperus longus* or *Phragmites australis* (group 10, Suppl. material 1: Table S10); therophytic ephemeral nitrophilous communities dominated by *Xanthium italicum*, *Bidens tripartita* subsp. *tririfera* and *Persicaria lapathifolia* subsp. *lapathifolia* (group 11, Suppl. material 1: Table S11); perennial hygro-nitrophilous vegetation characterized by *Epilobium hirsutum* or *Galega officinalis* (group 12, Suppl. material 1: Table S11); perennial hygro-nitrophilous vegetation characterized by *Sparganium erectum*, and *Carex acuta* (group 16, Suppl. material 1: Table S16); perennial hygro-nitrophilous vegetation characterized by *Carex otrubae*, *Rorippa amphibia* or *Gratiola officinalis* (group 19, Suppl. material 1: Table S19).

Discussion
Phytosociological interpretation of plant communities
The phytosociological interpretation of plant communities highlighted by cluster analysis (Fig. 2) led to identifying 39 plant communities, described below according to their floristic, phytocoenological, and ecological features. *POTAMOGETONO PECTINATI-MYRIOPHYLLETUM SPICATI* Rivas Goday 1964 (group 1, Suppl. material 1: Table S1, rels 1–2)
Hydrophytic vegetation characterized by the submerged species *Myriophyllum spicatum*, attributed to the *Potamogetono pectinati-Myriophylletum spicati* association (*Potamogetonion pectinati* alliance). This community, generally common in water bodies characterized by a high concentration of organic sediments (Barko and Smart 1986; Ceschin and Salerno 2008), is uncommon in the Palude di Colfiorito, where water depth exceeds 50 cm.

In 1967, Pedrotti found at the Palude di Colfiorito a *Myriophyllum spicatum*-dominated community, attributed to the *Myriophylletum spicati* association, which had a localized distribution (Pedrotti 2019).

The association was reported in lacustrine and fluvial environments in Italy, e.g., along the River Tiber (Lastrucci et al. 2012), at the Lakes of Massaciuccoli (Lastrucci et al. 2017c) and Martignano (Azzella et al. 2013). Although some authors (Minissale and Spampinato 1985; Pirone et al. 1997; Tomei et al. 2001; Brullo et al. 2001, 2002; Ceschin and Salerno 2008) reported *Myriophyllum spicatum* communities in central-southern Italy as *Myriophylletum spicati* and attributed them to the *Nymphaeion albae* alliance, we attributed this community to the *Potamogetonion pectinati* alliance following many European and Italian authors (e.g. Felzines 1983; Golub et al. 1991; Pedrotti 1991, 1995; Loidi et al. 1997; Brzeg and Wojterska 2001; Sburlino et al. 2008; Lastrucci et al. 2010a; Šumberová 2011a; Pedrotti 2019).

**PERSICARIA AMPHIBIA** community (group 1, Suppl. material 1: Table S1, rels 3–5)

Hydrophytic species-poor community dominated by *Persicaria amphibia*, with *Myriophyllum verticillatum* and ingressive species from the *Phragmites-Magnocaricetea* class (*Phragmites australis, Mentha aquatica* subsp. *aquatica*, and Carex acuta).

We found this community of the *Nymphaeion albae* alliance, in the stagnant waters of the Palude di Colfiorito, with water depth ranging from a few centimeters to 50 cm during the year.

*Persicaria amphibia* communities have been reported from north-eastern Italy (Sburlino et al. 2008), in Lake Bolsena (Latium) (Iberite et al. 1995), Valdichiana and along the River Arno (Tuscany) (Lastrucci et al. 2007, 2010a, b), in Umbria and Abruzzo (Buchwald 1994; Orsomando 2002; Landucci et al. 2011), and in Sicily (Brullo et al. 1994).

**MYRIOPHYLLETUM VERTICILLATI** Gaudet ex Šumberová in Chytrý 2011 (group 1, Suppl. material 1: Table S1, rels 6–7)

Hydrophytic vegetation characterized by *Myriophyllum verticillatum*, a submerged species occurring in meso-eutrophic waters.

This community, attributed to the *Myriophylletum verticillati* association (*Potamogetonion pectinati* alliance), occurs in habitats in an advanced stage of terrestrialization (Šumberová 2011b) and is quite common in stagnant waters of the Palude di Colfiorito (water depth ranging from a few centimeters to more than half a meter). This community was sporadic at the end of the 1960s (Pedrotti 2019). In Italy, this association is uncommon, occurring in Latium (Ceschin and Salerno 2008), Tuscany (Lastrucci et al. 2016), and Sicily (Brullo et al. 1994, 2002; Raimondo et al. 2000).

**NYMPHAEETUM ALBAE** Vollmar 1947 (group 1, Suppl. material 1: Table S1, rels 8–10)

Species-poor hydrophytic vegetation, dominated by *Nymphaea alba*, sometimes with *Myriophyllum verticillatum* and *Persicaria amphibia*. Following Šumberová (2011a) and Tomaselli et al. (2006), we attributed this community to the *Nymphaeetum albae* Vollmar 1947 association (*Nymphaeion albae* alliance). We found this community in the stagnant waters of the Palude di Colfiorito, 0.5-1 m-deep, where it forms very extensive stands. This is consistent with Šumberová (2011a), who stated that this association significantly contributes to water body filling by its high biomass production.

According to Pedrotti (1975, 2019), *Nymphaea alba* occurred in the 1960s inside the subassociation *Myriophylo-Potamogetonietum lucentis nymphaeetusum*.

The association was reported at the Lake of Massaciuccoli (Tuscany) by Lastrucci et al. (2017c), in Piedmont (Guglielmetto Mugion and Montacchini 1993-1994), Lombardy (Andreis and Zavagno 1996), Veneto (Anoé and Caniglia 1987), Trentino (Canullo et al. 1990), and Friuli-Venezia Giulia (Poldini 1989).

**CALLITRICHE STAGNALIS** community (group 2, Suppl. material 1: Table S2)

Hydrophytic vegetation dominated by *Callitriche stagnalis*, with *Ranunculus trichophyllus*, of the *Ranunculion aquatilis* alliance, with ingressive species from the *Nasturtio-Glycerietalia* (Nasturtium officinale, Helosciadium nodiflorum, Veronica anagallis-aquatica, and Berula erecta).

We found this community in stagnant or slowly flowing waters of ditches; toward the banks, it was in contact with the helophytic vegetation of the *Helosciadietum nodiflorum*, *Nasturtietum officinalis*, and *Veronica anagallis-aquatica* community.

Pedrotti (2019) found in the outer part of the Palude di Colfiorito, along spring-fed ditches, the *Veronico beccabungeta-Callitrichetum stagnalis* Müller 1962, which differs from our relevés for the presence of *Veronica beccabunga* and *Glyceria fluviatilis*.

In accordance with some Italian authors (e.g. Corbett and Pirone 1989; Baldoni and Biondi 1993; Venanzoni and Gigante 2000), we did not attribute *C. stagnalis*-dominated communities to the association *Callitrichetum stagnalis* Segal 1967, given their low floristic richness.

In Italy *C. stagnalis*-dominated communities have been found in the Venetian Plain (Marchiori and Sburli 2006), Tuscany, Marche, Umbria, Latium, and Abruzzo (Corbett and Pirone 1989; Baldoni and Biondi 1993; Buchwald 1994; Venanzoni and Gigante 2000; Ceschin and Salerno 2008; Lastrucci and Becattini 2008; Mereu et al. 2010), and in Sardinia (Biondi and Bagella 2005).
POTAMOGETONOCRISPIRANUNCULETUM TRICHOPHYLLIIImchenetzky 1926 (group 3, Suppl. material 1: Table S3, rels 1–5)

Ranunculus trichophyllus-dominated hydrophytic community, with Callitrichetum stagnalis, referred to the Ranunculion aquatilis alliance. The species composition included elements of the Glycerio-Sparganiion alliance and higher-rank syntaxa (e.g. Nasturtietum officinalis, Veronica anagallis-aquatica, and Glyceria notata).

The association is uncommon in the stagnant or slowly flowing waters along ditches.

In Italy, Ranunculus trichophyllus-dominated communities were found in northeastern and central Italy, and in Sicily (e.g. Ferro 1980; Corbetta and Pirone 1989; Buchwald 1994; Gerold and Tomaselli 1997; Tomi et al. 2001; Pirone et al. 2004; Tomasi and Caniglia 2004; Lasruchi et al. 2010a; Landucci et al. 2011).

GLYCERIETUM NOTATAE Kulczyński 1928 (group 3, Suppl. material 1: Table S3, rels 6–9)

Species-poor plant community, physiognomically characterized by Glyceria notata and other species of the Glycerio-Sparganiion alliance and higher syntaxa (e.g. Veronica anagallis-aquatica, Nasturtietum officinale, Mentha aquatica subsp. aquatica, and Myosotis scorpioides) and ingressive species from the Potamogetonetea class (Ranunculus trichophyllus).

The association is widespread in the ditches, in contact with the Nasturtietum officinalis association and the Veronica anagallis-aquatica community. In the sections with slow flowing water, it was found at the border of the watercourse, toward the inside, in contact with the Potamogetonetea class (Ranunculus trichophyllus).

In Italy this vegetation type is frequent, being recorded by many authors from sea level to the mountain belt (e.g. Cortini Pedrotti et al. 1973; Canullo et al. 1988; Corbetta and Pirone 1989; Pedrotti et al. 1992; Baldoni and Biondi 1993; Buchwald 1994; Pedrotti 1995; Marchiori and Sbrullino 1997; Scoppola 1998; Biondi et al. 1999; Lasruchi et al. 2004; Pedrotti 2008).

BERULETUM ERCTAE Roll 1938 (group 4, Suppl. material 1: Table S4, rels 1–3)

Helophytic vegetation characterized by Berula erecta, with species of the Glycerio-Sparganiion alliance and higher syntaxa (Glyceria notata, Veronica anagallis-aquatica, and Nasturtietum officinale).

In the study area, it occurs along the ditches of the Palude di Colfiorito, near the banks of the deepest ones, where it is in contact with Helosciadietum nodiflori, towards the central part of the ditch section.

This community (syn. Veronico-Sietum erctic Passarge 1982, Veronico beccabungae-Beruletum erectae Passarge 1999) was found by Prosser and Sarzo (2003) and Pedrotti (1995) in Trentino, Pedrotti (2008) in the “Marcite di Norcia” (Umbria), by Ceschin and Salerno (2008) along the Rivers Tevere, Aniene and Treia (Latium), and in Molise (Canullo et al. 1988).

RORIPPO ANCIPITIS-CATABROSETUM AQUATICÆ (Oberdorfer 1957) Müller et Görs 1961 (group 4, Suppl. material 1: Table S4, rel. 4)

Plant community with a dominance of Catabrosa aquatica, with Veronica anagallis-aquatica, Glyceria notata, and Helosciadium nodiflorum, growing on slow-flowing or temporarily stagnant waters. It hosts some species of the Molinio-Arrhenatheretea class, such as Holcus lanatus, Poa pratensis and Dactylis glomerata, because it is in contact with the temporarily flooded meadows of the Ranunculion velutini alliance. Following Landucci et al. (2020), the composition of this community fits with that of the Rorippo ancippitis-Catabrosetum aquaticae association (Glycerio-Sparganiion alliance).

We found this community along the main ditch that crosses the Piano di Colle Croce.

The Catabrosa aquatica community found along the River Nera (Marche, central Italy) by Buchwald (1994), which was attributed to the Catabrosetum aquaticae Rübel 1911, should be referred to this association.

VERONICA ANAGALLIS-AQUATICA SUBSP. AQUATICA community (group 4, Suppl. material 1: Table S4, rels 5–9)

Veronica anagallis-aquatica-dominated community, with Nasturtietum officinalis and some ingressive species from the Molinio-Arrhenatheretea and Bidentetetea classes. The occurrence of Veronica anagallis-aquatica and Nasturtietum officinale justifies its placement in the Glycero-Sparganiion alliance.

The community was found in stagnant or slightly flowing waters, 20-50 cm deep, in contact with Nasturtietum officinalis and the Callitriche stagnalis community.

NASTURTETUM OFFICINALIS Gilli 1971 (group 4, Suppl. material 1: Table S4, rels 10–12)

Single-species or species-poor pioneer helophytic community, which establishes after human disturbance, with a dominance of Nasturtium officinale, with Veronica anagallis-aquatica and ingressive species from Molino-Arrhenatheretea.

This community, typical of sunny, quickly to slowly flowing, oligo- to eutrophic waters (Buchwald 1994), is distributed in small stands along the ditches that cross cultivated lands, in contact with Helosciadietum nodiflori, Glycerietum notatae, Callitriche stagnalis community, and Veronica anagallis-aquatica community.

In Italy, this community is widely spread (e.g. Barberis and Mariotti 1981; Canullo et al. 1988; Géhu and Biondi 1988; Corbetta and Pirone 1989; Baldoni and Biondi 1993; Pedrotti 1995; Biondi et al. 1997; Pirone et al. 1997; Scoppola 1998; Bracco et al. 2000; Brullo et al. 2002; Prosser
and Sarzo 2003; Tomasi and Caniglia 2004; Ceschin and Salerno 2008; Pedrotti 2008; Lastrucci et al. 2010b, 2012, 2016, 2017c).

HELOSCHIADETUM NODIFLORI Maire 1924 (group 4, Suppl. material 1: Table S4, rels 13–16)

Vegetation of ditches characterized by Helosciadium nodiflorum with elements of the Glycerio-Sparganion alliance and the Nasturtio-Glycerietalia order (Nasturtium officinale, Veronica anagallis-aquatica, Berula erecta, and Glyceria notata).

We found this community along a short stretch of a ditch at the Palude di Colfiorito, in contact with Beruletum erectae and Nasturtietum officinalis, where water was 50-60 cm deep.

The association is rather frequent in Italy (e.g. Pedrotti, 1967, 1995, 2008; Canullo et al. 1988; Baldoni and Biondi 1993; Buchwald 1994; Pirone et al. 1997; Brullo et al. 2001, 2002; Prosser and Sarzo 2003; Biondi and Bagella 2005; Sbrulino et al. 2008; Mereu et al. 2010; Lastrucci et al. 2016).

ELEOCHARITETUM PALUSTRIS Savič 1926 (group 5, Suppl. material 1: Table S5)

Single-species or species-poor pioneer plant community, physiognomically characterized by Eleocharis palustris subsp. palustris, sometimes associated with species of the Molinio-Arrhenatheretea class, coming from the surrounding meadows. The community develops where the soil is subject to periodic cycles of submergence and emergence until the end of spring and can tolerate long periods of flooding, but it can also withstand periods with dry soil (Šumberová 2011a).

We found this association in small patches at the edge of Palude di Colfiorito, in contact with communities referred to Phragmiton communis and Bidention tripartitae alliances.

This vegetation type is distributed in northern and central Italy (e.g. Pedrotti et al. 1992; Buchwald 1994; Mariotti 1995; Biondi et al. 1997; Venanzoni and Gigante 2000; Tomei et al. 2001; Landi et al. 2002; Angiolini et al. 2003; Lastrucci et al. 2007, 2010a,b, 2012, 2019b).

SCHOENOPLECTETUM LACUSTRIS Chouard 1924 (group 6, Suppl. material 1: Table S6, rels 1–11)

Community characterized by Schoenoplectus lacustris, mostly occurring in the outer vegetation belt of the Palude di Colfiorito, where it forms dense and extensive monospecific stands between Phragmitetum/Phalaridetum and open waters. Where the stands are less dense, other species of the Phragmition communis alliance and higher-rank syntaxa, including Phragmites australis, Phalaris arundinacea, and Typha latifolia, enter into the composition of this community.

The Schoenoplectetum lacustre is in close contact with other associations of the Phragmition communis alliance, especially in the Palude di Colfiorito, and sometimes occupies the whole section of unmanaged ditches.

The association is rather frequent across Italy in marshes, around lakes and along watercourses (Fascetti et al. 1989; Poldini 1989; Brullo et al. 1994; Iberite et al. 1995; Venanzoni and Gigante 2000; Merloni and Piccoli 2001; Landi et al. 2002; Venanzoni et al. 2003; Lastrucci et al. 2007; Ceschin and Salerno 2008; Lastrucci et al. 2019b).

IRIDETUM PSEUDACORI Eggler 1933 ex Brzeg et M. Wojterska 2001 (group 6, Suppl. material 1: Table S6, rels 12–15)

Plant community with a dominance of Limniris pseudacorus, with species of the Phragmition communis alliance (e.g. Typha latifolia and Schoenoplectus lacustris) and ingressive species from the Molinio-Arrhenatheretea class, coming from the surrounding meadows.

We found this association inside depressions in the humid meadows and along some ditches of the Piano di Colfiorito.

Limniris pseudacorus-dominated communities had been found in various Italian wetlands from the Trentino-Alto Adige to Sicily (e.g. Brullo et al. 1994; Pedrotti 1995; Pirone et al. 1997; Raimondo et al. 2000; Arrigoni and Papini 2003; Prosser and Sarzo 2003; Maiorca et al. 2005; Presti et al. 2005; Ceschin and Salerno 2008; Lastrucci et al. 2010a,b, 2016).

TYPHETUM LATIFOLIAE Nowiński 1930 (group 6, Suppl. material 1: Table S6, rels 16–20)

Species-poor plant community, characterized by Typha latifolia, associated with other species of the Phragmition communis alliance (Schoenoplectus lacustris and Glyceria maxima).

Typhetum latifolii occurs in stagnant or slowly flowing waters of marshes and ditches, less than 50 cm deep, in contact with other associations of Phragmito-Magnocaricetalia and, to the inside of the basins and ditches, with the hydrophytic coenoses of Potamogetoneta.

It is very common in Italian wetlands (e.g. Martini and Poldini 1980; Corbetta and Pirone 1989; Baldoni and Biondi 1993; Biondi and Baldoni 1994; Buchwald 1994; Biondi et al. 1997; Bracco et al. 2000; Venanzoni and Gigante 2000; Viciani and Raffaelli 2003; Prosser and Sarzo 2004; Ceschin and Salerno 2008; Lastrucci et al. 2010a,b, 2012).

CAREX HIRTA community (group 6, Suppl. material 1: Table S6, rels 21–23)

Species-poor plant community, with a dominance of Carex hirta. Due to the occurrence of elements of Potentillion anserinae and higher-rank syntaxa, we placed this community in the Potentillion anserinae alliance, even though the presence of some elements of the Phragmito-Magnocaricetalia class marks its transition towards the coenoses of flooded habitats. Because of the lack of floristic characterization, we could not classify it at the association level.

Toward the inside of the basins, this community is in contact with helophytic communities of Phragmition
communis and Magnocaricion gracilis, and toward the external areas, with Ranunculion velutini meadows.

In Tuscany, Lastrucci et al. (2019b) found a community characterized by Carex hirta and C. otrubae, in fresh, partially shaded and not submerged soils. Biondi and Ballelli (1995) described in Umbria a Carex hirta-dominated association, the Ranunculo acri-Caricetum hirtae, which was found by Ciaschetti et al. (2020) in the highlands of Abruzzo. However, in our opinion there are not enough elements to attribute this community to this association, because all the diagnostic species except Carex hirta are absent (Carex leporina, Ranunculus acris, R. repens, and Alopecurus rendeli).

GLYCERIETUM MAXIMAE Nowiński 1930 corr. Šumberová, Chytrý et Danihelka in Chytrý 2011 (group 6, Suppl. material 1: Table S6, rels 24–30)

Species-poor plant community of marshes and ditches, with a dominance of Glyceria maxima, which is associated with other species of the Phragmition communis alliance and higher syntaxa, including Phragmites australis, Phalaris arundinacea, Alisma plantago-aquatica, Sparganium erectum, and Lycopus europaeus.

The community forms more or less extensive stands in the outer part of the Palude di Colfiorito basin, where, according to Pedrotti and Murria (2020) is reducing its extent, and in small parts of some ditches in other plains, in contact with the associations of the Phragmition communis and Glycerio-Sparganion alliances.

In Italy this vegetation type is reported from lowland to submontane areas of northern and central Italy (e.g. Pedrotti 1965; Gerdol et al. 1979; Arrigoni and Ricceri 1982; Piccoli and Gerdol 1982; Marchiori and Sbrulino 1986; Pedrotti 1995; Sartori and Bracco 1997; Catorci and Orsomando 2001; Lastrucci et al. 2010b, 2014).

CARICETUM VESICARIAE Chouard 1924 (group 7, Suppl. material 1: Table S7)

Species-poor, sometimes monospecific helophytic community, dominated by Carex vesicaria, belonging to the Magnocaricion gracilis alliance, with a few other species of Phragmito-Magnocaricetae class (e.g. Typha latifolia, Glyceria notata, and Rorippa amphibia), typical of stagnant waters and marshy meadows, which grows on meso-eutrophic, mineral or semi-peaty soils (Mierwald 1988).

The association is uncommon in the study area and occurs along a short stretch of the main ditch of the Piano di Arvello.

The association had been found in wetlands of northern and central Italy (Cortini Pedrotti et al. 1973; Martini and Poldini 1980; Montanari and Guido 1980; Pirone 1987; Marchiori et al. 1993; Buchwald 1994; Gerdol and Tomaselli 1997; Marchiori and Sbrulino 1997; Rossi and Alessandri 1998; Prosser and Sarzo 2003; Lastrucci et al. 2008).

CARICI OTRUBAE-JUNCETUM INFLEXI Minissale et Spampinato 1985 (group 8, Suppl. material 1: Table S8)

Species-poor sub-nitrophilous and sub-hygrophilous community dominated by Juncus inflexus subsp. inflexus, associated with species of the Potentillo-Polygonetalia order and Molinio-Arrhenatheretae class, e.g. Carex otrubae, Ranunculus repens, Carex hirta, Galium album subsp. album, and Rumex acetosa. The species composition of the community allows us to place it in the Potentieto-Polygonetalia order of the Molinio-Arrhenatheretae class. This is consistent with Landucci et al. (2020), who excluded Juncus inflexus communities from the Phragmito-Magnocaricetae vegetation in Europe.

The species composition of this community differs from that of Galio palustris-Juncetum inflexi, described by Venanzoni and Gigante (2000), because of the absence of Galium palustre and Scutellaria galericulata and the prevalence of species of the Molinio-Arrhenatheretae class. It also differs from the Mentho longifoliae-Juncetum inflexi Lohmeyer ex Oberdorfer 1957 association because Mentha longifolia, characteristic of the association, is absent. Because of the dominance of the helophyte Juncus inflexus subsp. inflexus and the presence of Carex otrubae, we attributed this community to the Carici otrubae-Juncetum inflexi, described at Lake Gurrda in northeastern Sicily by Minissale and Spampinato (1985) and found in Calabria (Maiorca et al. 2005) and Tuscany (Lastrucci et al. 2019b).

The association is in contact with some communities of Phragmition communis, i.e. Phalaridetum arundinaceae, Schoenoplectetum lacustris, Glycerietum maximae, and with the humid meadows of the Ranunculion velutini alliance. The other contact vegetation is the Carex otrubae community, toward the banks of some ditches subjected to periodic desiccation.

URTICO DIOICAE-SAMBUCETUM EBULI (Br.-Bl. in Br.-Bl., Gajewski, Wraber et Wa1as 1936) Br.-Bl. in Br.-Bl., Roussine et Nègre 1952 (group 9, Suppl. material 1: Table S9)

Thermo-heliothermal and nitrophilous association, characterized by Sambucus ebulus, with Urtica dioica and species of the Balloto-Conion maculati alliance and higher syntaxa, such as Conium maculatum, Rubus caesius, Cruciata laevipes, Galium aparine, and ingressive species from Molinio-Arrhenatheretae.

The association occurs sporadically on nitrogen-rich soils, at the edge of roads, paths, and hedges around the wetlands.

This association has been found in northern (Poldini 1980; Tomassi et al. 2006), central (Biondi and Ballelli 1982; Lastrucci et al. 2010a,b, 2014), and southern Italy (Brullo et al. 1998; Maiorca and Spampinato 1999).

CARICETUM RIPARIAE Mâthé et Kovács 1959 (group 10, Suppl. material 1: Table S10, rels 1–3)

Species-poor Carex riparia-dominated community, with a low number of Phragmito-Magnocaricetae species and ingressive elements from the Molinio-Arrhenatheretae class. The occurrence of C. acuta and C. vesicaria, besides the dominant species, allows its attribution to the community of the Caricetum ripariae association, included in
the Magnocaricion gracilis alliance, following Landucci et al. (2020).

This community is very fragmented and forms dense stands in marshy meadows and ditches, in contact with the communities of the Phragmition communis and Magnocaricion gracilis alliances.

This association is rather frequent, but endangered, across the Italian Peninsula (e.g. Anò and Caniglia 1987; Orsomando 1993; Pirone et al. 1997; Sartori and Bracco 1997; Prosser and Sarzo 2004; Landucci et al. 2013; Lastrucci et al. 2014, 2016) and Sicily (Brullo et al. 1998, 2002).

CYPERETUM LONGI (Micevski 1957) Micevski 1963 (group 10, Suppl. material 1: Table S10, rels 4–5)

Community characterized by Cyperus longus, poor in elements of the Phragmito-Magnocaricetea class, with several ingressive species from Molinio-Arrhenatheretea.

Because of the dominance of Cyperus longus and the presence of species of the Phragmito-Magnocaricetea and Molinio-Arrhenatheretea classes, following Landucci et al. (2020), this plant community fits with the Cyperetum longi association (Phragmition communis alliance).

This community is uncommon in the study area, where it forms small and dense stands, in periodically flooded soils, in contact with Phragmitetum australis and the communities of the Ranunculion velutini alliance.

In Italy, the association was found in Tuscany (Lastrucci et al. 2010a,b, 2016), Umbria (Venanzoni and Gigante 2000; Pedrotti 2008; Lastrucci et al. 2012), Abruzzo (Corbetta and Pirone 1989; Pirone et al. 2003), Molise (Paura et al. 2004), Basilicata (Venanzoni et al. 2003), and Sicily (Brullo et al. 1994).

PHRAGMITETUM AUSTRALIS Savic 1926 (group 10, Suppl. material 1: Table S10, rels 6–21)

Helophytic single-species or species-poor community, dominated by Phragmites australis, attributed to the Phragmitetum australis association, including species of the Phragmition communis alliance and higher syntaxa, as well as ingressive elements from the Molinio-Arrhenatheretea and Artemisietea vulgaris classes.

It is the dominant type of vegetation in the Palude di Colfiorito, where it develops in stagnant eutrophic waters with ground flooded from autumn to early summer and not drying in summer. In the other plains, this association occurs in the bed of the ditches.

If it is not subjected to periodic disturbance (mowing or tillage), this community tends to colonize the marshy and humid meadows in the outer vegetation band of the Palude di Colfiorito and the uncultivated lands in contact with the wetland vegetation (Catorci et al. 2010). Lastrucci et al. (2019a) documented the increasing fragmentation related to the dieback process of the reed bed along the waterfront and the expansion of the reeds in terrestrial habitats formerly occupied by different types of natural vegetation. Phragmites australis is in fact a highly competitive species, which can invade other plant communities in the absence of disturbance. This colonization process was observed for the Carex panicua peaty meadow community, which once had spread over a large area in the south-western part of the Palude di Colfiorito (Pedrotti 1975) and has disappeared as a consequence of competition with Phragmites australis. In fact, relevés carried out in the area formerly occupied by the Carex panicua community (Pedrotti 2019), with very rare and interesting species from a biogeographical and conservation viewpoint, such as Dactylorhiza incarnata and Epipactis palustris, were grouped by the cluster analysis among those of Phragmitetum australis, indicating a dynamic stage of vegetation. Nowadays, this area is almost completely invaded by shrubs (Pedrotti 2019).

To the inside of the basin, the community is in contact with the hydrophytic communities of the Nymphaeion alliance, while to the outside of the basin, it is in contact with other Phragmito-Magnocaricetea and Molinio-Arrhenatheretea communities, with which it sometimes forms cover. The association is very common in all the countries of the temperate zone, including Italy (e.g. Corbetta and Pirone 1989; Baldoni and Biondi 1993; Buchwald 1994; Iberite et al. 1995; Pirone et al. 1997; Venanzoni and Gigante 2000; Arrigoni and Papini 2003; Ceschin and Salerno 2008; Lastrucci et al. 2010a,b, 2012, 2017c, 2019b). In particular, in the Palude di Fucecchio, Lake Chiusi (Tuscany), Lake Vico (Latinum), Lake Trasimeno, and Palude di Colfiorito (Umbria), Lastrucci et al. (2017a) described seven variants, four of which (with Myriophyllum spicatum, Schoenoplectus lacustris, Calystegia sepium, and Urtica dioica) were found at the Palude di Colfiorito.

POLYGONO LAPHATHIFOLII-XANTHETUM ITALICI Pirola et Rossetti 1974 (group 11, Suppl. material 1: Table S11, rel. 1)

Therophytic ephemeral plant community, which appears in late-summer in temporarily flooded nutrient-rich and silty-sandy soils, characterised by species of the Bidentetea tripartitae class and ingressive elements from Stellarietea mediae and Artemisietea vulgaris classes. Because of the dominance of Xanthium italicum and the occurrence of Persicaria lapathifolia, we attributed it to the Polygono lapathifoli-Xanthietum italicci association (Chenopodion rubri alliance).

The very fragmented stands of this association (sometimes extended a few square meters) occur on the external edge of humid meadows, in contact with croplands.

The association is known for the border of water basins on silty-sandy nitrophilous soils (Lastrucci and Becattini 2008; Scandrello 2009), but it is more common along watercourses in northern Italy (Liguria, Lombardia, Emilia Romagna), central Italy, Molise, Sicily (e.g. Mariotti 1995; Assini 1997; Sartori and Bracco 1997; Biondi et al. 1997, 1999, 2004; Brullo et al. 2002; Paura et al. 2004; Ceschin and Salerno 2008; Lastrucci et al. 2010b; Crisanti and Taffetani 2015).

BIDENTETUM TRIPARTITAE Miljan 1933 (group 11, Suppl. material 1: Table S11, rels 2–5)
Therophytic ephemeral plant community of temporarily flooded, nutrient-rich areas, which appears in the late summer, characterized by the annual species Bidens tripartita subsp. tripartita and Persicaria lapathifolia, characteristic of the association Bidnetetum tripartitae and higher syntaxa, and transgressive species from Potentillion anserinae alliance.

The very fragmented stands of this association, sometimes extended a few square meters, occur at the edge of marshy and humid meadows, which are flooded until late spring-early summer and emerge in mid-late summer.

Two variants of this association, characterized by Persicaria lapathifolia and Chenopodiastrum murale were found by Pedrotti and Murrja (2020) in the eastern part of the Palude di Colfiorito.

In Italy, it was found in northern and central Italy and Sicily (Martini and Poldini 1980; Marchiori et al. 1993; Biondi et al. 1999, 2003; Sarzo et al. 1999; Brullo et al. 2002; Pirone et al. 2003; Prosser and Sarzo 2004).

**EPILOBIUM HIRSUTUM** community (group 12, Suppl. material 1: Table S12, rels 2–7)

Epiobium hirsutum-dominated nitrophilous community found at the edge of the humid meadows of Ranunculion velutini. Given that most of the species of this community are characteristic of Potentillion anserinae and higher syntaxa, e.g. Ranunculus repens, Galega officinalis, and Lotus corniculatus, we placed it in the Potentillion anserinae alliance.

**GALEGA OFFICINALIS** community (group 12, Suppl. material 1: Table S12, rels 2–7)

Nitrophilous pioneer community, physiognomically characterized by Galega officinalis, including species of the Potentillion anserinae alliance and higher syntaxa, e.g. Ranunculus repens, Galium album subsp. album, and Poa trivialis. The occurrence of ingressive species from the Phragmito-Magnocaricetalia, Stellarioidea mediae, and Artemisietalia vulgaris classes indicates the placement of this community between the helophytic vegetation of Phragmitioni communis / Magnocaricion gracilis and anthropogenic vegetation.

This community occurs along the banks of ditches at the borders of the plains, periodically flooded during the year, with alternation of a flooding phase in winter and spring and a summer emergence phase.

Venanzoni and Gigante (2000) described in the Lakes Trasimeno and Alviano (Umbria) the Cirso trifolietti-Galegetum officinalis association, placed in the Potentillion anserinae alliance. Compared to that association, our relevés lack Cirsiun cireticum subsp. triumfettii, Convolvulus sepium, and Lotus tenuis, characteristic species of this association. However, we did not find enough elements to describe a new association.

Pedrotti and Murrja (2020) found a similar community in the eastern part of the Palude di Colfiorito and referred it to the Cirsius triumfettii-Galegetum officinalis association; however, in our opinion, this attribution is doubtful because it lacks the characteristic species except C. cireticum subsp. triumfettii.

**DESHAMPSIO-CARICETUM DISTANTIS** Pedrotti 1976 (group 13, Suppl. material 1: Table S13)

Thick-sward wet meadows, dominated by Deschampsia cespitosa. The occurrence of Ranunculus velutinus, Lolium arundinaceum subsp. arundinaceum, Orchis laxiflora, Belvalia romana, Trifolium resupinatum, and Alopecurus rendlei justifies placing the community in the Ranunculion velutini alliance and the Trifolio-Hordeetalia order. The occurrence of Carex distans, besides Deschampsia cespitosa, allows its attribution to the Deschampsio-Caricetum distantis association, described by Pedrotti (1976) in the nearby Piani di Montelago (Marche).

This community, found in depressions flooded until early summer and moist until the end of summer, is in contact with Hordeo-Ranunculetum velutini meadows, inside which it sometimes forms more or less extended patches, and with communities of the Phragmitetalia and Nasturtio-Glycerietalia orders.

The association is endemic of the humid meadows of central and southern Italy (Pedrotti 1975; 1976; Canullo et al. 1988; Pedrotti et al. 1992; Pirone 1997; Catorci and Orsomando 2001; Tardella et al. 2002).

**HORDEO-RANUNCULETUM VELUTINI** Pedrotti 1976 (group 14, Suppl. material 1: Table S14)

Community of humid hay meadows with a dense sward, common in areas that remain flooded until early spring, while the ground dries up in the early summer. It is physiognomically characterized by Ranunculus velutinus, Cynosurus cristatus, Poa pratensis subsp. pratensis, Centaurea jacea subsp. jacea, and Trifolium pratense.

The occurrence of Lolium arundinaceum subsp. arundinaceum, Orchis laxiflora, and Gaudinia fragilis, besides Ranunculus velutinus, justifies placing the community in the Ranunculion velutini alliance and the Trifolio-Hordeetalia order, while the presence of Hordeum secalinum, Bromus racemosus subsp. racemosus, Trifolium dubium, T. resupinatum, Alopecurus rendlei, and Belvalia romana indicates that the community fits with the association Hordeo-Ranunculetum velutini.

This association is in contact with the helophytic associations of Phragmito-Magnocaricetalia toward the inside of the basins, and with the therophytic nitrophilous communities, and croplands, toward the outside.

This association, described by Pedrotti (1976) in the nearby Piani di Montelago (Marche), is endemic to the central and southern Apennines (Pedrotti 1967, 1975; Canullo et al. 1988; Pedrotti et al. 1992; Venanzoni 1992; Catorci and Orsomando 2001; Tardella et al. 2002).

**SPARGANIETUM ERECTI** Roll 1938 (group 15, Suppl. material 1: Table S15)

Plant community dominated by Sparganium erectum, which forms more or less thick stands. The dominant species and the presence of elements of the Glycerio-Sprar-
ion alliance led us to attribute this community, following
Venanzoni and Gigante (2000), Lastrucci et al. (2010b),
and Pedrotti (2019), to the Sparganietum erecti association.

We found the plant community in stagnant waters, 10-
50 cm deep, in contact with Phragmitetum australis and
Glycerietum maximae.

It has been reported in northern, central, and south-
ern Italy (e.g. Marchiori and Sburlino 1986, 1997; Corbe-
ta and Pirone 1990; Baldoni and Biondi 1993; Buchwald
1994, Pedrotti 1995; Brullo et al. 1998; Venanzoni and
Gigante 2000; Prosser and Sarzo 2003; Venanzoni et al.
2003; Ceschin and Salerno 2008; Lastrucci et al. 2010b,
2012, 2016, 2017c).

CARICETUM GRACILIS Savič 1926 (group 16, Suppl.
material 1: Table S16)

Species-poor helophytic association, characterized by
Carex acuta, which forms thick stands, with species of the
Magnocaricion gracilis alliance and higher syntaxa (Car-
ex vesicaria, Galium palustre subsp. elongatum, Phalaris
arundinacea, etc.) and sporadic occurrences of ingressive
species of the Potentillo-Polygonetalia and Trifolio-Horde-
talia orders (Molinio-Arrhenatheretalia class).

The association occurs where the soil is frequent-
ly flooded from autumn to spring and remains muddy
during summer, often in contact with other communities
of the Phragmito-Magnocaricetalia class.

This community is more frequent in northern Italy,
but is recorded from several localities across the Italian
peninsula (e.g. Cortini Pedrotti et al. 1973; Martini and
Poldini 1980; Marchiori and Sburlino 1986; Marchiori et
al. 1993; Venanzoni 1988; Buffa et al. 1995; Pirone and
Tammaro 1995; Marchiori and Sburlino 1997; Sartori and
Bracco 1997; Bracco et al. 2000; Prosser and Sarzo 2003).

POTENTILLILLA REPTANS community (group 17, Suppl.
material 1: Table S17)

Species-poor hygro-nitrophilous plant community,
dominated by Potentilla reptans.

The prevalence of floristic elements of Potentillion
anserinaceae and higher syntaxa (Potentilla reptans, Rumex
crispus, Oenanthe fistulosa, and Thalictrum lucidum) led
us to place this community in the Potentillion anserinaceae
alliance.

This community differs in species composition from
Rorippa amphibiae-Potentilletum reptantis described in
Valdichiana (Tuscany, Italy) by Lastrucci et al. (2010a),
because of the absence of Rorippa amphibia, R. prostrata,
Bolboschoenus maritimus, and Oenanthe silaifolia; howev-
er, there are no elements to describe a new association.

The Potentilla reptans community is generally present
on the bottom of the sinkholes, in contact with Phalaris
arundinacea and Carex acuta-dominated stands.

PHALARIDETUM ARUNDINACEAE Libbert 1931
TYPICUM (group 18, Suppl. material 1: Table S18, rels
1–15; holotypus Table 1, rel. 2 in Libbert 1931)

ALOPECURETOSUM BULBOSI subass. nova (group 18,
Suppl. material 1: Table S18, rels 16–31, holotypus relevé 30)

CAREX ACUTA VARIANT (group 18, Suppl. material 1: Table S18, rels 16–24)

Helophytic association dominated by Phalaris arun-
dinacea, with other species of Phragmito-Magnocaricetalia
(e.g. Phragmites australis, Scutellaria galericulata, Eleo-
charis palustris, Lythrum salicaria, and Carex acuta) and
ingressive species from Molinio-Arrhenatheretalia (e.g. Loli-
um arundinaceum subsp. arundinaceum, Centarea jacea
subsp. jacea, and Trifolium pratense). The species compo-
osition allows us to place this community in the Phragmi-
tion communis alliance (Phragmitetalia order, Phragmi-
to-Magnocaricetalia class), following Landucci et al. (2020).

The association is rather frequent across the Italian pen-
insula (e.g. Bracco 1981; Marchiori et al. 1993; Buchwald
1994; Venanzoni and Gigante 2000; Arrigoni and Papini
2003; Prosser and Sarzo 2003; Tomasi and Caniglia 2004;
Lastrucci et al. 2007, 2010a,b, 2014; Ceschin and Salerno
2008).

The typical form of this community was found in sites
with stagnant eutrophic waters, at the edge of ditches and
swallow holes, characterized by seasonal fluctuations,
in contact with other helophytic coenoses of Phragmi-
to-Magnocaricetalia to the inside of the basin and the main
ditches, and with wet meadows of Trifolio-Hordeetalia,
hygro-nitrophilous communities and croplands to the
outside.

In the areas where water is drained more rapidly by
larger canals to foster the mowing of the surrounding hay
meadows, and the soil remains waterlogged and humid for
a shorter period, the species composition of the commu-
nity changes, increasing species from the Molinio-Arrhe-
natheretalia class. The occurrence of this group of species
indicates the transition from Phalaridetum arundinaceae
to humid meadows of Ranunculion velutini and allows us
to describe the new subassociation Phalaridetum arundi-
aceae alopearetosum bulbosi, whose differential species
are Alopecurus bulbosus subsp. bulbosus, A. rendlei, Oe-
nanthe fistulosa, Trifolium resupinatum, Centarea jacea
subsp. jacea, Galium debile, and Plantago lanceolata.

In small depressions of few centimeters or in contact
with marsh vegetation of the Magnocaricion gracilis,
where water stands for more time during the year, Carex
acuta tends to become codominant with Phalaris arundi-
acea. We attributed this aspect to a Carex acuta variant
of the subassociation Phalaridetum arundinaceae alope-
aretosum bulbosi.

CAREX OTRUBAE community (group 19, Suppl. materi-
al 1: Table S19, rels 1–5)

Species-poor plant community of the stagnant waters
dominated by Carex otrubae, present exclusively along the
banks of ditches of modest depth, which during the year
undergo periods of submergence (winter-early spring) and
emergence (summer), depending on the variability of the
water supply resulting from rainfall.
Carex otrubae communities found by Venanzoni and Gigante (2000) at Lakes Trasimeno and Aviano (Umbria), Minissale and Spampinato (1995) and Brullo et al. (2002) in Sicily, by Cortini Pedrotti et al. (1973) and Pedrotti (1982a) at the Pian Grande of Castelluccio di Norcia (Umbria), attributed to Cypero longi-Caricetum otrubae or Caricetum otrubae, were placed in the Magnocaricion elatae alliance, while Buchwald (1994) placed the Carex otrubae coenoses found at Pian Grande and Pian Piccolo (Sibillini Mountains, Umbria) in the Potentillion anserinae alliance; instead, Lastrucci et al. (2014) attributed the C. otrubae community found at Lake Montepulciano to the Cypero longi-Caricetum otrubae association, in the Mentho-Juncion inflexi. Because of the absence of species of Magnocaricion elatae, and the prevalence of floristic entities of Potentillion anserinae and higher syntaxa (Ranunculus repens, Gratiola officinalis, Carex hirta, and Galium album subsp. album), we considered it more appropriate to place this plant community in the Potentillion anserinae alliance.

The Carex otrubae community is in contact, toward the center of the ditch section, with the Oenanthe aquatics-Rorippetum amphibiae, Carici otrubae-Juncetum inflexi, Glycerietum notatae, and Caricetum vesicariae associations, while toward the external areas, it is in contact with the humid meadows of the Ranunculion velutini.

GRATIOLA OFFICINALIS community (group 19, Suppl. material 1: Table S19, rels 6-11)

Community characterized by Gratiola officinalis, which colonizes soils undergoing alternation of spring floods and summer desiccation, with species from peaty and marshy meadows, such as Carex panicca, Dactylorhiza incarnata, Ranunculus flammula, and Oenanthe fistulosa, and elements of Potentillo-Polygonetalia, such as Mentha pulegium subsp. pulegium, Carex hirta, C. otrubae, Ranunculus repens, and Galium album subsp. album.

We found this community inside depressions 20-30 cm deep, surrounded by the humid meadows of Ranunculion velutini alliance.

Two associations physiognomically characterized by Gratiola officinalis have been identified in Hungary (Ranunculo flammulaceae-Gratiolietum Borhidi and Juhász 1985 of the Eleocharition acicularis alliance, see Borhidi and Juhász 1985), the Czech Republic and Slovakia (Lathyro palustris-Gratiolietum Balatová-Tuláčková 1966 of the Deschampsiion cespitosae alliance, Botta-Dukát et al. 2005). In Italy, Pedrotti (1982b) referred the occurrence of a community characterized by Gratiola officinalis, Juncus inflexus, and Mentha pulegium in 20-40 cm deep depressions in the basin of Lake Trasimeno, however without phytosociological relevés. Biondi and Bagella (2005) described the Alisimo lanceolatae-Gratiolietum officinalis association (Glycerio-Sparganion) in Sardinia, and the same association was found by Gigante et al. (2013) on the western side of Lake Trasimeno (Umbria). Lastrucci and Becattini (2008) found in temporarily flooded meadows near “Bo-sco ai Frati” (Tuscany) a Gratiola officinalis community, attributed to the Molinio-Arrhenatheretea class.

Because of the different floristic composition and biogeographic contexts, the abovementioned syntaxa do not seem suitable for interpreting the analyzed community; however, there are no elements to describe a new association. Given the high frequencies of species of Potentillion anserinae and the higher syntaxonomic units, we propose placing this community in the Potentillion anserinae alliance.

OENANTHO AQUATICAE-RORIPTEM AMPHIBIAE Lohmeyer 1950 (group 19, Suppl. material 1: Table S19, rel. 12-15)

Plant community physiognomically characterized by Rorippa amphibia, with Mentha aquatica subsp. aquatica, Myosotis scorpioides and other species of the Phragmito-Magnocaricetea class, such as Phalaris arundinacea, Glyceria maxima, Alisma plantago-aquatica, Glyceria nodata, and Typha latifolia. Sometimes there are submerged hydrophytic rooting species, such as Myriophyllum verticillatum, Ranunculus trichophyllus, and Callitriche stagnalis. The occurrence of species such as Gratiola officinalis, Ranunculus repens and Rumex conglomeratus indicates an early dynamic stage of this community, which will probably lead to progressive terrestrialization, testified by the Rorippa amphibia community, extremely species-poor and mainly composed of nitrophilous and ruderal species, found at the border of the Palude di Colfiorito by Pedrotti and Murrja (2020).

We refer this community to the Oenanthe-Rorippetum association and the Eleocharito palustris-Sagittario sagittifolii alliance, often published under the synonym name Oenanthon aquaticae Hejny 1948 (Baldoni and Biondi 1993; Biondi et al. 2003).

The plant community develops in stagnant or slowly flowing waters, less than 50 cm deep, in contact with communities of the Phragmition communis alliance. It is indicated in northern and central Italy (e.g. Pedrotti 1977; Baldoni and Biondi 1993; Marchiori et al. 1993; Biondi and Baldoni 1994; Marchiori and Sburlino 1997; Lastrucci et al. 2007; Pedrotti and Murrja 2020).

Changes in the occurrence of plant communities

In the relevés carried out in the period 1963-1977, Pedrotti reported 40 plant communities (Suppl. material 2: Table S20), 10 hydrophytic (Charetea, Potamogetonea, and Lemnetea classes), 17 helophytic (Phragmito-Magnocaricetea), six humid meadow communities (Molinio-Arrhenatheretea), three communities of peat bogs (Scheuchzerio-Caricetea nigrae), two of temporarily flooded lands (Bidentetea), one of Isoëto-Nanojuncetea, and one of Epilobietea angustifolii (Pedrotti 1975, 2019) (Suppl. material 2: Table S20).

In our survey (years 2005-2009), we found 39 plant communities referred to the Potamogetonea (six com-
munities), Bidentetalia (2), Phragmito-Magnocaricetea (21), Molinio-Arrhenatheretea (9), and Epilobietea angustifolii (1) classes. Twenty-two of them confirm the findings of Pedrotti (1975, 1976, 2019), Buchwald (1994), Orsomando (2000, 2002), and Tardella et al. (2002), while 17 were new records for the study area. Twenty-four communities, found by Pedrotti (1975, 2019), instead, were not confirmed (eight of Characeae, Lemnietea minoris, and Potamogetonetea, one of Bidentetalia; seven of Phragmito-Magnocaricetea; three of Schuchzerio-Caricetea fuscae, four of Molinio-Arrhenatheretea and one of Isóeto-Nanojuncetea).

Changes in the occurrence of the habitats of conservation interest

As far as habitats of community interest are concerned, 19 plant communities found by Pedrotti in the 1960s/1970s can be ascribed to seven habitats of community interest (Suppl. material 2: Table S20). Three of these habitats (3140 – Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.; 3170* – Mediterranean temporary ponds; and 7230 – Alkaline fens) have not been confirmed in our research. In particular, habitat 7230, related to the peat bog, has completely disappeared. In the early 2000s, there was still a residual area characterized by Carex panicea, Epipactis palustris, and Dactylorhiza incarnata (Tardella, pers. obs.), which was invaded by Phragmites australis in the subsequent years (see Suppl. material 1: Table S10, relevés 6–7) and, then, by shrubs (Pedrotti 2019). The habitats that can be confirmed, also in the light of the most recent available relevés are: 3150 – Natural eutrophic lakes with Magnopotamion or Hydrocharition-type vegetation (two communities of the Potamogetonion and two of the Nymphaeion alliances); 3260 – Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation (two communities of the Ranunculion aquatilis); 3270 – Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (one community of the Bidenten tripartitae and one of the Chenopodion rubri); and 6510 – Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis) (two communities of the Ranunculion velutini).

Conclusions

We found a considerable richness in plant communities (39 vegetation units, belonging to five vegetation classes). Most of them are of high conservation interest in central Italy because they are endemic to the central and southern Apennines (meadows of the Ranunculion velutini alliance), rare or endangered in peninsular Italy (hydrophytic and helophytic vegetation of Potamogetonetea and Phragmito-Magnocaricetea classes), and deemed habitats of community interest according to the 92/43/EEC Directive. However, we did not confirm 24 plant communities found in the past, most of which can be attributed to habitats of community interest.

The studied wetland system underwent several alterations over time and is still threatened by the reduction of precipitation due to climate change, anthropic activities outside or bordering on the basins, such as tillage of croplands, circulation of agricultural vehicles, cropland fertilization that causes eutrophication of the water bodies, and unauthorized water collection for irrigation purposes. The lack or the discontinuity of management and maintenance interventions in part of the study area, especially the lack of management of the reed beds, canals, and ditches, could further negatively impact the biodiversity of the wetland system. The reed expansion to the outside of the basins, the increase in the extent of the Nymphaetum albae, and the filling of small artificial watercourses is threatening rare species (e.g. Ranunculus ophioglossifolius, R. flammula, Equisetum fluviatile, and Ophioglossum vulgatum, see Ballelli et al. 2010) and fragmenting or substituting plant communities of small extent, such as some hydrophytic and therophytic communities. Moreover, these pressures are exacerbated by the absence of buffer zones covered by meadows between arable lands and wetlands.

To preserve plant species and vegetation diversity of these wetlands, besides the implementation of the usual maintenance activities (cleaning of ditches and mowing of the hay meadows), some conservation actions are advisable, such as the periodical mowing of the reed bed to contain its expansion outward, and the removal of dead material from the bottom of water pools and canals. Finally, the monitoring of the species composition of plant communities, and of changes in the vegetation mosaic, periodically updating the vegetation maps, is of great importance for the management of the wetland system.

Syntaxonomic scheme

POTAMOGETONETEA Klika in Klika et Novák 1941
POTAMOGETONETALIA Koch 1926
Potamogetonion Libbert 1931
Potamogetono pectinati-Myriophylletum spicati Rivas Goday 1964
Myriophylletum verticillati Gaudet ex Šumberová in Chytrý 2011
Nymphaeetum albae Oberd. 1957
Nymphaetum albae Vollmar 1947
Persicarietum amphibia community
Ranunculion aquatilis Passarge ex Theurillat in Theurillat et al. 2015
Potamogetono crispi-Ranunculetum trichophylli Imchenetzky 1926
Callitricho stagnalis community

BIDENTETEA Tüxen et al. ex von Rochow 1951
BIDENTETALIA Br.-Bl. et Tüxen ex Klika et Hadač 1944
Bidention tripartitae Nordhagen ex Klika et Hadač 1944
Bidentetum tripartitae Miljan 1933
Chenopodion rubri (Tüxen in Poli et J. Tüxen 1960) Hiltibig et Jage 1972
Polygono lapathifolii-Xanthietum italicì Pirola et Rossetti 1974

PHRAGMITO-MAGNOCARICETEA Klika in Klika et Nová 1941
PHRAGMITETALIA Koch 1926

Chenopodion rubri (Tüxen in Poli et J. Tüxen 1960) Hilbig et Jage 1972

Polygono lapathifolii-Xanthietum italicì Pirola et Rossetti 1974

PHRAGMITETALIA Koc 1926
Glycerietum maximae Nowiński 1930 corr. Šumberová, Chytrý et Danihelka in Chytrý 2011

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Competing interests
The authors have declared that no competing interests exist.

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Federico M. Tardella & Vincenzo M. Di Agostino: Wetland vegetation of the Altipiani di Colfiorito

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Supplementary material 1

Tables S1–S19
Authors: Federico Maria Tardella, Vincenzo Maria Di Agostino
Data type: phytosociological tables
Explanation note: Phytosociological tables (Tables S1–S19) of the surveyed plant communities.
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Link: https://doi.org/10.3897/PlantSociology.57.58883.suppl1

Supplementary material 2

Table S20
Authors: Federico Maria Tardella, Vincenzo Maria Di Agostino
Data type: data table
Explanation note: List of the plant communities found in the current research and of those found by other authors in the past.
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Link: https://doi.org/10.3897/PlantSociology.57.58883.suppl2