Hacquetia DOI: 10.2478/hacq-2022-0016 sciendo

Vegetation and Annex I habitats of a suburban river in southern Tuscany (central Italy): remnants of plant diversity or need for restoration?

Emanuele Fanfarillo[1], Tiberio Fiaschi[1], Paolo Castagnini[1], Leopoldo de Simone[1] & Claudia Angiolini[1,2]

Key words: aquatic plant community, biodiversity, phytosociology, riparian habitat, urban area, wetland.

Ključne besede: vodne rastlinske združbe, biodiverziteta, fitocenologija, obrežni habitat, urbano območje, mokrišče.

Abstract

Using vegetation as a bioindicator in urban and degraded areas is an effective way to assess the status of the environment. In this work, we present the results of a phytosociological investigation of a suburban river and of its surroundings in southern Tuscany (Bestina river and its tributary Bestinino in Asciano, Province of Siena). By means of 94 phytosociological relevés, we identified 34 plant communities belonging to the 17 classes. Six habitats included in the 92/43/EEC Directive, plus two habitats recently proposed for inclusion, were identified, as well as one habitat of regional interest. The study revealed that, despite the high levels of human disturbance, aquatic and herbaceous riparian vegetation is still well-preserved, though mostly represented by stress-tolerant communities. On the contrary, most of the vegetation types not being directly linked to the river dynamic are in poor conservation status. Despite this, some habitats of community interest were detected even in non-riverine sites. Our work provides the basic knowledge for future restoration of the Bestina river and of its surroundings, wished by the Tuscany Region.

Izvleček

Uporaba vegetacije kot bioindikatorja na urbanih in degradiranih območjih je učinkovit način ocene stanja okolja. V tem delu predstavljamo rezultate fitocenološkega preučevanja reke v suburbanem okolju in njegove okolice v južni Toskani (reka Bestina in njen pritok Bestinino v Ascianu, pokrajina Siena). Z 94-imi fitocenološkimi popisi smo določili 34 rastlinskih združb, ki spadajo v 17 razredov. Določili smo 6 habitatov s Habitatne Direktive in 2 habitata, ki so ju nedavno predlagali za vključitev v direktivo, ter en habitat v deželnem interesu. V raziskavi smo ugotovili, da je kljub visoki stopnji človekovih motenj, vodna in zeliščna obrežna vegetacija še vedno dobro ohranjena, vendar jo sestavljajo predvsem združbe, odporne na stres. Nasprotno je večina tipov vegetacije, ki niso neposredno povezani z rečno dinamiko, v slabem ohranitvenem stanju. Kljub temu smo nekaj habitatov v javnem interesu zaznali tudi na nerečnih mestih. Naše delo predstavlja temeljno poznavanje vegetacije za namen obnove reke Bestina in njene okolice v prihodnosti, kar je želja dežele Toskana.

Corresponding author:
Tiberio Fiaschi
E-mail: tiberio.fiaschi@gmail.com

Received: 15. 9. 2022
Accepted: 5. 1. 2023

1 Department of Life Sciences, University of Siena, Siena, Italy

2 National Biodiversity Future Center, Palermo, Italy

Introduction

The description of vegetation is an important starting point for the environmental knowledge of a given area since the analysis of spontaneous plant communities allows an immediate and effective evaluation of the current and past status of the environment. In fact, spontaneous flora and plant communities can be used as a global indicator of environmental processes, allowing quick assessments of the health status of ecosystems (Pignatti et al., 2001; Bonari et al., 2021a). Wetlands are among the most threatened natural ecosystems, and the main drivers of their loss are land degradation by agricultural activities and urbanization (Gardner et al., 2015). Despite this, many well-preserved freshwater habitats survive. These represent important biodiversity reservoirs, since they host threatened species and vegetation types (Gigante et al., 2016, 2018; Angiolini et al., 2019; Orsenigo et al., 2020). The disappearance of such habitats and their decrease in extent and quality implies, besides biodiversity loss, a reduction of ecosystem services such as regulation of water cycles and mitigation of microclimates (Janssen et al., 2016; Environmental Protection Agency, 2020).

Among wetlands, rivers have a key role in supporting biodiversity, for instance acting as ecological corridors that enhance genetic exchanges between plant and animal populations (Johansson et al., 1996; Palmer et al., 2010). In urban areas, rivers and their riparian vegetation play important ecological and social functions: they provide habitats for wildlife, act as filters and barriers, supply resources, increase the diversity of urban landscapes, and offer recreational areas for people (Caneva et al., 2021). As a consequence of their location, urban rivers are directly exposed to many anthropic pressures that have negative impacts on their biodiversity, sustainability, and functional features (Baschak & Brown, 1995).

Several anthropic threats at both local and global scales affect riparian ecosystems (Richardson et al., 2007). In recent centuries, river flora, vegetation, and habitats have been depleted due to direct and indirect anthropogenic alterations, which modified key ecological factors that regulate the distribution of species and communities (Lastrucci et al., 2012). Aiming at the protection and correct management of fluvial environments, in 2000 the World Water Council created River Contracts, participatory tools that involve local people in initiatives (Angelini, 2017). These can be effective policy tools to restore and improve the environmental status of riverine habitats, starting from descriptive surveys as a baseline for future restoration (Caneva et al., 2021).

Italy is an important reservoir of aquatic plant diversity (Bolpagni et al., 2018). In southern Tuscany, like elsewhere, rivers and all wetlands have decreased in extent and quality, with a reduction of plant diversity and the spread of alien species (Viciani et al., 2014; Lazzaro et al., 2020; Viciani et al., 2020). However, relic patches of valuable wetland vegetation can still be found even in areas highly modified by human activities, such as intensive agricultural landscapes (Lastrucci et al., 2010a; Bonari et al., 2021b).

In this paper, we present the results of a phytosociological study of the urban stretch of two small watercourses located in southern Tuscany, central Italy: Bestina River and the final part of its tributary Bestinino. The research was carried out in the context of a River Contract. We describe both aquatic and riparian vegetation and plant communities growing in the surroundings, not directly influenced by the river. This work aims at understanding the status of the environment by describing vegetation and habitats of conservation interest in the study area, and it will be used as a baseline for the definition of a restoration project of the Bestina river and of its surroundings.

Materials and methods

Study area

The study area is located in southern Tuscany (central Italy), along the stretches of the Bestina river and of its tributary Bestinino bordering the village of Asciano, in the central part of the province of Siena (43.235519° N, 11.561644° E, EPSG 4326 – Figure 1). In the Middle Ages, Asciano was considered the "barn of Siena", due to its countryside being particularly suitable for wheat cultivation. Wheat was ground in 12 mills located on the Bestina river. Thus, Asciano has played an important role for the town of Siena and its people since ancient times (Barlucchi, 1997). The urban center lies within a clayey hilly landscape deeply engraved by small watercourses, at an elevation of about 200 m a.s.l. It is placed in the middle of the "Crete Senesi" area, between two Special Areas of Conservation (SACs) of the Natura 2000 network: "Crete di Camposodo e Crete di Leonina" (IT5190004) and "Monte Oliveto Maggiore e Crete di Asciano" (IT5190005) (Tuscany Region, 2021). This area is characterized by the presence of badlands, i.e., patches of highly eroded land that were widely studied by botanists due to their peculiar biodiversity (Maccherini et al., 2000, 2011; Gallart et al., 2013). On the contrary, studies on wetland vegetation are lacking.

The study area lies on the border between a Mediterranean and a temperate submediterranean climate, slightly continental. As for bioclimate, the thermotype is lower mesotemperate and the ombrotype is upper subhumid

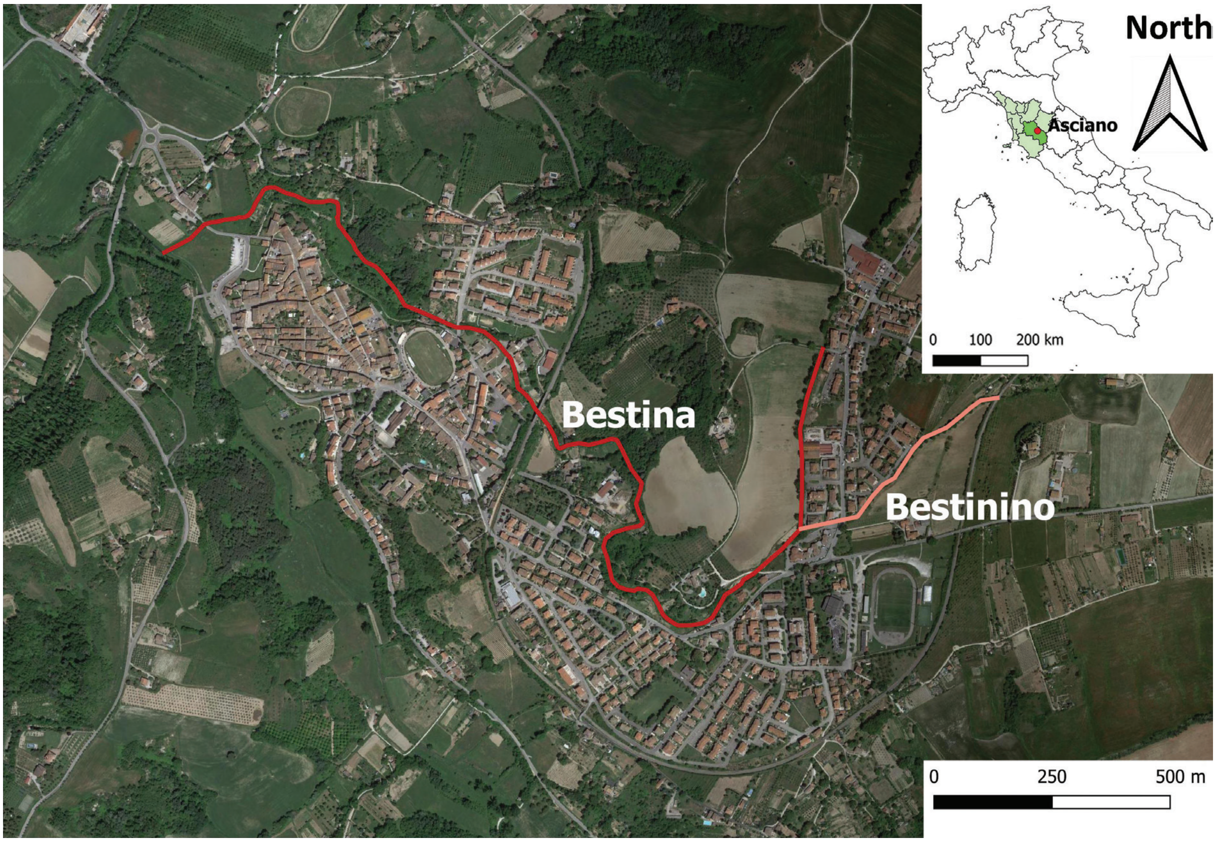

Figure 1: The investigated stretches of Bestina (red) and Bestinino (pink) rivers and location of the study area (red dot) in Tuscany and Italy.
Slika 1: Raziskovani odseki rek Bestina (rdeče) in Bestinino (roza) in lokacija raziskovanega območja (rdeča točka) v Toskani in Italiji.

(Pesaresi et al., 2017). Geological substrates are mainly represented by sandy alluvial deposits, especially close to the river. Far from the river, Pliocene re-sedimented sands are common. Travertine outcrops are present along the watercourse (Tuscany Region, 2021). Land use is mainly urban, industrial, and agricultural. Shrublands and woods are scarce and usually occur as residual patches (Tuscany Region, 2021).

Vegetation survey

The survey of plant communities was carried out between June 2020 and June 2021. We started from aquatic and riparian habitats. Then we investigated the river surroundings, including shores, banks, wood fragments, shrubs, hedges, walls, orchards, and ruderal sites. We carried out 94 relevés using the classic phytosociological method of the Zurich-Montpellier school, which implies a varying size of the relevés (Braun-Blanquet, 1964; Biondi, 2011).

Vascular plants were identified according to Pignatti et al. (2017–2019) and liverworts were identified according to Paton (1999). The taxonomic nomenclature follows the Portal to the Flora of Italy (2021 onwards) for vascular plants and Aleffi et al. (2020) for liverworts. The syntaxonomic nomenclature follows the original authors for associations and subassociations, Biondi et al. (2014a) for suballiances, and Mucina et al. (2016) for alliances, orders, and classes. The syntaxonomy of floodplain woods is according to Gennai et al. (2021). For the associations of the class *Phragmito-Magnocaricetea*, we followed Landucci et al. (2020). Characteristic species of syntaxa were detected according to the original authors for associations and subassociations, to Biondi et al. (2014a) for alliances and suballiances, and to Mucina et al. (2016) for classes. Habitats of community interest were identified following Biondi et al. (2009a). Moreover, we identified habitats recently proposed for the inclusion in the Annex I of the Habitats Directive (Spampinato & Puglisi, 2009; Casavecchia et al., 2021). We also checked for the presence of habitats of regional interest, according to the LR 30/2015 (Tuscany Region, 2015).

Data analysis

The relevés were subjected to an agglomerative hierarchical cluster analysis (Unweighted Pair Group Method with Arithmetic mean – UPGMA) (square root transformation of percentage species covers, converted as the central value of each Braun-Blanquet cover class; distance measure: Bray-Curtis) in the package "*cluster*" of R-project (R Core Team, 2021; Maechler et al., 2022). The relevés were managed in the software Juice, version 7.1.25 (Tichý, 2002). Then, a DCA analysis was carried out using the function decorana in the package "*vegan*" of R-project (Oksanen et al., 2021). Ecological indicator values according to Pignatti et al. (2005) were passively transposed on the ordination plot to visually detect the main ecological gradients.

Results

Cluster analysis and ordination of the relevés

The UPGMA analysis produced 33 interpretable clusters. The first division of the dendrogram separated the vegetation of shady walls with dripping water (3 relevés) from the rest of plant communities. The second division discriminated against synanthropic herbaceous communities (15 relevés). The third division separated aquatic, gravel bed, and helophytic herbaceous vegetation (42 relevés) from fringes, shrublands, and woods (34 relevés) (Figure 2).

Figure 3 shows the DCA ordination plot. The centroids of clusters resulting from the UPGMA are marked with the corresponding number and Pignatti indicator values are passively transposed. The analysis highlighted that the main gradient of diversity (first axis) was mostly correlated with decreasing moisture and increasing temperature (from aquatic vegetation to synanthropic thermo-xerophilous vegetation). Increasing levels of nitrophily of the plant communities were positively correlated with moisture. Moreover, a gradient of increasing light and continentality was detected along the second axis (from the communities of humid shaded walls to those of open herbaceous habitats, across shrublands and woods).

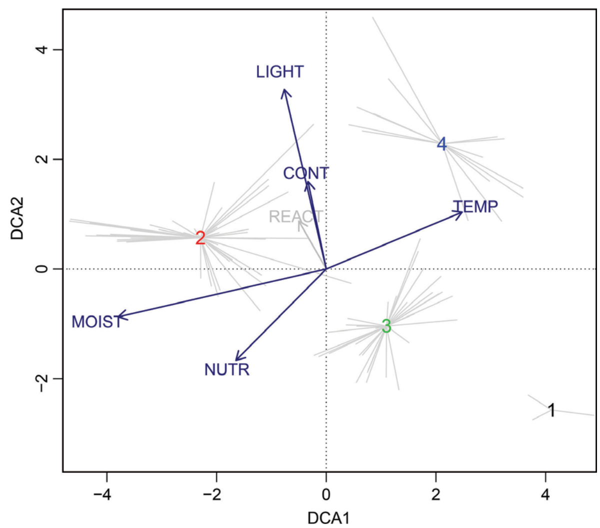

Figure 3: DCA ordination plot of the relevés. Numbers correspond to the centroids of the clusters resulting from the UPGMA. Vectors show Mean Pignatti indicator values (significant factors are highlighted in blue); CONT = Continentality; TEMP = Temperature; MOIST = Moisture; NUTR = Nutrients; REACT = Soil Reaction. Numbers correspond to the centroids of the main four groups of relevés from the cluster analysis: 1: vegetation of shady walls with dripping water; 2: aquatic, gravel bed, and helophytic herbaceous vegetation; 3: fringes, shrublands, and woods; 4: synanthropic vegetation.

Slika 3: Ordinacijski diagram popisov iz analize DCA. Številke ustrezajo centroidom klastrov iz analize UPGMA. Vektorji prikazujejo povprečne vrednosti Pignattijevih indikatorskih vrednosti (značilni faktorji so prikazani z modro barvo); CONT = kontinentalnost; TEMP = temperatura; MOIST = vlažnost; NUTR = hranila; REACT = reakcija tal. Številke ustrezajo glavnim štirim skupinam popisov iz klastrske analize: 1: vegetacija senčnih zidov s kapljajočo vodo; 2: vodna, prodiščna in močvirska zeliščna vegetacija; 3: gozdni robovi, grmovja in gozdovi; 4: sinantropna vegetacija.

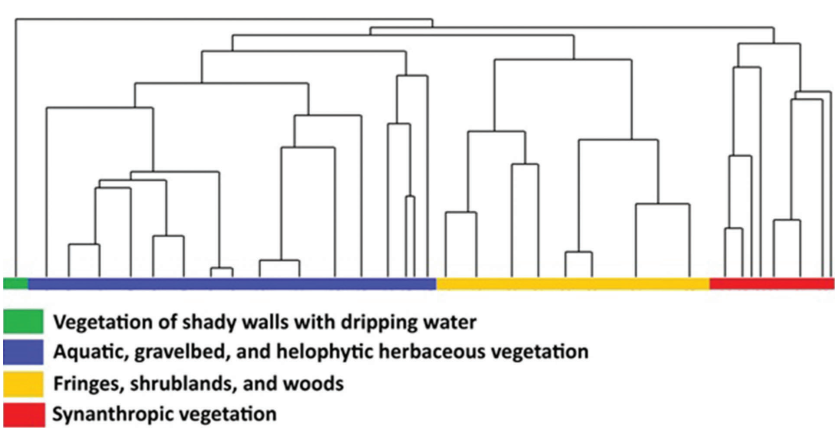

Figure 2: Dendrogram resulting from the UPGMA cluster analysis. The colored bars correspond to the relevés included in each cluster.
Slika 2: Dendrogram UPGMA klastrske analize. Obarvane črte predstavljajo popise, ki so vključeni v vsakega od klastrov.

Detected plant communities

Vegetation of shady walls with dripping water

Conocephalo conici-Adiantetum capilli-veneris Caneva, De Marco, Dinelli, Vinci 1995
(Table 1, Supplementary material)

This association develops on vertical shady walls with dripping water. It is dominated by liverworts in the lower layer (*Conocephalum conicum*, *Pellia epiphylla*) and by the fern *Adiantum capillus-veneris* in the upper one. It was described in the archaeological sites of Rome by Caneva et al. (1995). It is not very common in the study area, where it colonizes both artificial and natural vertical or slightly inclined wet rocky substrates. It is an example of the habitat 7250 "Mediterranean wet inland cliffs", recently proposed for the inclusion in Annex I of the Habitats Directive in Italy, and present in several Mediterranean countries (Spampinato & Puglisi, 2009).

Aquatic, gravel bed, and helophytic herbaceous vegetation

Typhetum latifoliae Nowiński 1930
(Table 2, Supplementary material)

Helophytic vegetation dominated by *Typha latifolia* occurs in shallow waters, sometimes in contact with *Sparganium neglectum* communities. Aquatic species like *Callitriche palustris*, *Veronica anagallis-aquatica* and *Helosciadium nodiflorum* are present in the lower layer. This vegetation type is classifiable in the association *Typhetum latifoliae.* It usually develops in eutrophic conditions, in sites rich in organic sediments with possible soil anoxia, and tolerates summer drying (Landucci et al., 2013). It has a broad ecology and tolerance to disturbances like pollution by agricultural activities (Suska-Malawska et al., 2014). Such formations are very rare in the study area, where they are present as residual small patches. Communities dominated by *Typha* spp. are classified in the *Phragmition communis*, and were thus recently proposed as the new Annex I habitat of Directive 92/43/EEC "Freshwater large sedge and reed beds" (Casavecchia et al., 2021).

Glycerio-Sparganietum neglecti Koch 1926
(Table 3, Supplementary material)

Helophytic communities dominated by *Sparganium neglectum* are to be classified in the *Glycerio-Sparganietum neglecti*. They are up to 2 m high, and develop in hollows with still or slow-flowing water. *Stachys palustris* is often abundant in the lower layer. In flooded sites, *Callitriche palustris* is present with low covers. In sites with less flooding and deeper soils, less hygrophilous species occur, e.g., *Ranunculus repens*, *Rumex conglomeratus*, and *Poa trivialis*. The *Glycerio-Sparganietum* develops in water bodies in an advanced stage of terrestrialization, with mesotrophic to eutrophic waters, often in contact with other associations of *Phragmito-Magnocaricetea* (Landucci et al., 2013). It is rare in the study area, but common elsewhere in Tuscany and Italy (Lastrucci et al., 2007; Ceschin & Salerno, 2008; Pedrotti, 2008). Formerly classified in the *Glycerio-Spargapion*, it was recently classified in the *Phragmition communis* (Landucci et al., 2020). Communities classified in the latter alliance were recently proposed as a new Annex I habitat of Directive 92/43/EEC under the name "Freshwater large sedge and reed beds", though *Sparganium* species are not mentioned as diagnostic (Casavecchia et al., 2021). Moreover, the *Glycerio-Sparganietum* identifies a habitat of regional interest in Tuscany (LR 30/2015).

Glycerietum notatae Kulczyński 1928 nom. mutat. propos.
(Table 4, Supplementary material)

This community is dominated by *Glyceria notata.* It develops in flowing, shallow, and base-rich waters. Compared to other vegetation types dominated by *Glyceria* species, it better tolerates nutrient-rich waters and disturbance (Landucci et al., 2013). In the study area, this association occurs near the riverbank in moderately flowing waters. The presence of species like *Nasturtium officinale*, *Ranunculus repens,* and *Convolvulus arvensis* suggest a transition towards less hygrophilous conditions and a higher anthropic disturbance. This vegetation type is quite rare in the study area, though it is common across Italy (Pedrotti, 2008; Tardella & Di Agostino, 2020). As part of the *Glycerio-Sparganion*, it is a habitat of regional interest in Tuscany (LR 30/2015).

Helosciadietum nodiflori Maire 1924
(Table 5, Supplementary material)

This vegetation type is dominated by *Helosciadium nodiflorum*, which is accompanied by few other hygrophilous species (*Nasturtium officinale, Veronica anagallis-aquatica*, *Glyceria notata*). It is common along both rivers, in contact with communities dominated by *Nasturtium officinale*. It develops in slow-flowing, nutrient-poor to quite nutrient-rich, cool and oxygen-rich waters (Buchwald, 1994). In one relevé, we recorded the dominance of *Persicaria amphibia* over *Helosciadium nodiflorum*. This probably represents a transition towards *Persicaria amphibia*-dominated communities developing in sites that are submerged for most of the year but dry out in summer, which were detected elsewhere in central Italy (Lastrucci et al., 2007, 2010a, b; Landucci et al., 2013). The association *Helosciadietum nodiflori* is widespread in Tuscany and in the whole of Italy, especially in the Peninsular part (Sciandrello, 2009; Mereu et al., 2010; Spampinato et al., 2019). It is a habitat of regional interest in Tuscany since it is classified in the *Glycerio-Sparganion* (LR 30/2015).

Paspalo paspaloidis-Polypogonetum viridis Br.-Bl. 1936
(Table 6, Supplementary material)

We detected some communities dominated by the alien grass *Paspalum distichum*. They develop in shallow waters and in riverbanks, in contact with vegetation types dominated by *Agrostis stolonifera*. Despite the absence of the character species *Polypogon viridis*, we classify this community in the association *Paspalo paspaloidis-Polypogonetum viridis*, according to previous interpretations in Tuscany (Lastrucci et al., 2010a; Mereu et al., 2010). These communities can be attributed to the EU habitat 3280 "Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*".

Agrostis stolonifera community
(Table 7, Supplementary material)

Strips of dense grasslands dominated by *Agrostis stolonifera* develop in shallow waters and on riverbanks, on moist, compact, deep, and nutrient-rich soils. Sometimes they are in contact with communities of *Paspalo paspaloidis-Polypogonetum viridis*, which colonize more disturbed sites. Species related to permanently wet substrates also occur, such as *Mentha aquatica*, *Nasturtium officinale,* and *Veronica anagallis-aquatica*. Nitrophilous pioneer species such as *Urtica dioica* and *Galium aparine* are frequent. In Tuscany, similar communities were classified in the association *Rorippo-Agrostietum stoloniferae* (Lastrucci et al., 2010a; Mereu et al., 2010). Due to the absence of *Rorippa sylvestris* in our relevés, we classify them at the alliance level in the *Potentillion anserinae.*

Bolboschoenetum glauci Grechushkina, Sorokin et Golub 2011 (Table 8, Supplementary material)

We detected the presence of communities dominated by *Bolboschoenus glaucus* forming narrow bands on muddy substrates, in sites with shallow water that progressively dry out during summer. *B. glaucus* is the more thermophilous species of the genus *Bolboschoenus* in Europe. It is related to freshwater environments, but it adapts to summer drying (Hroudová et al., 2007). We classify this vegetation type in the *Bolboschoenetum glauci*, a typical association of periodically flooded habitats, with strong fluctuations of water levels. In the study area, it develops between hydrophytic and helophytic communities both in the Bestina and Bestinino rivers.

Ranunculetum repentis Knapp 1946
(Table 9, Supplementary material)

Dense, species-poor vegetation dominated by *Ranunculus repens* was found in wet but not permanently flooded banks, in contact with *Nasturtium officinale*-dominated communities. We classify this vegetation type in the *Ranunculetum repentis*, already detected in nearby areas by Lastrucci et al. (2010b). Hygrophilous species like *Lycopus europaeus, Mentha aquatica,* and *Persicaria lapathifolia* are sometimes present and even quite abundant.

Lycopus europaeus community
(Table 10, Supplementary material)

A vegetation type dominated by *Lycopus europaeus* develops along the shores, close to running water, on silty-clayey soils being flooded for most of the year. The dominant species is associated with a few other hygrophilous taxa like *Carex pendula*, *Helosciadium nodiflorum*, and *Persicaria amphibia*. Synanthropic species such as *Anisantha sterilis, Artemisia vulgaris*, and *Avena sterilis* colonize the community from surrounding man-made areas. These communities are not very common in Italy, since *L. europaeus* usually does not behave as a dominant species, but occurs with low covers in other hygrophilous vegetation types (Lastrucci et al., 2010a). It is considered a diagnostic species of the class *Phragmito-Magnocaricetea*, without a particular linkage to lower-rank syntaxa (Landucci et al., 2020). Difficulties in the syntaxonomic framing of vegetation types dominated by *L. europaeus* were already highlighted by other authors in Tuscany, who classified these communities into high-rank syntaxa (*Phragmitetalia, Phragmito-Magnocaricetea*) (Landi et al., 2002; Lastrucci et al., 2010b). Following such previous interpretations, we classify this vegetation type in the class *Phragmito-Magnocaricetea*.

Callitrichetum palustris (Dihoru 1975 .) Burescu 1999
(Table 11, Supplementary material)

Callitriche palustris-dominated hydrophytic communities develop in sites with mainly slow-flowing water. The dominant species is occasionally accompanied by submerged forms of hygrophilous plants like *Veronica anagallis-aquatica* and *Nasturtium officinale*. We can classify this vegetation type, frequently found in the study area, in the *Callitrichetum palustris*. This association reaches its maximum development in spring, and it occurs in clear, nutrient-poor, neutro-alkaline, still or slow-flowing waters (Schotsman, 1967). It was recently detected in Calabria, southern Italy (Maiorca et al., 2020). Such formations are examples of the habitat 3260 "Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation".

Nasturtietum officinalis Gilli 1971
(Table 12, Supplementary material)

Species-poor communities dominated by *Nasturtium officinale* develop in shallow waters. Other hygrophilous species such as *Helosciadium nodiflorum* and *Veronica anagallis-aquatica* also occur, as well as nitrophilous taxa like *Persicaria lapathifolia* and alien taxa like *Bidens frondosa*. This vegetation type develops in sunny, fast or slow-flowing, oligotrophic to eutrophic waters (Buchwald, 1994). In the study area, it forms a band of varying size all along the rivers, and it is also present inside ditches between orchards. This community is widespread in Tuscany and in the rest of Italy (Landucci et al., 2013; Tardella & Di Agostino, 2020). Like all the associations included in the alliance *Glycerio-Sparganion*, it is protected on a regional level by LR 30/2015 (Tuscany Region, 2015).

Potametum crispi von Soó 1927
(Table 13, Supplementary material)

Dense formations dominated by *Potamogeton crispus* are common in ponds and in sites with slow-flowing water. Algae of the genus *Chara* are sometimes present. This species-poor vegetation type can be classified in the *Potametum crispi*, a community developing in both lentic and lotic waters, even when polluted (Šumberová, 2011), and on nutrient-rich muds. It is quite common in Tuscan lakes, rivers, and channels (Landi et al., 2002; Mereu et al., 2010). This community, recently detected in other rivers of the surroundings (Rivieccio et al., 2021), identifies the habitat 3260 "Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation" (Biondi et al., 2009b). The attribution to the habitat 3260 is due to the location of this vegetation type in running waters. In fact, when developing in still waters, communities dominated by *Potamogeton* species are considered representative of the habitat 3150 "Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation".

Parvo-Potamogetono-Zannichellietum pedicellatae Soó 1947
(Table 14, Supplementary material)

Zannichellia palustris builds almost monospecific grasslands a few centimeters underwater, classifiable in the *Parvo-Potamogetono-Zannichellietum pedicellatae* (syn. *Zannichellietum palustris* Lang 1967). This association is present in other watercourses of Tuscany, such as the Arno river, the Pesa river, the Tiber river, and the Merse river (Landi et al., 2002; Lastrucci et al., 2010a; Mereu et al., 2010). It is quite common in the study area, especially in still or slow-flowing waters with a good sediment deposition. It is considered an indicator of eutrophic and chlorine-rich waters (Iberite et al., 1995; Ceschin & Salerno, 2008). Communities classified in the alliance *Zannichellion pedicellatae* are mostly linked to coastal meso-eutrophic brackish waters, but can reach inner areas as a consequence of eutrophication and pollution (Viciani et al., 2022). Like the *Potametum crispi*, this community must be referred to the habitat 3260 "Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation".

Polygono lapathifolii-Xanthietum italici Pirola et Rossetti 1974 (Table 15, Supplementary material)

This hygro-nitrophilous, therophytic community is dominated by *Persicaria lapathifolia*, *Xanthium italicum,* and *Bidens frondosa*. It develops on dry gravel beds and sandy soils. It is dependent by the deposition of new alluvial material at each flood and by anthropic disturbance (Pirone, 1991). It reaches its maximum development in summer (Ceschin & Salerno, 2008), replacing pioneer winter-annual communities on alluvial soils (Amor et al., 1993). It is present in several watercourses and wetlands of Tuscany (Landi et al., 2002; Lastrucci & Becattini, 2008; Lastrucci et al., 2010b). In the study area, this vegetation type occurs in small beaches or islets that are dry in summer. Despite the relevant presence of alien species, it is an example of the Directive habitat 3270 "Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation".

Fringes, shrublands, and woods

Convolvulo-Epilobietum hirsuti Hilbig, Heinrich et Niemann 1972 (Table 16, Supplementary material)

A nitrophilous community dominated by *Epilobium hirsutum* was detected on the riverbank, on pebbly soil. Taxa like *Agrostis stolonifera*, *Lycopus europaeus*, *Persicaria maculosa*, *Ranunculus repens*, and *Urtica dioica* also occur. Though *Convolvulus sepium* is missing in the only carried out relevé, the ecology and floristic composition allow classifying this vegetation type in the association *Convolvulo sepii-Epilobietum hirsuti* (*Senecionion fluviatilis, Epilobietea angustifolii*), already detected in central Italy by several authors (Lastrucci & Becattini, 2008; Pedrotti, 2008). It develops in non-permanently flooded sites, even disturbed (Pedrotti, 2008). It occurs in small patches all along the Bestina river, and it is an example of the habitat 6430 "Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels".

Helianthus tuberosus community
(Table 17, Supplementary material)

Helianthus tuberosus-dominated hygrophilous and subnitrophilous communities occur on embankments, a couple of meters above the water level. Valuable wetland species like *Stachys palustris* and *Scrophularia auriculata* occur in the lower layer. This alien species-dominated vegetation type shows ecological similarities with the association *Oenothero biennis-Helianthetum tuberosi* Bolòs, Monserrat et Romo 1988, described in Spain (Bolòs et al., 1988). Nevertheless, the lack of species like *Elymus repens, Pastinaca sativa,* and *Oenothera biennis* does not allow classifying our vegetation type into such association. Similar communities were frequently reported in Italy, including Tuscany, mainly along watercourses, but they were never classified at the association level (Lastrucci et al., 2010a; Viciani et al., 2020). They replace herbaceous communities of the habitats 3270 ("Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation") and 6430 (Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels) (Lazzaro et al., 2020; Viciani et al., 2020). Following previous authors, we classify this vegetation type in the alliance *Senecionion fluviatilis* (syn. *Calystegion sepii*).

Pruno-Rubenion ulmifolii O. Bolòs 1954
(Table 18, Supplementary material)

In areas not directly influenced by the river, shrub communities are dominated by *Acer campestre*, *Crataegus monogyna*, *Prunus spinosa*, and/or *Ulmus minor*. These coenoses can be classified in the *Pruno-Rubion ulmifolii* alliance, including thermophilic shrublands that develop under conditions of high atmospheric and edaphic humidity, in dynamic contact with *Quercus pubescens* and *U. minor* woods. Their floristic composition includes some Mediterranean evergreen species, like *Rosa sempervirens*, *Rhamnus alaternus*, and *Quercus ilex*. At a more detailed level, we can classify them in the suballiance *Pruno-Rubenion ulmifolii*, which identifies sub-Mediterranean, sub-hygrophilous shrub communities, characterized by a relevant Mediterranean influence (Blasi et al., 2002; Biondi et al., 2014a).

Dioscoreo communis-Populetum nigrae Poldini et Vidali in Poldini, Sburlino ex Vidali, 2017 *typicum* and *populetosum albae* (Biondi, Vagge, Baldoni ex Taffetani, 1999) Poldini, Vidali ex Castello, 2020
(Table 19, Supplementary material)

Fragments of residual riparian woods dominated by *Populus nigra*, *P. alba*, and/or *Salix alba* are present along the Bestina River. Formerly attributed to two distinct associations (*Salici-Populetum nigrae* (Tüxen 1931) Meyer-Drees 1936 and *Populetum albae* Br.-Bl. 1931 ex Tchou 1947), such communities were recently classified in the *Dioscoreo communis-Populetum nigrae* as the two subassociations *typicum* and *populetosum albae* (Gennai et al., 2021). These woods occur in riparian areas that are only marginally influenced by the river (e.g., abandoned meanders), and that are subject to submersion in the wet season (Gennai et al., 2021). In the study area, they are only present as very small patches, and their typical floristic composition is altered by the ingression of species from open and ruderal habitats (*Brachypodium rupestre, Medicago lupulina, Torilis arvensis*). Examples of this vegetation type were detected all over Italy (Venanzoni & Gigante, 2000; Ceschin & Salerno, 2008; Gennai et al., 2021). Along the Bestina, they represent degraded fragments of the habitat 92A0 "*Salix alba* and *Populus alba* galleries".

Quercus pubescens community
(Table 20, Supplementary material)

True non-riparian woodlands are missing in the study area. However, immediately outside the riparian area on clayey substrates, we detected a thicket community dominated by *Quercus pubescens* representing an intermediate successional stage between *Pruno-Rubenion* shrublands and *Quercus pubescens* woodlands. We classify this vegetation type in the class *Crataego-Prunetea*. We speculate that it is dynamically linked to woods classifiable in the *Roso sempervirentis-Quercetum pubescentis* Biondi 1986, since character species of this association are frequent in the surrounding shrublands (*Lonicera etrusca, Rosa sempervirens, Rubia peregrina*). Moreover, woods classified in the *Roso-Quercetum* are present in nearby areas (Allegrezza et al., 2002). This evidence highlights the possibility of future development of the priority habitat 91AA* "Eastern white oak woods".

Clematido vitalbae-Arundinetum donacis Biondi et Allegrezza 2004 (Table 21, Sumaterial)

Arundo donax, an archaeophyte native to central Asia, builds dense reed formations both along the rivers and in contact with orchards. In Italy, this species is among the few archaeophytes having a negative impact on many aquatic and terrestrial Directive habitats, including some present or potentially present along the Bestina and Bestinino rivers (habitats 3260, 3270, 3280, and 92A0) (Lazzaro et al., 2020). We classify *A. donax*-dominated communities of the study area in the association *Clematido vitalbae-Arundinetum donacis*, described in Marche, central Italy (Biondi & Allegrezza, 2004). This is a sub-hygrophilous and sub-nitrophilous community that develops on damp, nutrient-rich soils, which periodically dry out. The lower layer hosts shrubs and lianas like *Clematis vitalba*, *Hedera helix,* and *Prunus spinosa,* and nitrophilous herbs such as *Chaerophyllum temulum, Picris hieracioides,* and *Urtica dioica.*

Galio erecti-Brachypodietum rupestris Allegrezza et al. 2016 (Table 22, Supplementary material)

This heliophilous and mesophilous meadow community is dominated by *Brachypodium rupestre*, and it builds the edge of thermophilous *Quercus pubescens* woods, influenced by the river only occasionally, during flood events. It can be classified in the association *Galio erecti-Brachypodietum rupestris*, widespread in the hills of central Italy (Allegrezza et al., 2016). Dynamically, it represents a very mature herbaceous vegetation type, as highlighted by the presence of shrubs like *Crataegus monogyna, Rubus caesius,* and *R. ulmifolius*.

Ailanthus altissima community (Table 23, Supplementary material)

Ailanthus altissima-dominated forest patches are frequent around the Bestina River. These woods are one-layered and develop in agricultural and peri-urban sites on alluvial, silty-sandy soils, i.e. in conditions of good soil moisture availability under high anthropic disturbance. They mainly occur on the slopes above the watercourse, since *A. altissima* does not tolerate prolonged submersions (Badalamenti et al., 2013). The shrub layer is quite species-poor, and it is dominated by *Hedera helix* and *Rubus ulmifolius*, locally accompanied by *Cornus sanguinea, Laurus nobilis*, and *Robinia pseudoacacia*. The herbaceous layer is rich in nitrophilous/ruderal annual and perennial species (*Anisantha sterilis*, *Cichorium intybus*, *Elymus repens, Lamium maculatum, Urtica dioica*), highlighting a heavy and frequent anthropic disturbance. The collected data allow classifying these communities in the alliance *Lauro nobilis-Robinion pseudoacaciae*, which includes several associations of *A. altissima*-dominated woods (Montecchiari et al., 2020).

Sambuco nigrae-Robinietum pseudacaciae Arrigoni, 1997 (Table 24, Supplementary material)

Most of the wood communities developing along the slopes and in small plains around the Bestina river are dominated by the Northern American invasive tree *Robinia pseudoacacia*, which replaces native meso-hygrophilous oak woods on alluvial or colluvial deposits, on damp soils rich in organic matter. Other alien species such as *Ailanthus altissima*, *Parthenocissus quinquefolia,* and *Phytolacca americana* occur too. Shrubs and lianas such as *Clematis vitalba, Hedera helix, Rubus ulmifolius*, and *Sambucus nigra* are frequent in the understory. The herbaceous layer is rich in both annual and perennial, ruderal, and nitrophilous species like *Anisantha sterilis*, *Chelidonium majus, Lamium maculatum*, and *Urtica dioica*. The mesophilous ecology of these coenoses is highlighted by the presence of *Convolvulus sepium, Corylus avellana,* and *Equisetum telmateia*. We classify this vegetation type in the association *Sambuco nigrae-Robinietum pseudoacaciae*, described in northern Tuscany and recently included in the alliance *Lauro nobilis-Robinion pseudoacaciae* (Arrigoni, 1997; Allegrezza et al., 2019).

Sambucus nigra community (Table 25, Supplementary material)

In the study area, the mantle of *Robinia pseudoacacia* forests is represented by *Sambucus nigra*-dominated shrublands, whose abundance is promoted by the nitrogen-fixing *R. pseudoacacia* itself (Arrigoni, 1997). Such mantles are documented by one relevé, in which *Sambucus nigra* is accompanied by other nitrophilous shrubs and vines like *Clematis vitalba* and *Rubus ulmifolius*. Nitrophilous species like *Chaerophyllum temulum*, *Chelidonium majus*, and *Urtica dioica* grow in the herbaceous layer. We frame this community in the alliance *Lauro nobilis-Robinion pseudoacacie.*

Salicetum albae Issler 1926 (Table 26, Supplementary material)

Small, residual patches of woodland dominated by *Salix alba* are present in a fragmented way in the study area. Such communities often settle in direct contact with running water, on sandy substrates where soil evolution is prevented by the continuous deposition of alluvial material (Pirone, 1991). The herbaceous layer hosts hygro-nitrophilous species such as *Chaerophyllum temulum*, *Equisetum telmateia*, and *Galium aparine*. In riparian habitats, these communities are among the most resistant to the anthropogenic impact, although being often small and fragmented (Biondi et al., 2002). As a consequence, they are rich in heliophilous and/or synanthropic species such as *Anisantha sterilis*, *Artemisia vulgaris, Avena sterilis,* and *Silene latifolia*. Along the Bestina, they are degraded remnants of the habitat 92A0 "*Salix alba* and *Populus alba* galleries" (Biondi et al., 2012).

Calystegio-Equisetetum telmateiae Jovanović 1993 (Table 27, Supplementary material)

Tall-size, high-covering herbaceous vegetation dominated by *Equisetum telmateia* is frequent on periodically mown banks of the Bestina River, even in sites with high slopes. These hygro-nitrophilous communities develop in areas with high moisture and high light conditions, often in contact with running water, and on the edge of riparian forests. In the outer part of riverbanks, these stands are often in contact with crops. Besides *E. telmateia,* the presence of the characteristic species *Convolvulus sepium, Elymus repens,* and *Galium aparine* allows classifying this vegetation type in the association *Calystegio-Equisetetum telmateiae* Jovanović 1993, described in Serbia. To the best of our knowledge, this is its first record in Italy. These communities develop along disturbed rivers and channels, or in other moist ruderal sites, on sandy and nutrient-rich soils (Jovanović, 1993). As part of the alliance *Senecionion fluviatilis*, they should be attributed to the habitat 6430 "Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels". However, this habitat still needs an adequate characterization, especially regarding its low-elevation variant, which is scarcely known. Given the synanthropic character of the *Calystegio-Equisetetum*, we here provisionally do not consider it as representative of the habitat 6430.

Rubus ulmifolius-Solanum dulcamara community
(Table 28, Supplementary material)

Low spiny shrublands co-dominated by *Rubus ulmifolius* and *Solanum dulcamara* are present in the lower part of steep riverbanks, in contact with the water. The high coverage of the dominant species results in a poor herbaceous layer, characterised by ruderal taxa like *Galium aparine, Silene latifolia,* and *Parietaria judaica,* with a sporadic presence of hygrophilous species such as *Carex pendula*, *Helosciadium nodiflorum,* and *Ranunculus repens*. *Convolvulus sepium* is sometimes abundant. We classify this community in the alliance *Lauro nobilis-Sambucion nigrae*, due to the presence of several diagnostic floristic elements (*Hedera helix, R. ulmifolius, Sambucus nigra*) (Biondi et al., 2014b).

Synanthropic vegetation

Mercurialietum annuae Kruseman et Vlieger 1939 ex Westhoff et al., 1946 (Table 29, Supplementary material)

Arable plant communities colonising orchards along the Bestina river can be classified in the *Mercurialietum annuae*. This vegetation type is dominated by nitrophilous annual species and it develops in contexts of high anthropic disturbance, especially in fertilized crops in late spring. Less frequently, it can be found in ruderal sites. Characteristic species include *Amaranthus retroflexus*, *Chenopodium album, Mercurialis annua*, and *Solanum nigrum*. This association is common in orchards and permanent crops of Italy (Baldoni et al., 2001; Fanfarillo et al., 2019a).

Bryo-Saginetum apetalae Blasi et Pignatti 1984
(Table 30, Supplementary material)

This community develops in the centre of paths, under intense trampling, and it is characterised by annual species with a prostrate habit (*Euphorbia prostrata*, *Polygonum arenastrum*, *Eleusine indica*, *Poa annua*, *Oxalis corniculata*, *Portulaca oleracea*) associated with a conspicuous bryophyte layer. This vegetation type can be classified in the association *Bryo-Saginetum apetalae* (alliance *Polycarpion tetraphylli*), which was described in Rome and later detected all over Italy (Blasi & Pignatti, 1984; Mele et al., 2002; Ceschin et al., 2006).

Potentillo reptantis-Sorghetum halepensis Fanfarillo et Angiolini in Fanfarillo et al., 2022
(Table 31, Supplementary material).

Sorghum halepense builds large, species-poor perennial grasslands in ruderal or sub-ruderal sites, classifiable in the association *Potentillo reptantis-Sorghetum halepensis*. Such communities have their phenological optimum between summer and early autumn. They are particularly common along roadsides, in ditches, and in fallow land, in both urban and agricultural areas, in sites with a good water availability (Fanfarillo et al., 2022). In Asciano, they are documented by one relevé only, in which *Convolvulus arvensis,* a characteristic species of the association, occurs in the lower layer.

Hordeetum leporini Br.-Bl. 1952
(Table 32, Supplementary material)

This vegetation type, species-poor and dominated by *Hordeum murinum* subsp. *leporinum*, is found in moderately disturbed ruderal contexts, in particular along the edge of roads and lanes, reaching its maximum development during the spring months. The dominant species is accompanied by annual or biennial synanthropic taxa having their maximum development in spring, such as *Anisantha diandra*, *Galium aparine*, *Capsella bursa-pastoris*, and *Poa annua*. This association is common in the Mediterranean (Ceschin et al., 2006; Cano-Ortiz et al., 2014), where it is often in dynamic and spatial contact with taller synanthropic grasslands dominated by *Dasypyrum villosum* (Fanfarillo et al., 2019b).

Alysso alyssoidis-Sedion Oberd. et T. Müller in T. Müller 1961 (Table 33, Supplementary material)

Compact, sunny outcrops of travertine rock and travertine artificial walls host pioneer, xerophilous, and calcicolous communities classifiable in the alliance *Alysso alyssoidis-Sedion albi.* An abundant layer of lichens and bryophytes is present. Dominant species are *Petrosedum rupestre* and *Saxifraga tridactylites*. Communities classified in the *Alysso-Sedion* are known in several places of central Italy, where they develop on base-rich substrates such as limestone and travertine (Scoppola & Angiolini, 2001; Angiolini et al., 2008). These small patches are examples of degradation of the priority habitat 6110* "Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*". They show an impoverished and altered floristic composition due to their synanthropic position and to cutting/chemical weeding, with the colonisation of ruderal species such as *Crepis sancta* subsp. *nemausensis*, *Papaver rhoeas*, and *Senecio vulgaris*.

Parietaria judaica community
(Table 34, Supplementary material)

The communities colonising artificial walls, under conditions of good nutrient availability, are characterised by the constant presence of *Parietaria judaica*, accompanied by other typical species of urban walls such as *Asplenium ceterach, Chelidonium majus,* and *Umbilicus rupestris*. We classify this vegetation type, which is widespread in Italy (Brullo & Guarino, 2002), in the alliance *Cymbalario-Asplenion* and in the class *Cymbalario-Parietarietea diffusae*. However, given the lack of diagnostic species, we were not able to classify it into a known association.

Trifolietum resupinato-nigrescentis Molinier et Tallon 1968 (Table 35, Supplementary material)

This community was found in an olive grove and it is characterised by small annual herbaceous species. The presence of the characteristic species *Trifolium nigrescens* and *Medicago arabica* allows its classification in the association *Trifolietum resupinato-nigrescentis*, which develops under slight disturbance, on alluvial, clayey, neutro-basic soils, possibly affected by temporary flooding. Nearby the study area, this vegetation type was detected in Umbria, where, as in our case, the diagnostic species *Trifolium resupinatum* is missing (Gigante & Venanzoni, 2007).

Discussion and conclusions

Detected vegetation types and status of the environment

The survey led to the identification of 34 plant communities. Six habitats included in the 92/43/EEC Directive, plus two habitats recently proposed for inclusion, were identified, as well as one habitat of regional interest. Moreover, we detected a potential for the development of the priority habitat 91AA*. Despite the high anthropogenic pressure, most occurring aquatic communities indicate a relatively good status of the environment, representing interesting remnants of naturalness in a man-made landscape. On the other hand, restoration measures are needed for riparian and terrestrial areas, where plant communities are mainly represented by synanthropic and alien-dominated vegetation types, as a result of heavy disturbance. This evidence confirms the importance of wetlands as biodiversity reservoirs in urban areas, consequently providing many biodiversity-related ecosystem services (Baschak & Brown, 1995; Caneva et al., 2021). Such results also underline the effectiveness of River Contracts in highlighting the nature value of riverine ecosystems by financing descriptive surveys.

A valuable community, representing a proposed Directive habitat, is the *Conocephalo conici-Adiantetum capilli-veneris*, which has the peculiarity to develop not only in natural sites (in the study area, prevalently along the Bestina river), but even in synanthropic sites (Caneva et al., 1995). The abundance of liverworts suggests that this community provides bryophyte-related ecosystem services such as stabilization of substrates, water purification, and water storage in dry periods, improving the status of the environment (Hodgetts et al., 2019). Thus, it represents a valuable element in artificial springs and fountains.

Communities of the class *Potamogetonetea* point to relatively eutrophic conditions, as a consequence of agricultural activities and run-off from urban surfaces. Both the *Potametum crispi* and the *Parvo-Potamogetono-Zannichellietum pedicellatae* are dominated by a moderately nitrophilous species, which can even tolerate polluted waters (Pignatti et al., 2005; Šumberová, 2011). In the Bestina river, such communities are usually not found in contact with the *Callitrichetum palustris*, which, on the contrary, is an indicator of nutrient-poor conditions (Schotsman, 1967). Consistently, it is present in parts of the river with clearer waters. The framing of all these vegetation types into the habitat types of the Habitats Directive is sometimes challenging, since they can be attributed either to the habitat 3150 "Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation" or to the habitat 3260 "Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation", based on their presence in lakes or rivers, respectively. This issue was already raised nearby our study area (Rivieccio et al., 2021), since these two habitats share a lot of diagnostic species (Biondi et al., 2009a). Since we studied a riverine environment, we attributed them to the habitat 3260.

Marsh vegetation is well-preserved, building a diversified band that includes communities of the alliance *Glycerio-Sparganion*, such as *Glycerietum notatae, Helosciadietum nodiflori,* and *Nasturtietum officinalis*. Such communities show low levels of invasion by synanthropic species, except for the invasive neophyte *Bidens frondosa*. Their presence and good conservation status suggest a good quality of the environment. These vegetation types are important in building a buffer zone between running water and dry areas highly modified by anthropic activities, since they are characterised by species with high abilities in the uptake of nutrients and pollutants (Warwick & Downes, 1980; Bellino et al., 2020). Despite being neglected by the 93/42/EEC Directive, such plant communities are protected in Tuscany by the law LR 30/2015 as habitats of regional interest. Valuable riparian vegetation types are also those classified in the alliance *Potentillion anserinae*, namely the *Ranunculetum repensis* and the *Agrostis stolonifera* community. In fact, such communities have some conservation value and might deserve to be subjected to protection measures (Angiolini et al., 2017).

Helophytic vegetation is poorly represented in the study area, where only some patches of *Bolboschoenetum glauci*, *Glycerio-Sparganietum neglecti*, and *Typhetum latifoliae* were detected. This evidence suggests that, moving away from running water, the anthropic influence quickly gets stronger and environmental quality decreases since the helophytic band was removed almost everywhere to establish orchards and gardens, or as a consequence of mowing activities carried out to facilitate water runoff. The lack of a true helophytic band causes the loss of ecosystem services such as natural water purification, besides removing an important habitat for wetland animals (Tanneberger et al., 2009; Zerbe et al., 2013).

The hygro-nitrophilous pioneer vegetation colonizing muddy-sandy gravel beds, classified in the *Bidentetea*, is rich in ruderal and alien species. However, such communities, like those classified in the alliance *Paspalo-Agrostion*, represent a Directive habitat. Even the presence of the pioneer *Polygono lapathifolii-Xanthietum italici* is not an indicator of low environmental quality. Such communities replace late in the season winter-annual gravel communities dominated by native species, and are so far widespread (Amor et al., 1993). The seasonal turnover between native and alien species is common in annual synanthropic plant communities, as it happens, for instance, in arable and ruderal vegetation (Latini et al., 2020; Fanfarillo & Kasperski, 2021).

The abundance and diversity of herbaceous synanthropic communities even in sites close to the river indicates a very high anthropic pressure on the waterbody. Some ruderal communities (*Parietaria judaica* community, *Bryo-Saginetum apetalae*) are relegated to strictly urban sites, thus not indicating a low quality of riverine habitats. Agricultural vegetation types can be considerably species-rich, and some of them, like the *Mercurialietum annuae* and the *Trifolietum resupinato-nigrescentis*, can even provide useful services in agricultural land (Storkey & Neve, 2018). However, in the study area, synanthropic vegetation is in general too close to the river, indicating the absence of a buffer zone isolating the aquatic ecosystem from the urban/agricultural ones, with a consequent worsening of the status of the environment. Moreover, cutting and chemical weeding affected *Alysso-Sedion* communities, already being significantly degraded by the (sub)urban location. The alien-dominated association *Potentillo reptantis-Sorghetum halepensis* was scarcely observed in the study area, but considering the invasiveness of the dominant species it could spread in the next few years, also considering that *Sorghum halepense* is one of the most widespread alien species in Italy (Stinca et al., 2021; Fanfarillo et al., 2022).

Meso-xerophilous semi-natural vegetation is overall in good conservation status, but woods are missing or reduced to open/shrubby stands classifiable in the class *Crataego-Prunetea*, indicating the pressure of agricultural activities but not necessarily low environmental quality, as indicated by the low presence of alien or ruderal species. Mesophilous fringe, shrub, and forest vegetation is not as preserved. Woods are mainly dominated by alien species, especially *Robinia pseudoacacia*, and native riparian woods are only present as remnant patches of *Salicetum albae* and *Dioscoreo communis-Populetum nigrae*. The unfavorable conservation status of riparian woody vegetation in the study area has negative implications for biodiversity conservation. Native riparian forests are hotspots of species richness, carry out important ecological functions, and many of them represent Natura 2000 habitats (Biondi et al., 2009a; Pielech et al., 2021). Thus, restoration and reclamation of natural riparian woody plant communities are needed to improve the status of the environment along the river. Tall-size fringe communities are also affected by the invasion of some alien species, in particular *Helianthus tuberosus*, with the loss of Natura 2000 habitats (e.g., habitat 6430).

By the characterization of vegetation types, our study provided the first understanding of the status of plant communities and of the environment in the study area. We highlighted the elements of the riverscape needing conservation and the ones needing restoration or reclamation. Thus, we provided the basis for future activities aiming at improving the riverine ecosystem and its surroundings under the River Contract.

Syntaxonomic scheme

Adiantetea Br.-Bl. et al. 1952
Adiantetalia Br.-Bl. ex Horvatić 1934
Adiantion Br.-Bl. ex Horvatić 1934
Conocephalo conici-Adiantetum capilli-veneris Caneva, De Marco, Dinelli, Vinci 1995
Potamogetonetea Klika in Klika et Novák 1941
Potamogetonetalia Koch 1926
Potamogetonion Libbert 1931
Potametum crispi von Soó 1927
Callitricho hamulatae-Ranunculetalia aquatilis Passarge ex Theurillat in Theurillat et al. 2015
Ranunculion aquatilis Passarge ex Theurillat in Theurillant et al. 2015
Callitrichetum palustris (Dihoru, 1975 n.n.) Burescu 1999
Zannichellietalia pedicellatae Schaminée, Lanjouw et Schipper ex Mucina et Theurillat ined.
Zannichellion pedicellatae Schaminée, Lanjouw et Schipper ex Passarge 1996
Parvo-Potamogetono-Zannichellietum pedicellatae Soó 1947
Phragmito-Magnocaricetea Klika in Klika et Novák 1941
Lycopus europaeus community
Phragmitetalia Koch 1926
Phragmition communis Koch 1926
Glycerio-Sparganietum neglecti Koch 1926
Typhetum latifoliae Nowiński 1930
Nasturtio-Glycerietalia Pignatti 1953
Glycerio-Sparganion Br.-Bl. et Sissingh in Boer 1942
Nasturtietum officinalis Gilli 1971
Glycerietum notatae Kulczyński 1928 nom. mut.prop.
Helosciadietum nodiflori Maire 1924
Oenanthetalia aquaticae Hejný ex Balátová-Tuláčková et al. 1993
Eleocharito palustris-Sagittarion sagittifoliae Passarge, 1964
Bolboschoenetum glauci Grechushkina et al. 2011
Bidentetea Tx. et al., ex von Rochow 1951
Paspalo-Heleochloetalia Br.-Bl. ex Rivas Goday 1956
Paspalo-Agrostion semiverticillati Br.-Bl. in Br.-Bl. et al. 1952
Paspalo paspaloidis-Polypogonetum viridis Br.-Bl. 1952
Bidentetalia Br.-Bl. et Tx. ex Klika et Hadač 1944
Chenopodion rubri (Tx. in Poli et J. Tx., 1960) Hilbig et Jage 1972
Polygono lapathifolii-Xanthietum italici Pirola et Rossetti 1974
Molinio-Arrhenatheretea Tx. 1937
Potentillo-Polygonetalia avicularis Tx. 1947
Potentillion anserinae Tx. 1947
Ranunculetum repentis Knapp 1946
Agrostis stolonifera community
Epilobietea angustifolii Tx. et Preising ex von Rochow 1951
Convolvuletalia sepium Tx. ex Moor 1958
Senecionion fluviatilis Tx. ex Moor 1958
Calystegio-Equisetetum telmateiae Jovanović 1993
Convolvulo-Epilobietum hirsuti Hilbig, Heinrich et Niemann 1972
Helianthus tuberosus community
Artemisietea vulgaris Lohmeyer et al., in Tx. ex von Rochow 1951
Elytrigio repentis-Dittrichietalia viscosae Mucina 2016
Inulo viscosae-Agropyrion repentis Biondi et Allegrezza 1996
Potentillo reptantis-Sorghetum halepensis Fanfarillo et Angiolini in Fanfarillo et al. 2022
Papaveretea rhoeadis S. Brullo et al. 2001
Papaveretalia rhoeadis Hüppe et Hofmeister ex Theurillat et al. 1995
Veronico-Euphorbion Sissingh in Passarge 1964
Mercurialietum annuae Kruseman et Vlieger, 1939 ex Westhoff et al. 1946
Chenopodietea Br.-Bl. in Br.-Bl. et al. 1952
Chenopodietalia Br.-Bl. in Br.-Bl. et al. 1936
Hordeion murini Br.-Bl. in Br.-Bl. et al. 1936
Hordeetum leporini Br.-Bl. 1952
Brometalia rubenti-tectorum (Rivas Goday et Rivas-Mart., 1973) Rivas-Mart. et Izco 1977
Echio-Galactition tomentosae O. de Bolòs et Molinier 1969
Trifolietum resupinato-nigrescentis Molinier & Tallon 1968
Polygono-Poetea annuae Rivas-Mart. 1975
Polygono arenastri-Poetalia annuae Tx. in Géhu et al. 1972 corr. Rivas-Mart. et al. 1991
Polycarpion tetraphylli Rivas-Mart. 1975
Bryo-Saginetum apetalae Blasi et Pignatti 1984
Cymbalario-Parietarietea diffusae Oberd. 1969
Tortulo-Cymbalarietalia Segal 1969
Cymbalario-Asplenion Segal 1969
Parietaria judaica community
Sedo-Scleranthetea Br.-Bl. 1955
Alysso-Sedetalia Moravec 1967
Alysso alyssoidis-Sedion Oberd. et T. Müller in T. Müller 1961
Crataego-Prunetea Tx. 1962
Quercus pubescens community
Pyro spinosae-Rubetalia ulmifolii Biondi, Blasi et Casavecchia in Biondi et al. 2014
Pruno spinosae-Rubion ulmifolii O. de Bolòs 1954
Pruno-Rubenion ulmifolii O. Bolòs 1954
Arundo plinii-Rubion ulmifolii Biondi, Blasi, Casavecchia et Gasparri in Biondi et al. 2014
Clematido vitalbae-Arundinetum donacis Biondi et Allegrezza 2004
Lauro nobilis-Sambucetalia nigrae Biondi, Blasi, Casavecchia, Galdenzi et Gasparri in Biondi et al. 2014
Lauro nobilis-Sambucion nigrae Biondi, Blasi, Casavecchia, Galdenzi et Gasparri in Biondi et al. 2014
Rubus ulmifolius-Solanum dulcamara community

Trifolio-Geranietea sanguinei T. Müller 1962
Asphodeletalia macrocarpae Biondi et Allegrezza in Biondi et al. 2014
Dorycnio herbacei-Brachypodion rupestris Allegrezza et al. 2016
Galio erecti-Brachypodietum rupestris Allegrezza et al. 2016
Alno glutinosae-Populetea albae P. Fukarek ex Fabijanić 1968
Populetalia albae Br.-Bl. ex Tchou 1948
Dioscoreo communis-Populion nigrae Poldini et Vidali in Poldini, Sburlino ex Vidali 2017
Dioscoreo communis-Populetum nigrae Poldini et Vidali in Poldini, Sburlino ex Vidali 2017
typicum
populetosum albae (Biondi, Vagge, Baldoni ex Taffetani, 1999) Poldini, Vidali ex Castello 2020
Salicetea purpureae Moor 1958
Salicetalia purpureae Moor 1958
Salicion albae Soó 1951
Salicetum albae Issler 1926
Robinietea Jurko ex Hadač et Sofron 1980
Chelidonio-Robinietalia pseudoacaciae Jurko ex Hadac et Sofron 1980
Lauro nobilis-Robinion pseudoacaciae Allegrezza, Montecchiari, Ottaviani, Pelliccia & Tesei 2019
Ailanthus altissima community
Sambuco nigrae-Robinietum pseudacaciae Arrigoni 1997
Sambucus nigra community

Acknowledgments

We thank I. Bonini for the identification of liverworts and R. Valentini for his logistic support to this research.

Emanuele Fanfarillo https://orcid.org/0000-0001-5742-737X
Tiberio Fiaschi https://orcid.org/0000-0003-0403-2387
Paolo Castagnini https://orcid.org/0000-0003-2485-1742
Leopoldo de Simone https://orcid.org/0000-0002-3055-136X
Claudia Angiolini https://orcid.org/0000-0002-9125-764X

Funding

This research was funded by the Comune of Asciano ("La Lama" River Contract, funded by Tuscany Region - CUP B39C19000120004). The authors have declared that no competing interests exist.

The authors acknowledge the support of NBFC to University of Siena, funded by the Italian Ministry of University and Research, PNRR, Missione 4 Componente 2, "Dalla ricerca all'impresa", Investimento 1.4, Project CN00000033.

Bibliography

Aleffi, M., Tacchi, R., & Poponessi, S. (2020). New checklist of the Bryophytes of Italy. *Cryptogamie Bryologie, 41*(13), 147–195. https://doi.org/10.5252/cryptogamie-bryologie2020v41a13

Allegrezza, M., Biondi, E., Ballelli, S., Tesei, G., Ottaviani, C., & Zitti, S. (2016). *Brachypodium rupestre* (Host) Roem. & Schult. herbaceous communities of heliophilous edge in the *Trifolio medii-Geranietea sanguinei* Müller 1962 class. *Plant Sociology, 53*, 59–76. https://doi.org/10.7338/pls2016532/05

Allegrezza, M., Montecchiari, S., Ottaviani, C., Pelliccia, V., & Tesei, G. (2019). Syntaxonomy of the *Robinia pseudoacacia* communities in the central peri-adriatic sector of the Italian peninsula. *Plant Biosystems, 153*(4), 616–623. https://doi.org/10.1080/11263504.2019.1610108

Allegrezza, M., Baldoni, M., Biondi, E., Taffetani, F., & Zuccarello, V. (2002). Studio fitosociologico dei boschi a *Quercus pubescens* s.1. delle Marche e di alcune zone contigue dell'Appennino centro-settentrionale (Italia centrale). *Fitosociologia, 39*(1), 161–171.

Amor, A., Ladero, M., & Valle, C. J. (1993), Flora e vegetación vascular de la Comarca de La Vera e laderas meridionales de la Sierra de Tormantos (Cáceres, España). *Studia Botanica, 11*, 11–207.

Angelini, P. (2017). I Contratti di Fiume in Italia (e oltre confine). Il X Tavolo Nazionale dei Contratti di Fiume e il Contributo del Ministero dell'Ambiente alla diffusione e all'internazionalizzazione dei Contratti di Fiume. Ministero dell'Ambiente e della Tutela del Territorio e del Mare.

Angiolini, C., Gabellini, A., Frignani, F., Giallonardo, T., & De Dominicis, V. (2008). Contributo alla conoscenza della vegetazione della Riserva naturale provinciale "Monte Penna" (Grosseto, Toscana meridionale). *Atti della Società Toscana di Scienze Naturali, Memorie Serie B, 115*, 1–20.

Angiolini, C., Viciani, D., Bonari, G., & Lastrucci, L. (2017). Habitat conservation prioritization: A floristic approach applied to a Mediterranean wetland network. *Plant Biosystems, 151*(4), 598–612. https://doi.org/10.1080/11263504.2016.1187678

Angiolini, C., Viciani, D., Bonari, G., Zoccola, A., Bottacci, A., Ciampelli, P., Gonnelli, V., & Lastrucci, L. (2019). Environmental drivers of plant assemblages: are there differences between palustrine and lacustrine wetlands? A case study from the northern Apennines (Italy). *Knowledge & Management of Aquatic Ecosystems, 420*, 34. https://doi.org/10.1051/kmae/2019026

Arrigoni, P. V. (1997). Documenti per la carta della vegetazione delle Cerbaie (Toscana settentrionale). *Parlatorea, 2*, 39–71.

Badalamenti, E., & La Mantia, T. (2013). Stem-injection of herbicide for control of *Ailanthus altissima* (Mill.) Swingle: a practical source of power for drilling holes in stems. *iForest, 6*(3), 123–126. https://doi.org/10.3832/ifor0693-006

Baldoni, M., Biondi, E., & Loiotile, A. (2001). La vegetazione infestante i vigneti nelle Marche. *Fitosociologia, 38*, 63–68.

Barlucchi, A. (1997). *Il contado senese all'epoca dei Nove: Asciano e il suo territorio tra due e trecento*. Leo S. Olschki. Florence.

Baschak, L. A., & Brown, R. D. (1995). An ecological framework for the planning, design and management of urban river greenways. *Landscape and Urban Planning*, *33*, 211–225. https://doi.org/10.1016/0169-2046(94)02019-C

Bellino, A., Alfani, A., De Riso, L., Gregorio, R., Pellegrino, T., & Baldantoni, D. (2020). A promising cosmopolitan biomonitor of potentially toxic elements in freshwater ecosystems: concentration gradients in sensitive areas. *Ecological Indicators, 109*, 105801. https://doi.org/10.1016/j.ecolind.2019.105801

Biondi, E. (2011). Phytosociology today: Methodological and conceptual evolution. *Plant Biosystems, 145*, Suppl.1, 19–29. https://doi.org/10.1080/11263504.2011.602748

Biondi, E., & Allegrezza, M. (2004). L'Ambiente della Selva di Gallignano. *I Quaderni della Selva, 2*, 1–78.

Biondi, E., Calandra, R., Gigante, D., Pignattelli, S., Rampiconi, E., & Venanzoni, R. (2002). *Il paesaggio vegetale della Provincia di Terni*. Province of Terni, University of Perugia.

Biondi, E., Blasi, C., Burrascano, S., Casavecchia, S., Copiz, R., Del Vico, E., Galdenzi, D., Gigante, D., Lasen, C., Spampinato, G., Venanzoni, R., & Zivkovic, L. (2009a). *Manuale Italiano di interpretazione degli habitat della Direttiva 92/43/CEE*. Italian Botanical Society. Ministry for Environment, Land and Sea Protection of Italy. Retrieved September 15, 2021, from http://vnr.unipg.it/habitat/.

Biondi, E., Zivkovic, L., Esposito, L., & Pesaresi, S. (2009b). Vegetation, plant landscape and habitat analyses of a fluvial ecosystem in central Italy. *Acta Botanica Gallica, 156*(4), 571–587. https://doi.org/10.1080/12538078.2009.10516178

Biondi, E., Burrascano, S., Casavecchia, S., Copiz, R., Del Vico, E., Galdenzi, D., Gigante, D., Lasen, C., Spampinato, G., Venanzoni, R., Zivkovic, L., & Blasi, C. (2012). Diagnosis and syntaxonomic interpretation of Annex I Habitats (Dir. 92/43/ EEC) in Italy at the alliance level. *Plant Sociology, 49*(1), 5–37. http://dx.doi.org/10.7338/pls2012491/01

Biondi, E., Blasi, C., Allegrezza, M., Anzellotti, I., Azzella, M. M., Carli, E., Casavecchia, S., Copiz, R., Del Vico, E., Facioni, L., Galdenzi, D., Gasparri, R., Lasen, C., Pesaresi, S., Poldini, L., Sburlino, G., Taffetani, F., Vagge, I., Zitti, S., & Zivkovic, L. (2014a). Plant communities of Italy: The Vegetation Prodrome. *Plant Biosystems, 148*(4), 728–814. https://doi.org/10.1080/11263504.2014.948527

Biondi, E., Allegrezza, M., Casavecchia, S., Galdenzi, D., Gasparri, R., Pesaresi, S., Vagge, I., & Blasi, C. (2014b). New and validated syntaxa for the checklist of Italian vegetation. *Plant Biosystems, 148*(2), 318–332. https://doi.org/10.1080/11263504.2014.892907

Blasi, C., & Pignatti, S. (1984). La vegetazione degli ambienti calpestati della città di Roma. *Annali di Botanica, 42*(2), 11–16.

Blasi, C., Cutini, M., Di Pietro, R., & Fortini, P. (2002). Contributo alla conoscenza della sub-alleanza *Pruno-Rubenion ulmifolii* in Italia. *Fitosociologia, 39* (1), Suppl. 2, 129–14.

Bolòs, O. D., Montserrat Martí, J. M., & Díez, R. (1988). Comunitats vegetals higronitròfiles de la Catalunya pirinenca i de les terres properes. *Acta Botánica Barcinonensia, 37*, 33–44.

Bolpagni, R., Laini, A., Stanzani, C., & Chiarucci, A. (2018). Aquatic Plant Diversity in Italy: Distribution, Drivers and Strategic Conservation Actions. *Frontiers in Plant Science, 9*, 116. https://doi.org/10.3389/fpls.2018.00116

Bonari, G., Padullés Cubino, J., Sarmati, S., Landi, M., Zerbe, S., Marcenò, C., Scoppola, A., & Angiolini, C. (2021a). Ecosystem state assessment after more than 100 years since planting for dune consolidation. *Restoration Ecology, 29*, e13435. https://doi.org/10.1111/rec.13435

Bonari, G., Fiaschi, T., Fanfarillo, E., Roma-Marzio, F., Sarmati, S., Banfi, E., Biagioli, M., Zerbe, S., & Angiolini, C. (2021b). Remnants of naturalness in a reclaimed land of central Italy. *Italian Botanist, 11*, 9–30. https://doi.org/10.3897/italianbotanist.11.62040

Braun-Blanquet, J. (1964). *Pflanzensoziologie*. 3rd ed. Springer. Wien. https://doi.org/10.1007/978-3-7091-8110-2

Brullo, S., & Guarino, R. (2002). La classe *Parietarietea judaicae* Oberd. 1977 in Italia. *Fitosociologia, 39*(1), Suppl. 2, 5–27.

Buckwald, R. (1994). Vegetazione e odonatofauna negli ambienti acquatici dell'Italia Centrale. *Braun-Blanquetia*, 11.

Caneva, G., De Marco, G., Dinelli, A., & Vinci, M. (1995). Le classi *Parietarietea diffusae* (Rivas-Martinez 1964) Oberd. 1977 e *Adiantetea* Br.-Bl. 1947 nelle aree archeologiche romane. *Fitosociologia, 29*, 165–179.

Caneva, G., Ceschin, S., Lucchese, F., Scalici, M., Battisti, C., Tufano, M., Tullio, M. C., & Cicinelli, E. (2021). Environmental management of waters and riparian areas to protect biodiversity through River Contracts: The experience of Tiber River (Rome, Italy). *River Research and Applications, 37*(10), 1510–1519. https://doi.org/10.1002/rra.3869

Cano-Ortiz, A., Biondi, E., Gomes, C. J. P., Del Río González, S., & Cano, E. (2014). Soil and Phytosociological Characterisation of Grasslands in the Western Mediterranean. *American Journal of Plant Sciences, 5,* 3213–3240. http://dx.doi.org/10.4236/ajps.2014.521337

Casavecchia, S., Allegrezza, M., Angiolini, C., Biondi, E., Bonini, F., Del Vico, E., Fanfarillo, E., Foggi, B., Gigante, D., Gianguzzi, L., Lasen, C., Maccherini, S., Mariotti, M., Pesaresi, S., Pirone, G., Poldini, L., Selvi, F., Venanzoni, R., Viciani, D., Vidali, M., & Ciaschetti, G. (2021). Proposals for improvement of Annex I of Directive 92/43/EEC: Central Italy. *Plant Sociology, 58*(2), 99–118. https://doi.org/10.3897/pls2021582/08

Ceschin, S., Cutini, M., & Caneva, G. (2006). Contributo alla conoscenza della vegetazione delle aree archeologiche romane (Roma). *Fitosociologia, 43*(1), 97–139.

Ceschin, S., & Salerno, G. (2008). La vegetazione del basso corso del Fiume Tevere e dei suoi affluenti (Lazio, Italia). *Fitosociologia, 45*(1), 39–74.

Environmental Protection Agency. (2020). Wetlands Protection and Restoration. Retrieved December 21, 2021, from https://www.epa.gov/wetlands.

Fanfarillo, E., Scoppola, A., Lososová, Z., & Abbate, G. (2019a). Segetal plant communities of traditional agroecosystems: a phytosociological survey in central Italy. *Phytocoenologia, 49*(2), 165–183. https://doi.org/10.1127/phyto/2019/0282

Fanfarillo, E., Moretti, M., & Abbate, G. (2019b). The anthropogenic grasslands of the *Securigero Securidacae-Dasypyrion villosi* in central Mediterranean areas: Synecology, distribution and syntaxonomy. *Annali di Botanica, 9*, 1–38. http://dx.doi.org/10.13133/2239-3129/14625

Fanfarillo, E., & Kasperski, A. (2021). An index of ecological value for European arable plant communities. *Biodiversity and Conservation, 30*, 2145–2164. https://doi.org/10.1007/s10531-021-02191-x

Fanfarillo, E., Zangari, G., Küzmič, F., Fiaschi, T., Bonari, G., & Angiolini, C. (2022). Summer roadside vegetation dominated by *Sorghum halepense* in peninsular Italy: survey and classification. *Rendiconti Lincei. Scienze Fisiche e Naturali, 33*, 93–104. https://doi.org/10.1007/s12210-022-01050-3

Gallart, F., Marignani, M., Pérez-Gallego, N., Santi, E., & Maccherini, S. (2013). Thirty years of studies on badlands, from physical to vegetational approaches. A succinct review. *Catena, 106*, 4–11. https://doi.org/10.1016/j.catena.2012.02.008

Gardner, R. C., Barchiesi, S., Beltrame, C., Finlayson, C. M., Galewski, T., Harrison, I., Paganini, M., Perennou, C., Pritchard, D. E., Rosenqvist, A., & Walpole, M. (2015). *State of the World's wetlands and their services to people: a compilation of recent analyses*. Ramsar Convention Secretariat. Gland. *Ramsar Briefing Note no. 7*, 1–21. https://doi.org/10.2139/ssrn.258944

Gennai, M., Gabellini, A., Viciani, D., Venanzoni, R., Dell'Olmo, L., Giunti, M., Lucchesi, F., Monacci, F., Mugnai, M., & Foggi, B. (2021). The floodplain woods of Tuscany: towards a phytosociological synthesis. *Plant Sociology, 58*(1), 1–28. https://doi.org/10.3897/pls2021581/01

Gigante, D., & Venanzoni, R. (2007). Some remarks about the annual sub-nitrophilous vegetation of *Thero-Brometalia* in Umbria (central Italy). *Lazaroa, 28*, 15–34.

Gigante, D., Attorre, F., Venanzoni, R., Acosta, A. T. R., Agrillo, E., Aleffi, M., Alessi, N., Allegrezza, M., Angelini, P., Angiolini, C., Assini, S., & Azzella, M. M. (2016). A methodological protocol for Annex I Habitats monitoring: the contribution of vegetation science. *Plant Sociology, 53*(2), 77–87. https://doi.org/10.1007/s12210-018-0688-5

Gigante, D., Acosta, A. T. R., Agrillo, E., Armiraglio, S., Assini, S., Attorre, F., & Viciani, D. (2018). Habitat conservation in Italy: the state of the art in the light of the first European Red List of Terrestrial and Freshwater Habitats. *Rendiconti lincei. Scienze Fisiche e Naturali, 29*(2), 251–265. https://doi.org/10.1007/s12210-018-0688-5

Hodgetts, N., Cálix, M., Englefield, E., Fettes, N., García Criado, M., Patin, L., Nieto, A., Bergamini, A., Bisang, I., Baisheva, E., Campisi, P., Cogoni, A., Hallingbäck, T., Konstantinova, N., Lockhart, N., Sabovljevic, M., Schnyder, N., Schröck, C., Sérgio, C., … Jan Żarnowiec (2019). *A miniature world in decline: European Red List of Mosses, Liverworts and Hornworts*. IUCN. Brussels.

Hroudová, Z., Zákravský, P., Ducháček, M., & Marhold, K. (2007). Taxonomy, distribution and ecology of *Bolboschoenus* in Europe. *Annales Botanici Fennici, 44*, 81–102.

Iberite, M., Palozzi, A. M., & Resini, A. M. (1995). La vegetazione del Lago di Bolsena (Viterbo, Italia centrale). *Fitosociologia, 29*, 151–164.

Janssen, J., Rodwell, J., García Criado, M., Gubbay, S., Haynes, T., Nieto, A., Sanders, N., Landucci, F., Loidi, J., Ssymank, A., Tahvanainen, T., Valderrabano, M., Acosta, A., Aronsson, M., Arts, G., Attorre, F., Bergmeier, E., Bijlsma, R.-J., Bioret, F., & Gubbay, S. (2016). *European Red List of Habitats – Part 2. Terrestrial and freshwater habitats*. https://doi.org/10.2779/091372

Johansson, M. E., Nilsson, C., & Nilsson, E. (1996). Do rivers function as corridors for plant dispersal? *Journal of Vegetation Science, 7*(4), 593–598. https://doi.org/10.2307/3236309

Jovanović, S. (1993). *Calystegio-Equisetetum telmateiae* - nova higrofilna zajednica na području Beograda. *Acta herbologica, 2*(2), 47–59.

Landi, M., Angiolini, C., & De Dominicis, V. (2002). Analisi fitosociologica dei fiumi della Toscana meridionale: il tratto medio-basso del Merse (Italia centrale). *Studia botanica, 21*, 37–88.

Landucci, F., Gigante, D., Venanzoni, R., & Chytrý, M. (2013). Wetland vegetation of the class *Phragmito-Magno-Caricetea* in central Italy. *Phytocoenologia, 43*(1–2), 67–100. https://doi.org/10.1127/0340-269X/2013/0043-0545

Landucci, F., Šumberová, K., Tichý, L., Hennekens, S., Aunina, L., Biţă-Nicolae, C., Borsukevych, L., Bobrov, A., Čarni, A., De Bie, E., Golub, V., Hrivnák, R., Iemelianova, S., Jandt, U., Jansen, F., Kącki, Z., Lájer, K. Papastergiadou, E., Šilc, U., … Chytrý, M. (2020). Classification of the European marsh vegetation (*Phragmito-Magnocaricetea*) to the association level. *Applied Vegetation Science, 23*, 297–316. https://doi.org/10.1111/avsc.12484

Lastrucci, L., Viciani, D., Nuccio, C., & Melillo, C. (2007). Indagine vegetazionale su alcuni laghi di origine artificiale limitrofi al Padule di Fucecchio (Toscana, Italia Centrale). *Annali del Museo civico di Rovereto Sezione Archeologia, Storia, Scienze Naturali, 23*, 169–203.

Lastrucci, L., & Becattini, R. (2008). La vegetazione delle aree umide presso Bosco ai Frati (Firenze, Toscana). *Atti della Società Toscana di Scienze Naturali, Memorie, Serie B, 115*, 57–67.

Lastrucci, L., Paci, F., & Raffaelli, M. (2010a). The wetland vegetation of the Natural Reserves and neighbouring stretches of the Arno river in the Arezzo province (Tuscany, Central Italy). *Fitosociologia, 47*(1), 31–61.

Lastrucci, L., Landi, M., & Angiolini, C. (2010b). Vegetation analysis on wetlands in a Tuscan agricultural landscape (central Italy). *Biologia, 65*, 54–68. https://doi.org/10.2478/s11756-009-0213-5

Lastrucci, L., Landucci, F., Gonnelli, V., Barocco, R., Foggi, B., & Venanzoni, R. (2012). The vegetation of the upper and middle River Tiber (Central Italy). *Plant Sociology, 49*(2), 29–48. http://dx.doi.org/10.7338/pls2012492/02

Latini, M., Fanfarillo, E., De Luca, E., Iberite, M., & Abbate, G. (2020). The weed vegetation of the bean "Fagiolo Cannellino di Atina" and the red pepper "Peperone di Pontecorvo" PDO crops (Latium, central Italy). *Plant Sociology, 57*(1), 1–10. https://doi.org/10.3897/pls2020571/01

Lazzaro, L., Bolpagni, R., Buffa, G., Gentili, R., Lonati, M., Stinca, A., Rosario Acosta, A. T., Adorni, M., Aleffi, M., Allegrezza, M., Angiolini, C., Assini, S., Bagella, S., Bonari, G., Bovio, M., Bracco, F., Brundu, G., Caccianiga, M., Carnevali, L., … Lastrucc, L., (2020). Impact of invasive alien plants on native plant communities and Natura 2000 habitats: State of the art, gap analysis and perspectives in Italy. *Journal of Environmental Management, 274*, 111140. https://doi.org/10.1016/j.jenvman.2020.111140

Maccherini, S., Chiarucci, A., & De Dominicis, V. (2000) Structure and species diversity of *Bromus erectus* grasslands of biancana badlands. *Belgian Journal of Botany*, *133,* 3–14. http://dx.doi.org/10.2307/20794459

Maccherini, S., Marignani, M., Gioria, M., Renzi, M., Rocchini, D., Santi, E., Torri, D., Tundo, J., & Honnay, O. (2011). Determinants of plant community composition of remnant biancane badlands: a hierarchical approach to quantify species-environment relationships. *Applied Vegetation Science*, *14*(3), 378–387. https://doi.org/10.1111/j.1654-109X.2011.01131.x

Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., & Hornik, K. (2022). cluster: Cluster Analysis Basics and Extensions. R package version 2.1.3. Retrieved from https://CRAN.R-project.org/package=cluster

Maiorca, G., Crisafulli, A., Puntillo, D., Signorino, G., & Spampinato, G. (2020). Wetland vegetation of the Tarsia Lake Regional Nature Reserve (Calabria, southern Italy). *Mediterranean Botany, 41*(1), 67–84. https://doi.org/10.5209/mbot.61002

Mele, C., Annese, B., Albano, A., & Marchiori, S. (2002). Contributo alla conoscenza della flora e della vegetazione del centro storico di Lecce (Puglia – Italia). *Informatore Botanico Italiano, 34*(1), 91–104.

Mereu, L., Lastrucci, L., & Viciani, D. (2010). Contributo alla conoscenza della vegetazione del fiume Pesa (Toscana, Italia centrale). *Studia Botanica, 29*, 105–143.

Montecchiari, S., Allegrezza, M., Pelliccia, V., & Tesei, G. (2020). First syntaxonomical contribution to the invasive *Ailanthus altissima* (Mill.) Swingle forest communities at its southern limit in Europe. *Plant Sociology, 57*(2), 145–160. https://doi.org/10.3897/pls2020572/06

Mucina, L., Bültmann, H., Dierßen, K., Theurillat, J.-P., Raus, T., Čarni, A., Šumberová, K., Willner, W., Dengler, J., Gavilán García, R., Chytrý, M., Hájek, M., Di Pietro, R., Iakushenko, D., Pallas, J., Daniëls, F. J. A., Bergmeier, E., Santos Guerra, A., Ermakov, N., … Tichý, L. (2016). Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Applied Vegetation Science, 19,* Suppl. 1, 3–264. https://doi.org/10.1111/avsc.12257

Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, G. L., Stevens, M. H. H., Szöcs, E. &, Wagner, H. H. (2021). vegan: Community Ecology Package. R package version 2.5–7. 2020.

Orsenigo, S., Fenu, G., Gargano, D., Montagnani, C., Abeli, T., Alessandrini, A., Bacchetta, G., Bartolucci, F., Carta, A., Castello, M., Cogoni, D., Conti, F., Domina, G., Foggi, B., Gennai, M., Gigante, D., Iberite, M., Peruzzi, L., Pinna, M., & Rossi, G. (2020). Red list of threatened vascular plants in Italy. *Plant Biosystems, 155*(2), 310–335. https://doi.org/10.1080/11263504.2020.1739165

Palmer, M. A., Menninger, H. L., & Bernhardt, E. (2010). River restoration, habitat heterogeneity and biodiversity: A failure of theory or practice? *Freshwater Biology, 55*, 205–222. https://doi.org/10.1111/j.1365-2427.2009.02372.x

Paton, J. A. (1999). *The Liverworts Flora of the British Isles*. Brill Academic Publishers. Leida.

Pedrotti, F. (2008). La vegetazione delle marcite di Norcia (Italia centrale). *Braun-Blanquetia, 44*, 3–31. http://www.scienzadellavegetazione.it/sisv/libreria/braun-blanquetia/BRBL44.pdf

Pesaresi, S., Biondi, E., & Casavecchia, S. (2017). Bioclimates of Italy. *Journal of Maps, 13*(2), 955–960. https://doi.org/10.1080/17445647.2017.1413017

Pielech, R. (2021). Plant species richness in riparian forests: Comparison to other forest ecosystems, longitudinal patterns, role of rare species and topographic factors. *Forest Ecology and Management, 496*, 119400. https://doi.org/10.1016/j.foreco.2021.119400

Pignatti, S., Bianco, P. M., Fanelli, G., Paglia, S., Pietrosanti, S., & Tescarollo, P. (2001). *Le piante come indicatori ambientali*. ANPA. Rome.

Pignatti, S., Menegoni, P., & Pietrosanti, S. (2005). Bioindicazione attraverso le piante vascolari. Valori di indicazione secondo Ellenberg (Zeigerwerte) per le specie della Flora d'Italia. *Braun-Blanquetia, 39*, 3–97.

Pignatti, S., Guarino, R., & La Rosa, M. (2017-2019). *Flora d'Italia*. 2nd ed. Edagricole di New Business Media. Bologna.

Pirone, G. (1991). Flora e vegetazione del fiume Saline (Abruzzo). *Micologia e Vegetazione Mediterranea, 6*(1), 45–76.

Portal to the Flora of Italy. (2020 onwards). Portale della Flora d'Italia v. 2021.1. Retrieved December 21, 2021, from http://dryades.units.it/floritaly/

R Core Team. (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Retrieved December 21, 2021, from https://www.R-project.org/

Richardson, D. M., Holmes, P. M., Esler, K. J., Galatowitsch, S. M., Stromberg, J. C., Kirkman, S. P., Pyšek, P., & Hobbs, R. J. (2007). Riparian vegetation: degradation, alien plant invasions, and restoration prospects. *Diversity and Distributions, 13*, 126–139. https://doi.org/10.1111/j.1366-9516.2006.00314.x

Rivieccio, G., Aleffi, M., Angiolini, C., Bagella, S., Bazan, G., Bonini, F., Caria, M. C., Casavecchia, S., Castello, M., Dagnino, D., de Francesco, M. C., Farris, E., Fanfarillo, E., Fiaschi, T., Forte, L., Gianguzzi, L., Landucci, F., Maneli, F., Mantino, F., … Gigante, D. (2021). New national and regional Annex I Habitat records: from #26 to #36. *Plant Sociology, 58*(2), 77–98. https://doi.org/10.3897/pls2021582/07

Schotsman, H. D. (1967). *Les Callitriches: Espèces de France et taxa nouveaux d'Europe*. Éditions Paul Lechevalier. Paris.

Sciandrello, S. (2009). La vegetazione igrofila dei bacini artificiali della Provincia di Caltanissetta (Sicilia centro-meridionale). *Informatore Botanico Italiano, 41*(1), 53–62.

Scoppola, A., & Angiolini, C. (2001). Therophytic vegetation on carbonate soils of central Tyrrhenian Italy: synecology and syntaxonomy. *Fitosociologia, 38*, 77–89.

Spampinato, G., & Puglisi, M. (2009). *7250 New: Rupi stillicidiose mediterranee*. In: Biondi, E., et al. (eds) *Manuale Italiano di Interpretazione degli habitat di Direttiva 92/43/CEE*. Retrieved September 7, 2022, from http://vnr.unipg.it/habitat/cerca.do?formato=stampaidSegnalazione=83

Spampinato, G., Sciandrello, S., Giusso del Galdo, G., Puglisi, M., Tomaselli, V., Cannavò, S., & Musarella, C. M. (2019). Contribution to the knowledge of Mediterranean wetland biodiversity: Plant communities of the Aquila Lake (Calabria, Southern Italy). *Plant Sociology, 56*(2), 53–68. https://doi.org/10.7338/pls2019562/04

Stinca, A., Musarella, C. M., Rosati, L., Laface, V. L. A., Licht, W., Fanfarillo, E., Wagensommer, R. P., Galasso, G., Fascetti, S., Esposito, A., Fiaschi, T., Nicolella, G., Chianese, G., Ciaschetti, G., Salerno, G., Fortini, P., Di Pietro, R., Perrino, E. V., Angiolini, C., De Simone, L., & Mei, G. (2021). Italian vascular fora: new findings, updates and exploration of floristic similarities between regions. *Diversity, 13*(11), 600. https://doi.org/10.3390/d13110600

Storkey, J., & Neve, P. (2018). What good is weed diversity? *Weed Research, 58*, 239–243. https://doi.org/10.1111/wre.12310

Šumberová, K. (2011). *Vegetace vodních rostlin zakořeněných ve dně (Potametea)*. In: Chytrý, M. (Ed) Vegetace České republiky. Vodní a mokřadní vegetace. Academia. Prague.

Suska-Malawska, M., Pawlikowski, P., & Mętrak, M. (2014). Assessment of indicative value of *Typhetum latifoliae* communities in small ponds in post-agricultural area (Masurian Landscape Park). *Monitoring Środowiska Przyrodniczego, 15*, 85–92.

Tanneberger, F., Tegetmeyer, C., Dylawerski, M., Flade, M., & Joosten, H. (2009). Commercially cut reed as a new and sustainable habitat for the globally threatened Aquatic Warbler. *Biodiversity and Conservation, 18*, 1475–1489. https://doi.org/10.1007/s10531-008-9495-0

Tardella, F. M., & Di Agostino, V. M. (2020). Vegetation of the "Altipiani di Colfiorito" wetlands (central Apennines, Italy). *Plant Sociology, 57*(2), 113–132. https://doi.org/10.3897/pls2020572/04

Tichý, L. (2002). JUICE, software for vegetation classification. *Journal of Vegetation Science, 13,* 451–453. https://doi.org/10.1111/j.1654-1103.2002.tb02069.x

Tuscany Region. (2015). Legge regionale 19 marzo 2015, n. 30. Norme per la conservazione e la valorizzazione del patrimonio naturalistico-ambientale regionale. Modifiche alla l.r. 24/1994, alla l.r. 65/1997, alla l.r. 24/2000 ed alla l.r. 10/2010.

Tuscany Region. (2021). Geoscopio. Retrieved January 13, 2022, from https://www.regione.toscana.it/-/geoscopio

Venanzoni, R., & Gigante, D. (2000). Contributo alla conoscenza della vegetazione degli ambienti umidi dell'Umbria (Italia). *Fitosociologia, 37*(2), 13–63.

Viciani, D., Lastrucci, L., Dell'Olmo, L., Ferretti, G., & Foggi, B. (2014). Natura 2000 habitats in Tuscany (central Italy): synthesis of main conservation features based on a comprehensive database. *Biodiversity and Conservation, 23,* 1551–1576. https://doi.org/10.1007/s1053-014-0686-6

Viciani, D., Vidali, M., Gigante, D., Bolpagni, R., Villani, M., Acosta, A. T. R., Adorni, M., Aleffi, M., Allegrezza, M., Angiolini, C., Assini, S., Bagella, S., Bonari, G., Bovio, M., Bracco, F., Brundu, G., Buffa, G., Caccianiga, M., Carnevali, L., … Lastrucci, L. (2020). A first checklist of the alien-dominated vegetation in Italy. *Plant Sociology, 57*, 29–54. https://doi.org/10.3897/pls2020571/04

Viciani, D., Angiolini, C., Bonari, G., Bottacci, A., Dell'Olmo, L., Gonnelli, V., Zoccola, A., & Lastrucci, L. (2022). Contribution to the knowledge of aquatic vegetation of montane and submontane areas of Northern Apennines (Italy). *Plant Sociology, 59*(1), 25–35. https://doi.org/10.3897/pls2022591/03

Warwick, F. V., & Downes, M. T. (1980). Variation in nutrient removal from a stream by watercress (*Nasturtium officinale* R. Br.). *Aquatic Botany, 9*, 221–235. https://doi.org/10.1016/0304-3770(80)90024-8

Zerbe, S., Steffenhagen, P., Parakenings, K., Timmermann, T., Frick, A., Gelbrecht, J., & Zak, D. (2013). Ecosystem Service Restoration after 10 Years of Rewetting Peatlands in NE Germany. *Environmental Management, 51*, 1194–1209. https://doi.org/10.1007/s00267-013-0048-2

Supplementary material

Table 1 (Tabela 1): *Conocephalo conici-Adiantetum capilli-veneris* Caneva, De Marco, Dinelli, Vinci 1995
Table 2 (Tabela 2): *Typhetum latifoliae* Nowiński 1930
Table 3 (Tabela 3): *Glycerio-Sparganietum neglecti* Koch 1926
Table 4 (Tabela 4): *Glycerietum notatae* Kulczyński 1928 nom. mut. prop.
Table 5 (Tabela 5): *Helosciadietum nodiflori* Maire 1924
Table 6 (Tabela 6): *Paspalo paspaloidis-Polypogonetum viridis* Br.-Bl. 1952
Table 7 (Tabela 7): *Agrostis stolonifera* community (*Paspalo-Agrostion*)
Table 8 (Tabela 8): *Bolboschoenetum glauci* Grechushkina et al. 2011
Table 9 (Tabela 9): *Ranunculetum repentis* Knapp 1946
Table 10 (Tabela 10): *Lycopus europaeus* community (*Phragmito-Magnocaricetea*)
Table 11 (Tabela 11): *Callitrichetum palustris* (Dihoru, 1975 n.n.) Burescu 1999
Table 12 (Tabela 12): *Nasturtietum officinalis* Gilli 1971
Table 13(Tabela 13): *Potametum crispi* von Soó 1927
Table 14 (Tabela 14): *Parvo-Potamogetono-Zannichellietum pedicellatae* Soó 1947
Table 15 (Tabela 15): *Polygono lapathifolii-Xanthietum italici* Pirola et Rossetti 1974
Table 16 (Tabela 16): *Convolvulo-Epilobietum hirsuti* Hilbig Heinrich et Niemann 1972
Table 17 (Tabela 17): *Helianthus tuberosus* community (*Epilobietea angustifolii*)
Table 18 (Tabela 18): *Pruno-Rubenion ulmifolii* O. Bolòs 1954
Table 19 (Tabela 19): *Dioscoreo communis-Populetum nigrae* Poldini et Vidali in Poldini, Sburlino ex Vidali 2017
Table 20 (Tabela 20): *Quercus pubescens* community (*Crataego-Prunetea*)
Table 21 (Tabela 21): *Clematido vitalbae-Arundinetum donacis* Biondi et Allegrezza 2004
Table 22 (Tabela 22): *Galio erecti-Brachypodietum rupestris* Allegrezza et al. 2016
Table 23 (Tabela 23): *Ailanthus altissima* community (*Lauro-Robinion*)
Table 24 (Tabela 24): *Sambuco nigrae-Robinietum pseudacaciae* Arrigoni 1997
Table 25 (Tabela 25): *Salicetum albae* Issler 1926
Table 26 (Tabela 26): *Calystegio-Equisetetum telmateiae* Jovanović 1993
Table 27 (Tabela 27): *Rubus ulmifolius-Solanum dulcamara* community (*Lauro-Sambucion*)
Table 28 (Tabela 28): *Mercurialietum annuae* Kruseman et Vlieger, 1939 ex Westhoff et al. 1946
Table 29 (Tabela 29): *Bryo-Saginetum apetalae* Blasi et Pignatti 1984
Table 30 (Tabela 30): *Potentillo reptantis-Sorghetum halepensis* Fanfarillo et Angiolini in Fanfarillo et al. 2022
Table 31 (Tabela 31): *Hordeetum leporini* Br.-Bl. 1952
Table 32 (Tabela 32): *Alysso alyssoidis-Sedion* Oberd. et T. Müller in T. Müller 1961
Table 33 (Tabela 33): *Parietaria judaica* community (*Cymbalario-Asplenion* Segal 1969)
Table 34 (Tabela 34): *Trifolietum resupinato-nigrescentis* Molinier & Tallon 1968