






Research Article

A contribution to the phytosociological knowledge of the Molise region's river ecosystems (central-southern Italy)

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Abstract

The hydrophilous and hygrophilous vegetation occurring within the Biferno and Sordo Rivers, in the Molise administrative region (central-southern Italy), was investigated according to the phytosociological approach and syntaxonomically classified. Twenty-three plant communities were identified belonging to the following classes: *Salicetea purpureae*, *Alno glutinosae-Populetea*, *Phragmito-Magnocaricetea*, *Molinio-Arrhenatheretea*, *Epilobietea angustifolii*, *Bidentetea tripartitae*, *Filipendulo ulmariae-Convulvuletea sepium*, *Lemnetea minoris*, and *Potamogetonetea pectinati*. A new association, the *Zannichellietum peltatae* ass. nov. was described as an ecologically vicariant community of the *Zannichellietum palustris*. From a nomenclatural point of view, the following association names: *Bolboschoeno maritimi-Schoenoplectetum tabernaemontani*, *Pescicario lapathifoliae-Xanthietum orientalis* and *Stuckenietum pectinatae* were all proposed as nomina mutata nova (Art. 45 ICPN). Numerous discrepancies in the interpretation and syntaxonomic classification of the communities investigated were highlighted comparing the Prodrome of the Italian vegetation and the Euro-VegChecklist. Finally, six habitats of conservation value according to the 92/43/CEE Directive Habitats were identified and a critical analysis on the correspondence between specific plant communities and related Annex I Habitat codes was advanced.

Keywords

Conservation, Habitats directive, hydrophilous and hygrophilous vegetation, Molise region, phytosociology, syntaxonomy

Introduction

River ecosystems are characterized by a great diversity of physical conditions that allow the development of different types of biological communities. Thanks to their dynamism, these communities can adapt rapidly to the varying physical characteristics of the watercourses (Blanchet et al. 2020). On the other hand, the rivers are among the most threatened ecosystems due to the erosion of their habitats caused by the negative impact of multiple human activities. Dams and water diversion systems block fish

migration routes and disrupt habitats; water withdrawals for human use reduce river flows and consequently the ecological niches available to plants and animals, run-off from agricultural and urban areas, often without effective filtering and purification systems, worsens water quality (Altermatt et al. 2013).

The Natura 2000 network identifies river systems as sites of high ecological value, especially in their role of ecological corridors and migratory routes for a multitude of species (Naiman et al. 1993; Tabacchi et al. 1998; van der Nat et al. 2003). Accordingly, river ecosystems are

currently included in several habitats listed in Annex I of Directive 92/43/EEC (European Commission 2013). Preventing the deterioration of aquatic ecosystems and maintaining biodiversity is also a primary objective of the Water Framework Directive 2000/60/EC (Hooke 2007; Nardini et al. 2008; Van Looy et al. 2008; Mouton et al. 2009). It is not by chance that a key objective of the EU Biodiversity Strategy for 2030 is the restoration of freshwater ecosystems together with the improvement of the trophic and functional status of compromised habitats (Scheffer et al. 2003; Soana and Bartoli 2014).

The floristic knowledge of wetlands and other types of aquatic communities is a fundamental prerequisite to identify habitat types which are currently included in the Habitats Directive 92/43/EEC, and apply effective and consistent conservation measures (Benavent-González et al. 2014; Gigante et al. 2018). A recent comprehensive inventory of aquatic plant species and communities investigating on the main factors influencing species richness in aquatic ecosystems (Bolpagni et al. 2019) stated that a significant decline in species richness would be underway (especially in lowland aquatic ecosystems). The two factors considered mainly responsible for this decline were found to be changes in river discharge regimes and land reclamation. The same study revealed that the knowledge of these processes and their real weight in terms of “floristic biodiversity loss” remains partially undefined, as several aquatic species are often unrecorded in local-scale surveys.

On the other hand, the riverbed communities are sometimes difficult to identify correctly (i.e. in terms of their spatial and ecological boundaries) and, therefore, to sample and classify syntaxonically. A typical example is the rather sparse communities that temporarily emerge in early summer and are subject to occasional floods which prevent the establishment of well-defined vegetation types from both a floristic and structural point of view. These communities undoubtedly contribute to the ecosystem diversity, but this is often ignored or underestimated.

Phytosociological studies of riverine vegetation in peninsular Italy have mainly focused on relatively small areas or locally significant watercourses (e.g. Pirone 1991; Biondi et al. 1997, 1999; Maiorca et al. 2007; Ceschin and Salerno 2008; Lastrucci et al. 2010; Lastrucci et al. 2012). There are few phytosociological contributions that consider riverine vegetation in entire Italian administrative regions (Brullo and Spampinato 1990; Sartori and Bracco 1995; Tomei et al. 2001), or syntaxonomic large-scale frameworks concerning high-rank syntaxa framework (e.g. Scoppola 1982; Buchwald et al. 2000; Venanzoni and Gigante 2000; Biondi et al. 2004; Sburlino et al. 2004, 2008; Landucci et al. 2013, 2020). However, while they represent limited parts of the territory, the studies at local or regional scales often allow for a much more in-depth analysis of both flora and vegetation, thanks to the large number of phytosociological relevés carried out per unit area. For this reason, such studies are highly valued in practice, especially in environmental planning and design policies (usually managed by regional administrations),

such as the periodic monitoring and reporting of the conservation status of habitats under Directive 92/43/EEC.

The Molise administrative region (southern Italy) exhibits a large river system in which most of the watercourses have a typical torrential regime characterized by winter floods and pronounced summer lows. The vegetation mosaic characterizing the retrodunal environments (including the humid areas) of a great part of the Molise coastal sector has been intensively studied during the last thirty years (Taffetani and Biondi 1989; Izzi et al. 2007; Stanisci et al. 2007; Taffetani et al. 2011; Stanisci et al. 2012). In contrast, very little is known about the phytosociology and syntaxonomy of the aquatic and riparian communities of the inner areas. Pedrotti and Cortini Pedrotti (1978) identified the hygrophilous woodland association *Carici-Fraxinetum angustifoliae* (Bosco Fantine and Bosco Tanassi) in a limited area of the Biferno River, which has now disappeared. Canullo et al. (1988) carried out a phytosociological study of the wet and flooded meadows of the upper Trigno River valley where they identified several plant communities within a broad ecological pattern, including springs and streams, wet meadows, flooded meadows, transitional meadows and marshes. Still regarding the Trigno River, although restricted to the Abruzzo Region side, Pirone et al. (2009) carried out a phytosociological analysis of the alluvial deposits where they described two new associations of gravel-bed substrates. Finally, Aucelli et al. (2011) focused on the relationship between river channel adjustments and riparian vegetation responses by analysing significant stretches of the three Volturno, Trigno and Biferno Rivers. In this context of limited knowledge on the river ecosystems vegetation at regional level, we have carried out a vegetation study of two river ecosystems that had not yet been investigated from a phytosociological point of view. These are the Sordo River in the peri-urban area of the city of Isernia, and the middle and lower course of the Biferno River. The main objectives of this study were: i) to provide new phytosociological data on the riverine plant communities of the Molise region, which could be useful to support conservation, environmental and management policies; ii) to identify which are the main environmental factors that play a role in determining the spatial distribution of the different plant communities; iii) to update the regional floristic and coenological list of riverine ecosystems.

Methods

Study area

The research was carried out along two rivers in the Molise region: the Sordo River and the Biferno River (Fig. 1). The Sordo River is located in the municipality of Isernia (41°36'56.5"N, 14°14'35.5"E), is fed by the karstic water table of Monte Totila and flows, in its upper part, in a mild depression known as “Le Piane”, composed of lacustrine and alluvial sediments at an altitude of about

456–450 m a.s.l. (Giraudi et al. 1999). The portion of the river included between the spring of Capo d'Acqua and the confluence with the Rava River represents the stretch of interest in this study. From a bioclimatic point of view this area is included in the Temperate Region with an upper meso-temperate thermotype and a lower humid ombrotype (Rivas-Martínez et al. 2011; Pesaresi et al. 2014). No 92/43/EEC riverine habitats have been recognized to date for the Sordo basin.

The Biferno River (83.5 km) is the most important and representative river of the Molise Region within which its entire course unfolds, from source to mouth. It rises at an altitude of 500 m a.s.l., in the Matese mountains and collects the waters of a catchment area of about 1311 km². The Biferno is a perennial river with an alternation of low-water (spring-summer) and high-water (autumn-winter) levels. The upper reaches of the river are formed by Cretaceous limestone substrates, while the middle and lower reaches are formed by flaky clays and clay-limestone schists, creating a steep and rugged landscape (Amato et al. 2017). After crossing the Bojano plain, the river enters a narrow valley, near the village of Gualdi-afiera. The landscape then takes on the characteristics of a large lowland where the river slowly descends towards the Adriatic coast emptying into the sea with a delta-shaped mouth. The bioclimatic framework carried out by Pesaresi et al. (2014, 2017), based on the classification system of Rivas-Martínez et al. (2011), assigns the study area to the Mediterranean macrobioclimate with a prevalence of the lower meso-mediterranean thermotype (only a restricted initial portion of the river is addressed to the

sub-Mediterranean variant in the Temperate Region) and to the lower sub-humid ombrotype.

According to the information provided by the 3rd report of the Habitats Directive in Italy (<https://reportingdirettiva-habitat.isprambiente.it/habitat-basic-search>) the following (92/43/EEC) riverine Habitats are currently considered for the study area: 3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation; 3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation; 3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation; 3280 Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*; 6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels; 92A0 *Salix alba* and *Populus alba* galleries.

Sampling design and data collection

The vegetation sampling was carried out according to the classical phytosociological approach of the Zurich-Montpellier school (Braun-Blanquet 1932). All relevés were carried out during the spring-summer period of 2024. Species nomenclature followed Bartolucci et al. (2018) for the native species and Galasso et al. (2018) for the alien species, with all the subsequent updating reported in the Portal to the Flora of Italy (2025). Pignatti et al. (2017–2019) were used for species identification, while life forms and chorotypes refer to Pignatti et al. (2005). The set of collected relevés was arranged in a matrix consisting of

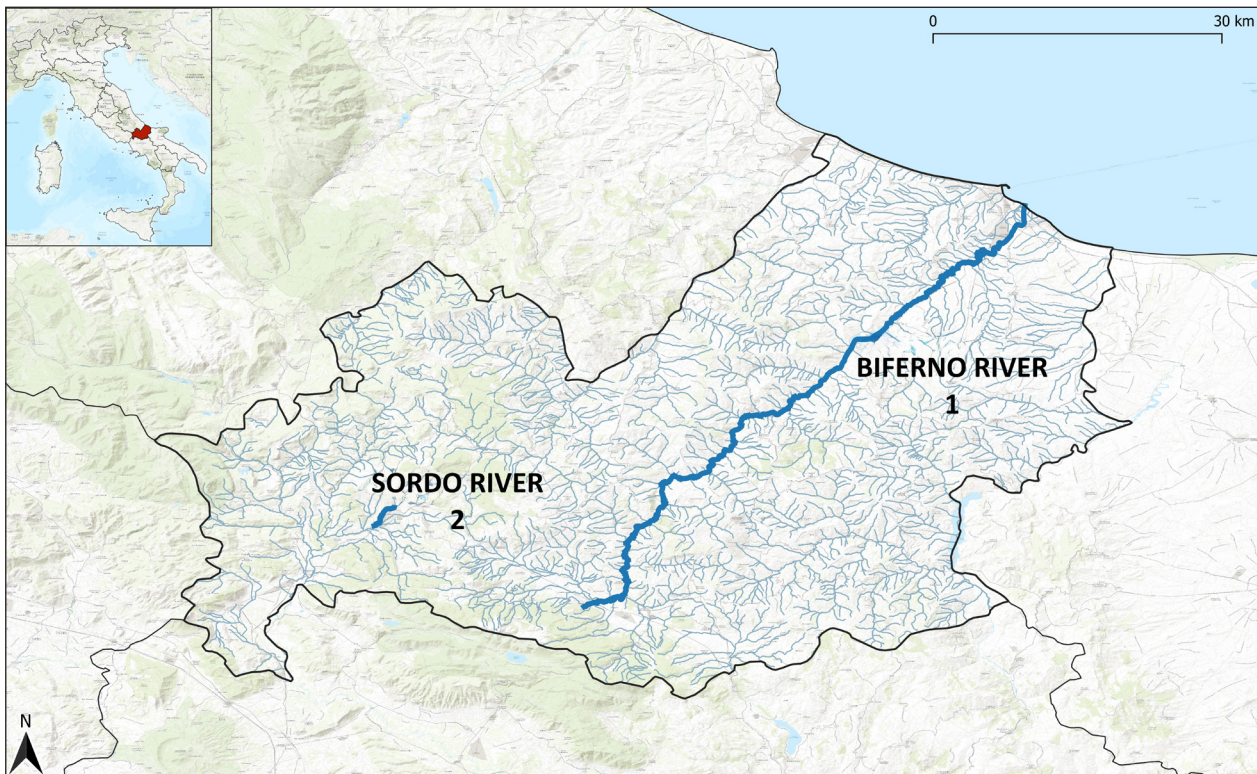


Figure 1. In the top box, marked in red colour, there is the location of the Molise Region in the Italian Peninsula. In the larger figure, the course of the Biferno River (1) and Sordo River (2) is traced and marked in blue colour.

80 relevés and 170 species where the original Braun-Blanquet cover-abundance scale codes were transformed into numerical ordinal values (1–9) following van der Maarel (1979). This matrix was numerically classified by means of a hierarchical classification, using the chord distance as similarity measure and an agglomerative clustering algorithm (UPGMA) on quantitative data. A PCA ordination was carried out to identify the main trends of coenological diversity. All the statistical analyses were carried out using the software PAST (Hammer et al. 2001). The nomenclature of the syntaxa identified and the final syntaxonomic framework follow Biondi et al. (2014) and Mucina et al. (2016), as well as subsequent updates (Chytrý et al. 2024).

Results

Statistical analysis

The dendrogram (Fig. 2) shows the occurrence of four main groups of communities marked by the numbers from 1 to 4. A first group of relevés in the right side of the dendrogram (4: T–V) includes communities belonging to a typical hydrophytic vegetation characterized by rooted macrophytes of slowly flowing shallow streams (*Potamogetonetea*); a second group of relevés (3: K–S), is characterized by a mixture of communities belonging to different types of vegetation, including hydrophytic communities dominated by rooted and floating macrophytes,

herbland vegetation of small freshwater streams and different types of helophytic vegetation (*Potamogetonetea*, *Lemnetea minoris*; *Nasturtio-Glycerietalia*, *Phragmito-Magnocaricetea*). A third group of relevés (2: F–J), is characterized by pioneer vegetation of periodically flooded meadows and nutrient-rich riverbanks and drained muddy substrates (*Molinio-Arrhenatheretea*, *Bidentetea*, *Galio-Urticetea*) together with tall-herb vegetation developed on the stony streambeds of the hilly belt with light anthropogenic features. Finally, a fourth group of relevés (1: F–J) includes both helophytic communities (*Phragmito-Magnocaricetea*) and wooded riparian communities (*Salicetea purpureae*; *Alno glutinosae-Populetea albae*).

The distribution of the relevés in the PCA diagram (Fig. 3) shows a Y-shaped arrangement and relatively low cumulative variance expressed by the first two PCA components (Component 1 = 13.93% and Component 2 = 10.02%). However, the communities appear sufficiently well separated, at least at the macro-groups level, with the riparian phanerophytic and “hygrophilous” hemicryptophytic communities predominantly located on the right side of the diagram and the “hydrophytic” vegetation communities exclusively on the left side of the diagram. The helophytic communities dominated by *Phragmites australis*, *Schoenoplectus tabernaemontani*, and *Typha latifolia* respectively, are arranged transversally across the entire dataset along the first axis following a gradient of increasing hygrophily (linked to the water depth) from right to left passing from the *Phragmitetum* (right side) to

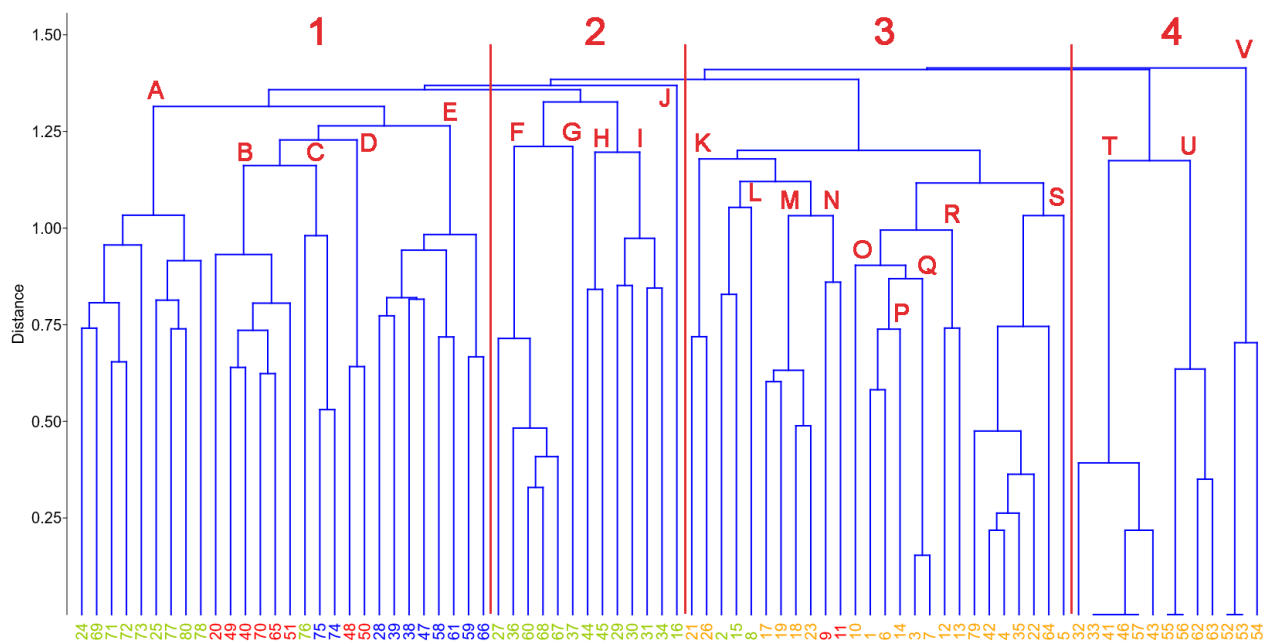


Figure 2. List of the communities identified with relevé numbers coloured on the basis of the life form of the dominant species: green = Hemicryptophytes+Geophytes+Therophytes; red = Helophytes; Blue = Phanerophytes; Orange = Hydrophytes 1: (A. *Caricetum hispidae*, B. *Phragmitetum australis*, C. *Rubo ulmifolii-Salicetum albae*, *Cirsio triumfetti-Eupatorietum cannabini*, D. *Bolboschoeno maritimi-Schoenoplectetum tabernaemontani*, E. *Dioscoreo communis-Populetum nigrae*); 2: (F. *Polypogono viridis-Paspaletum distichi*, G. *Persicario lapathifoliae-Xanthietum orientalis*, H. *Juncus fontanesii* community, I. *Polypogon monspeliensis* and *Persicaria lapathifolia* community, J. *Phalarido-Petasitetum hybridi*); 3: (K. *Veronico-Callitrichetum stagnalis*, L. *Convolvulo-Epilobietum hirsuti*, M. *Glycerio-Sparganietum neglecti*, N. *Typhetum latifoliae*, O. *Groenlandietum densae*, P. *Nasturtietum officinalis*, Q. *Potametum crispum*, R. *Lemnetum minoris*, S. *Helosciadietum nodiflorii*); 4: (T. *Zannichellietum peltatae*, U. *Potamogetonatum denso-nodosi*, V. *Stuckenietum pectinatae*).

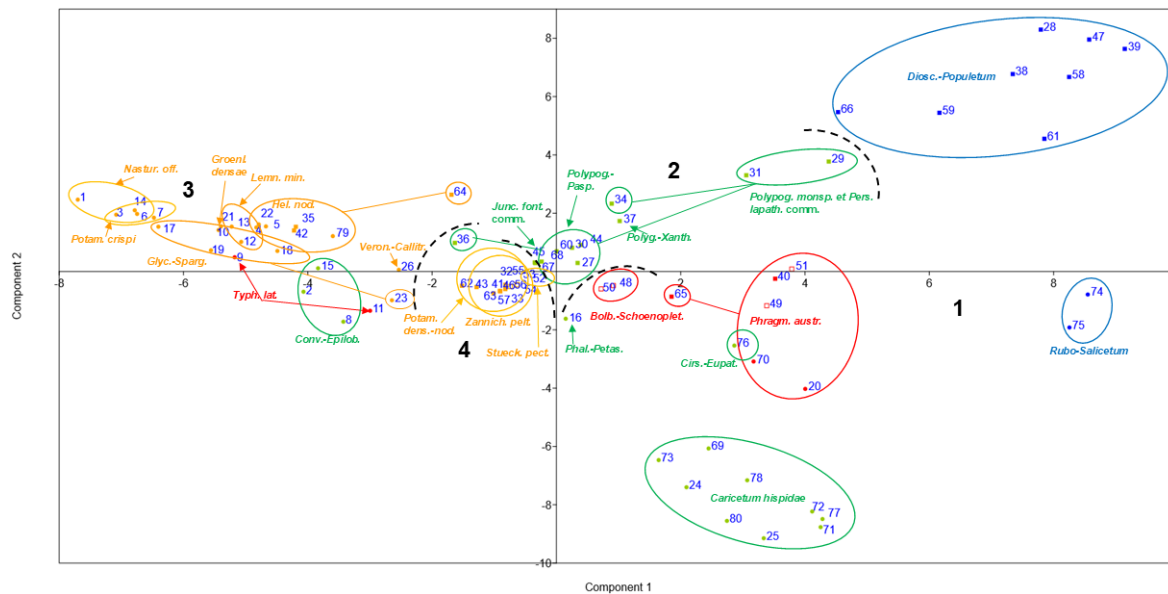


Figure 3. Ordination diagram of the relevés. Ellipses circumscribing the relevés of the different communities are coloured based on the dominant life form: green = Hemicryptophytes+Geophytes+Therophytes; red = Helophytes; Blue = Phanerophytes; Orange = Hydrophytes. The numbers in black bold style refer to the four clusters highlighted in the cluster analysis of Fig. 2. Cumulative variance: Component 1 = 13.935 and Component 2 = 10.022.

the *Typhetum* (left side). The distribution of communities along the second axis does not appear to reveal any significant gradients related to ecological or structural factors.

Vegetation communities identified

HYGROPHILOUS FORESTS

(*Salicetea purpureae*; *Salicetalia purpureae*; *Salicion albae*)

***Rubo ulmifolii-Salicetum albae* Allegrezza, Biondi et Felici 2006** (Suppl. material 1: table S1, relevés 1–2)

Floristic characterization: riverine woodland dominated by *Salix alba* and *Populus nigra*, accompanied in the consistent herbaceous layer mainly by *Carex pendula* and *Phragmites australis*.

Ecology: the *Salix alba* communities occur on deep soils close to the riverbed along the Sordo River.

Syntaxonomy: the reference to *Rubo ulmifolii-Salicetum albae* is in line with the syntaxonomic classification of *Salix alba* communities in Mediterranean and sub-Mediterranean climate zones. In this case, the reference provided at the association level is based on the fact that the community in question is characteristic of disturbed sites (as also reported as diagnostic feature in Allegrezza et al. 2006), and that, given the geographical location, both the *Salix alba* woodland relevés are characterised by some species with a strictly Mediterranean distribution (e.g. *Carex hispida* and *Cirsium creticum* subsp. *triumfetti*), which do not occur in the central-European association *Salicetum albae* Issler 1926.

92/43/EEC Habitats Directive: 92A0 – *Salix alba* and *Populus alba* galleries.

MESO-HYGROPHILOUS FORESTS

(*Alno glutinosae-Populetea albae*; *Populetales albae*; *Carici remotae-Fraxinion oxycarpae*)

***Dioscoreo communis-Populetea nigrae* Poldini et Vidali in Poldini, Sburlino et Vidali 2017** (Suppl. material 1: table S2, relevés 1–8)

Floristic characterization: riverine meso-hygrophilous forests dominated by *Populus nigra* sometimes accompanied in the dominant tree layer by *Salix alba*. The scrub layer is characterized by *Salix purpurea*, *S. triandra* (low frequency), *Cornus sanguinea* and *Hedera helix*. The presence of *Phragmites australis* is constant. In the herb layer the most frequent species are *Agrostis stolonifera* and *Brachypodium sylvaticum*. Important is the contribution of the alien flora, with *Robinia pseudoacacia* occurring in the secondary tree layer and *Amorpha fruticosa* exhibiting high cover values in some relevés.

Ecology: the *Populus nigra* woodlands are found on the outer part of the river terraces of the Biferno River, which are reached less frequently by floods.

Syntaxonomy: the *Populus nigra* communities of the study area can be assigned to the *Dioscoreo communis-Populetea nigrae* Poldini et Vidali in Poldini, Sburlino et Vidali, 2017. Compared to the original diagnosis of the association, the phytosociological relevés carried out in the study area reveal the presence of additional riparian tree species, such as *Salix alba* and *Salix triandra*, as well as a tendency to harbour invasive alien species, including *Amorpha fruticosa* and *Robinia pseudoacacia*. The *Dioscoreo-Populetea* was originally described for sandy-gravelly to sandy-silty well-drained soils bordering Alpine watercourses in north-eastern Italy (Poldini et al. 2017). In this case, reference is made

to the subass. *typicum*, which is slightly more thermophilic and does not involve the co-dominance of *Populus alba* in the tree layer (see Poldini et al. 2020). Despite their location in central-southern Italy, the *Populus nigra* communities sampled along the Biferno River do not exhibit a notable increase in Mediterranean species in the undergrowth when considering both the shrub and herb layers.

92/43/EEC Habitats Directive: 92A0 – *Salix alba* and *Populus alba* galleries.

MESO-HYGROPHILOUS MEADOWS

(*Molinio-Arrhenatheretea*; *Potentillo-Polygonetalia avicularis*; *Potentillion anserinae*)

***Juncus fontanesii* community** (Suppl. material 1: table S3, relevés 1–2)

Floristic characterization: monospecific community of *Juncus fontanesii* with sporadic presence of *Persicaria lapathifolia* and *Bidens frondosa*.

Ecology: edges of Biferno River, on humid sandy periodically flooded soils.

Syntaxonomy: the syntaxonomy of *Juncus fontanesii* as a dominant species within a community as well as its synecological and altitudinal ranges are still unclear. From a chorological point of view, *Juncus fontanesii* is a Mediterranean-Turanian species that occurs primarily in the central and southern regions of Italy (excluding Basilicata), while in areas above the Po Valley it is only present in Lombardy and Trentino (Lastrucci et al. 2004; Beccarisi et al. 2007; Pedrotti 2022). In most cases, *Juncus fontanesii* acts as a low-frequency species within the *Molinio-Arrhenatheretea* (Mucina et al. 2016) and *Isoeto-Nanojuncetea* communities (Pirone et al. 2003). In our dataset, only two relevés are dominated by *Juncus fontanesii*, so classification at the association or alliance level is difficult. Assuming the reference to *Molinio-Arrhenatheretea* is correct at the class level, the classification in *Potentillo-Polygonetalia avicularis* Tx. 1947 at the order level seems most appropriate, given the presence of anthropogenic species, such as *Amorpha fruticosa*, *Persicaria lapathifolia*, *Bidens frondosa*, and *Echinochloa crus-galli*.

92/43/EEC Habitats Directive: no.

***Cirsio triumfetti-Eupatorietum cannabini* Brullo et Spampinato 1990** (Suppl. material 1: table S4, relevé 1)

Floristic characterization: Hemicyptophytic community with *Cirsium creticum* subsp. *triumfettii* being the dominant species.

Ecology: This rare community forms a border to the *Salix alba* forest along the Sordo River. This association develops typically on the narrow riparian strips located between the riverbed and the woodland communities on the banks, but it tends to occupy larger surfaces in the event of the disappearance of the riverbank tree and shrub formations (Brullo and Spampinato 1990).

Syntaxonomy: the vegetation stands sampled in this study represent an impoverished aspect of the association

Cirsio-Eupatorietum cannabini Brullo et Spampinato 1990 described for Sicily. We have opted for classifying this association in the alliance *Potentillion anserinae* and in the order *Potentillo-Polygonetalia avicularis* which includes the temporarily flooded and heavily grazed zoo-anthropogenic nutrient-rich meadows and pastures of the temperate and Mediterranean regions of Europe. Mucina et al. (2016) include both the alliance and the order in the class *Molinio-Arrhenatheretea* while Biondi et al. (2014) in the class *Agrostietea stoloniferae* Oberdorfer 1983. However, similar communities dominated by *Eupatorium cannabinum* in the central and eastern Mediterranean are included in the alliance *Dorycnio recti-Rumicion conglomerati* while in the western Mediterranean these are classified in the alliance *Cynancho-Convolvulion sepium* (Mucina et al. 2016; Preislerová et al. 2022; Myśliwy and Pešić 2023). Both these alliances, considered by the authors as typical of nutrient-rich fringe riparian vegetation, are included in the order *Convolvuletalia sepium* and in the class *Epilobietea angustifolii*.

92/43/EEC Habitats Directive: 6430 – Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels.

MESO-HYGROPHILOUS MEADOWS

(*Molinio-Arrhenatheretea*; *Holoshoenetalia vulgaris*; *Polypogono viridis-Paspalion distichi*)

***Polypogono viridis-Paspaleto distichi* Br.-Bl. in Br.-Bl., Gajewski, Wraber et Walas 1936 nom. invers. et mut. Lastrucci et Viciani 2025** (Suppl. material 1: table S5, relevés 1–5, Fig. 4)

Floristic characterization: almost monospecific communities of *Paspalum distichum* with few companion species.

Ecology: it grows on Biferno River in humid areas on muddy or silty soils periodically submerged and constantly moved by man.

Syntaxonomy: Lastrucci and Viciani (2025) proposed the mutation and inversion of the name *Paspalo distichi-Polypogonetum viridis* due to the dominance of *Paspalum distichum* in the Braun-Blanquet et al. (1936) relevés. This community was originally named *Paspalum distichum* and *Agrostis verticillata* association, but today both *Agrostis verticillata* and *Agrostis semiverticillata* are considered synonyms of *Paspalum distichum*. As this association represents the nomenclatural type of the alliance *Paspalo-Agrostidion semiverticillati* which was later established by Braun-Blanquet et al. (1952), Lastrucci and Viciani (2025) also proposed the mutation and inversion of the alliance name in *Polypogono viridis-Paspalion distichi*. Regarding the classification at the higher rank syntaxa, Mucina et al. (2016) classify the alliance *Paspalo-Agrostidion semiverticillati* in the class *Bidentetea* Tx. et al. ex von Rochow 1951, which mainly comprises summer-annual pioneer vegetation. In contrast, both Rivas-Martinez et al. (2001) and Biondi et al. (2014) included the same alliance in the class *Molinio-Arrhenatheretea* which mainly comprises perennial vegetation. The latter reference seems to be the most



Figure 4. *Polypogono viridis-Paspaleum distichi* along the banks of Guardialfiera lake, formed by the Biferno River (photo D. Viciani, June 2024).

appropriate for classifying the *Polypogono-Paspaleum* stands found in the study area, as these are characterized by the absolute dominance of a perennial hemicryptophyte, with annual species playing a negligible role.

92/43/EEC Habitats Directive: 3280 – Even if the dominant species is an alien invasive species, this kind of community configure a conservation interesting habitat, named “Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*”.

PIONEER ANNUAL NITROPHILOUS AND HYGROPHILOUS VEGETATION

(*Bidentetea tripartitae*; *Bidentetalia tripartitae*; *Chenopodium rubri*)

***Persicario lapathifoliae-Xanthietum orientalis* Pirola et Rossetti 1974 nom. mut. nov.** (Suppl. material 1: table S6, relevé 1, Fig. 5A)

Floristic characterization: original specific component: *Xanthium orientale*, *Bidens frondosa* and *Amaranthus retroflexus*. Dominant species: *Xanthium orientale*.

Ecology: this community is influenced both by the river regime, which deposits new material with each flood, and by anthropogenic disturbances such as sewage discharges and waste accumulations. In our study the *Persicario-Xanthietum* develops along Biferno River on silty-pebbly substrates, strongly nitrified by the deposit of organic materials transported by the water.

Syntaxonomy: the syntaxonomic reference currently used for the pioneer herb subnitrophilous and partially anthropogenic vegetation, which is typical of temporarily dry, sandy and pebbly riverbeds is the *Polygono lapathifolii-Xanthietum italicum* Pirola et Rossetti 1974. Although *Xanthium orientale* occurs in many relevés of our dataset, only one relevé has been assigned directly to the *Polygono lapathifolii-Xanthietum italicum*, this relevé being the only one where the dominance of *Xanthium orientale*

was evident. This association was first described for the Reno River in the Emilia-Romagna Region (Pirola and Rossetti 1974 p. 22) in the form of two subassociations, a (presumably) typical one (Suppl. material 1: table S1), and a second subassociation named “*agrostietosum stoloniferi*” (Suppl. material 1: table S2), which is described as being less influenced by the hydrological regime. The *Polygono-Xanthietum* has since been identified in similar environments in several other torrential rivers, especially in central Italy (Pirone 1991; Biondi et al. 1999; Pirone et al. 2003). In our dataset there is only one relevé characterised by the dominance of *Xanthium italicum* which we have classified under this association (Suppl. material 1: table S6, rel. 1). In fact, The *Persicario lapathifoliae-Xanthietum orientalis* exhibits highly variable floristic compositions and species richness, depending on the granulometry of the substrate and the erosive action of water on this latter during floods. From an ecological point of view, the *Persicario-Xanthietum* association is found on pebbly-sandy riverbeds, and the cover degree of the dominant species varies with the grain size of the substrate, as does the total number of species in the community. This number tends to decrease as the density of *Xanthium* and *Polygonum* increases. In turn, the density of these species increases as the grain size becomes more refined. In the original publication (Pirola and Rossetti 1974), no type-relevés were indicated for either the association or the subassociation *agrostietosum stoloniferi*. For this reason, we selected hoc loco rel. 9 of table 1 in Pirola and Rossetti (1974) as the lectotypus for the name *Polygono lapathifolii-Xanthietum italicum typicum* and rel. 6 of table 2 in Pirola and Rossetti (1974) as the lectotypus for the *Polygono lapathifolii-Xanthietum italicum* subass. *agrostietosum stoloniferi*. From a taxonomic-nomenclatural point of view, the name *Polygonum lapathifolium* L. serves as the basionym of the name *Persicaria lapathifolia* (L.) Delarbre. The latter is currently considered the valid and accepted name for this taxon in the main international and national Floras and Checklists (see Euro+Med plant base 2006+; Pignatti et al. 2017; Bartolucci et al. 2018, 2024; Tropicos 2025; IPNI 2026). Specifically, the name *Polygonum lapathifolium* L. is no longer accepted in at least two floras covering its geographical distribution (Art. 45 of ICPN) (see Bartolucci et al. 2018). On the other hand, also the name *Xanthium italicum* was recently synonymized (Tomasello 2018) with the alien neophyte taxon *Xanthium orientale* L. and in this form it is now reported in the checklist of the Italian vascular flora (Bartolucci et al. 2024). For this reason we propose hoc loco the name *Persicario lapathifoliae-Xanthietum orientalis* Pirola et Rossetti 1974 as nomen mutatum novum (Art. 45). Accordingly, the complete and correct form of the name of the association in question is *Persicario lapathifoliae-Xanthietum orientalis* Pirola et Rossetti 1974 mut. Fortini, Di Pietro, Viciani, Di Marzio, Mezza, Lastrucci 2026.

92/43/EEC Habitats Directive: 3270 – Even if the dominant species is considered an invasive alien species, this kind of community configure the conservation

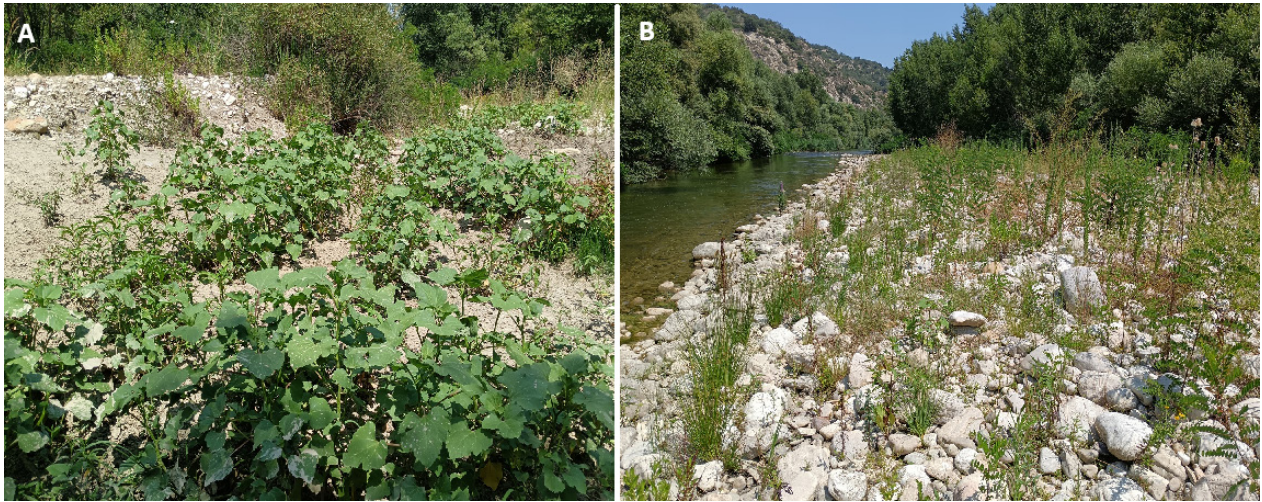


Figure 5. A. *Persicario lapathifoliae-Xanthietum orientalis* on sandy soil; B. *Polypogon monspeliensis* and *Persicaria lapathifolia* on pebbly soils in the Biferno River (photo R. Di Pietro, June 2024).

interesting habitat “Rivers with muddy banks with *Chenopodium rubri* p.p. and *Bidention* p.p. vegetation”.

***Polypogon monspeliensis* and *Persicaria lapathifolia* community** (Suppl. material 1: table S7, relevés 1–4, Fig. 5B)

Floristic characterization: Pebbly-clayey community with a highly variable floristic composition. Constant species are represented by *Polypogon monspeliensis*, *Bidens frondosa*, *Lythrum salicaria*, *Persicaria lapathifolia* and *Pulicaria dysenterica*.

Ecology: this community develops on riverbeds or river islands that appear in the early summer on a pebbly-clayey substrate. These areas are inundated during floods or in winter, and their vegetation is rather sparse because floods prevent stable vegetation from being established. This community are characterized by groups of ecologically diverse species, such as those typical of pebbly-clayey-sandy riverbeds, (*Persicaria lapathifolia*), hygrophilous species of humid depressions (*Scirpoides holoschoenus*, *Pulicaria dysenterica* and *Lythrum salicaria*), pioneer and ruderal species (*Verbena officinalis* and *Cirsium arvense*). In addition we found a woody component (*Populus nigra* and *Salix* sp. pl.) originating from the surrounding riparian forests, and some alien species (*Robinia pseudoacacia* and *Amorpha fruticosa*).

Syntaxonomy: this community is quite similar to the previously described *Persicario-Xanthietum* but differs in its extremely sporadic presence of *Xanthium orientale*. The high cover values of *Scirpoides holoschoenus*, alongside the sporadic presence of *Veronica anagallis-aquatica* and *Lycopus europaeus*, highlights the frequent presence of long-lasting floodwaters. The dominance of *Polypogon monspeliensis* is interesting, as this species thrives on sandy-clayey, humid or periodically flooded substrates, and is found in communities belonging to different alliances, including *Chenopodium rubri* (Julve 2025). We provisionally include this community in the *Chenopodium rubri* alliance, emphasizing its strong floristic heterogeneity.

92/43/EEC Habitats Directive: 3270 – Rivers with muddy banks with *Chenopodium rubri* p.p. and *Bidention* p.p. vegetation.

TALL-HERB SEMI-NATURAL PERENNIAL VEGETATION ON NUTRIENT-RICH RIPARIAN FRINGES

(*Epilobietea angustifolii*; *Convolvuletalia sepium*; *Senecionion fluviatilis*)

***Phalarido-Petasitetum hybridi* Schwick. 1933** (Suppl. material 1: table S8, relevé 1)

Floristic characterization: monospecific community of the geophyte *Petasites hybridus*.

Ecology: this vegetation colonizes sandy, detritus-rich and shallow riverbeds, particularly where the stream current loses its speed leading to the deposit of a large part of the mineral material and biomass transported. These environmental conditions favor entrance into the community of slightly nitrophilous species.

Syntaxonomy: the community is here assigned to the association *Phalarido-Petasitetum hybridi* due to the absolute dominance of *Petasites hybridus*. However, this reference should be considered preliminary. This association is very common in Central Europe (Rennwald et al. 2000) and has also been found in other areas of southern Italy (Maiorca and Spampinato 1999; Riviuccio et al. 2023). Similar associations include the *Chaerophyllo aurei-Petasitetum* identified in the Abruzzo region by Pedrotti et al. (1992) and the *Chaerophyllo hirsuti-Petasitetum* described for Slovenia (Čarni 1995). More recently Pedrotti (2008) described the association *Heracleo ternati-Petasitetum hybridi* for the central Apennines of the *Aegopodion podagrariae* alliance. The reference to the alliance and order rank is not univocal. For the alliance the choice is between *Petasition officinalis* Sill. 1933 em. Kopecký 1969 and *Aegopodion podagrariae* Tx. 1967, and *Senecionion fluviatilis* Tx. ex Moor 1958. For the order the possible references are *Convolvuletalia sepium* Tx. ex Moor 1958,

Galio-Alliaretalia Oberd. in Gors et T. Müller 1969 and *Petasito-Chaerophylletalia* Morariu 1967. According to Mucina et al. (2016) the reference at the class rank should be *Epilobietea angustifolii* or *Mulgedio-Aconitetea*, whereas, according to Biondi et al. (2014), it should be more properly assigned to the *Filipendulo ulmariae-Convolutetea sepium* Géhu et Géhu-Franck 1987 or to the *Galio aparines-Urticetea dioicae* Passarge ex Kopecký 1969. From a strictly physiognomic point of view, the most appropriate references would be that of the *Petasition officinalis* in terms of alliance and the *Petasito-Chaerophylletalia* at the order level. However, as explained in Mucina et al. (2016), the *Petasito-Chaerophylletalia* is representative of the tall-herb vegetation on nutrient-rich soils along mountain streams (as is the class *Mulgedio-Aconitetea* in the central-southern Apennines) and the same diagnosis was provided for the *Petasition officinalis* alliance (except for its type relevé). In fact, the nomenclatural, syntaxonomic situation of this type of vegetation is very complex and certainly cannot be resolved in this paper. In some cases (low altitude, slight anthropogenic disturbance), and net of the synonymies proposed by various authors, it can be placed on the border between three or four possible vegetation classes (e.g. *Mulgedio-Aconitetea*, *Epilobietea angustifolii*, *Galio-Urticetea*, *Filipendulo-Convolutetea*). Here we have considered the *Phalarido-Petasitetum* to still belong to the tall-herb fringe vegetation communities that develop on nutrient-rich riverbanks. Accordingly, we have decided to follow Mucina et al. (2016) opting for the following classification: *Epilobietea angustifolii*, *Convolutetalia sepium* and *Senecionion fluviatilis*.

92/43/EEC Habitats Directive: 6430 – Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels.

***Convolvulo-Epilobietum hirsuti* Hilbig, Heinrich et Niemann 1972** (Suppl. material 1: table S9, relevés 1–3)

Floristic characterization: hygro-nitrophilous communities composed of *Epilobium hirsutum* (dominant), *Sparganium neglectum*, *Helosciadium nodiflorum* subsp. *nodiflorum*. *Cirsium creticum* subsp. *triumfettii* may be locally co-dominant while *Lythrum salicaria* and *Bidens frondosa* may express high value cover.

Ecology: this community develops within the watercourses in periodically flooded humid areas that dry out during the summer. We carried out our surveys along a bend of the Sordo River on the outskirts of the city of Isernia, which is partially influenced by human disturbance.

Syntaxonomy: according to Mucina et al. (2016) the *Convolvulo-Epilobietum hirsuti* Hilbig, Heinrich et Niemann 1972 should be classified as *Epilobietea angustifolii*, *Convolutetalia sepium* Tx. ex Moor 1958, *Senecionion fluviatilis* Tx. ex Moor 1958. However, Biondi et al. (2014) classify it as *Filipendulo ulmariae-Convolutetea sepium*, *Calystegietalesia sepium*, *Calystegion sepium*. As previously mentioned, and as expressed in Mucina et al. (2016), the syntaxonomic and nomenclatural

relationships between the classes that could include the *Convolvulo-Epilobietum hirsuti* are very complex. In this paper we have opted for *Epilobietea angustifolii* following Mucina et al. (2016).

92/43/EEC Habitats Directive: 6430 – Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels.

TALL HELOPHYTIC VEGETATION

(*Phragmito-Magnocaricetea elatae*; *Bolboschoenetalia maritimi*; *Scirpion maritimi*)

***Bolboschoeno maritimi-Schoenoplectetum tabernaemontani* Bueno Sánchez et Prieto in Bueno Sánchez 1997. nom. mut. nov.** (Suppl. material 1: table S10, relevés 1–2)

Floristic characterization: monospecific community of geophytes dominated by *Schoenoplectus tabernaemontani* with the presence of *Phragmites australis*.

Ecology: this community was found alongside the Biferno River and represents a marshy vegetation located in partially salty, generally still or slow-moving waters.

Syntaxonomy: in this study, we opted to classify this community as *Bolboschoeno compacti-Scirpetum tabernaemontani*, which was described for the estuary of some rivers in northern Spain (Bueno Sánchez 1997), and in the alliance *Scirpion maritimi*. Our relevés are indeed all located near the mouth of the Biferno, almost at its entrance to the sea, in partially salty waters as evidenced by the presence of *Suaeda spicata*. From a nomenclatural point of view an upgrading of the original name *Bolboschoeno compacti-Scirpetum tabernaemontani* Bueno Sánchez et Prieto in Bueno Sánchez 1997 is required. In fact, both *Bolboschoenus compactus* (Hoffm.) Drobow and *Scirpus tabernaemontani* C.C. Gmel. (= *Scirpus lacustris* L. subsp. *tabernaemontani* (C.C. Gmel.) Syme) are currently considered synonyms of *Bolboschoenus maritimus* (L.) Palla and *Schoenoplectus tabernaemontani* (C.C. Gmel.) Palla



Figure 6. *Bolboschoeno maritimi-Schoenoplectetum tabernaemontani* in the lower reaches of the Biferno River (photo D. Viciani, June 2024).

respectively, which are the valid and accepted name for these two taxa in the main international and national Floras and Checklists (see Euro+med plant base 2006+; Tropicos 2025; IPNI 2026). Specifically, the names *Bolboschoenus compactus* (Hoffm.) Drobow and *Scirpus tabernaemontani* C.C. Gmel. are no longer accepted in at least two floras covering their geographical distribution (Govaerts and Simpson 2007; Di Natale et al. 2022). For this reason we propose *hoc loco* the name *Bolboschoeno maritimi-Schoenoplectetum tabernaemontani* Bueno Sánchez et Prieto in Bueno Sánchez 1997 as *nomen mutatum novum* (Art. 45).

92/43/EEC Habitats Directive: no

HERBLANDS AND SEDGE-BEDS

(*Phragmito-Magnocaricetea elatae*; *Nasturtio-Glycerietalia fluitantis*; *Glycerio-Sparganion*)

***Glycerio-Sparganietum neglecti* Koch 1926** (Suppl. material 1: table S11, relevés 1–4)

Floristic characterization: community of hydrophytes dominated by *Sparganium neglectum*.

Ecology: this community develops along Sordo River in still or slow-flowing, muddy waters.

Syntaxonomy: this syntaxon is often considered a “macro-association” incorporating also other *Sparganium* species. This genus is a critical and often difficult to distinguish at the species level in the field (Landucci et al. 2013; Lastrucci et al. 2024). The classification of the *Glycerio-Sparganietum neglecti* at the alliance level has changed over time. Landucci et al. (2013) classified this association in the *Glycerio-Sparganion*, whereas Landucci et al. (2020) in the *Phragmition australis*. In this study we opted for the *Glycerio-Sparganion*, as the *Glycerio-Sparganietum* appears to be an herbaceous vegetation typical of small freshwater streams, rather than a reed swamp vegetation.

92/43/EEC Habitats Directive: no

HERBLANDS AND SEDGE-BEDS

(*Phragmito-Magnocaricetea elatae*; *Nasturtio-Glycerietalia fluitantis*; *Apion nodiflori*)

***Nasturtietum officinalis* Gilli 1971** (Suppl. material 1: table S12, relevé 1–2)

Floristic characterization: a closed, monospecific community of aquatic macrophytes consisting of *Nasturtium officinale* accompanied by *Helosciadium nodiflorum* subsp. *nodiflorum* and *Veronica anagallis-aquatica* subsp. *anagallis-aquatica*.

Ecology: this community develops along the banks of the Sordo River in flowing water.

Syntaxonomy: in this study we opted to classify the association *Nasturtietum officinalis* within the alliance *Apion nodiflori* rather than within the *Glycerio-Sparganion*, that we consider distinct. This choice is because the dominant species of the investigated communities are

all rather small and exhibit a prostrate habit. However, Mucina et al. (2016) consider *Apion nodiflori* to be a synonym of *Glycerio-Sparganion*, as also reported in Landucci et al. (2020).

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***Helosciadietum nodiflori* Maire 1924** (Suppl. material 1: table S13, relevés 1–8, Fig. 7)

Floristic characterization: monospecific community dominated by *Helosciadium nodiflorum* subsp. *nodiflorum*.

Ecology: this community occurs along the banks of the Sordo River in clear and fresh running waters.

Syntaxonomy: *Helosciadietum nodiflori* is here classified in the alliance *Apion nodiflori*. In less hygrophilous communities that are subject to greater anthropic disturbance, there is a higher occurrence of species belonging to the classes *Bidentetea* and *Artemisietea*.

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Figure 7. *Helosciadietum nodiflori* occurring within lateral pool of the Sordo River (photo R. Di Pietro, June 2024).

REED SWAMP VEGETATION

(*Phragmito-Magnocaricetea elatae*; *Phragmitetalia communis*; *Phragmition communis*)

***Typhetum latifoliae* Nowiński 1930** (Suppl. material 1: table S14, relevés 1–2)

Floristic characterization: helophytic community dominated by *Typha latifolia*, with *Sparganium neglectum*, *Myosotis scorpioides* subsp. *laxa* and *Lemna minor* occurring in the understory.

Ecology: the *Typhetum latifoliae* is found in marshy areas characterized by clayey-muddy soils which emerge in summer, in significantly eutrophic environments resulting from the accumulation of organic sediment.

Syntaxonomy: the reference association is the *Typhe-tum latifoliae* Nowiński 1930. Typically, it is an almost monophytic association. In this case, however, stratification is evident, with a lower herbaceous layer clearly dominated by *Sparganium neglectum*.

92/43/EEC Habitats Directive: no

***Phragmitetum australis* Savič 1926 nom. corr.** (Suppl. material 1: table S15, relevés 1–6, Fig. 8)

Floristic characterization: large and dense reed community dominated by *Phragmites australis* with a rare presence of *Xanthium orientale*, *Lythrum salicaria* and *Convolvulus sepium*.

Ecology: this community exhibits a wide ecological amplitude, allowing it to be found in various types of wetland habitats, both along the Biferno and Sordo Rivers.

Syntaxonomy: The name *Phragmitetum australis* Savič 1926 was proposed as nom. corr. with a conserved type (over the name *Scirpo-Phragmitetum australis* W. Koch 1926) in Landucci et al. (2025).

92/43/EEC Habitats Directive: no

SEDGE-BED MARSH VEGETATION

(*Phragmito-Magnocaricetea elatae*; *Magnocaricetalia*; *Magnocaricion*)

***Caricetum hispidae* Brullo et Ronsisvalle 1975** (Suppl. material 1: table S16, relevés 1–9, Fig. 8)

Floristic characterization: a large and dense community dominated by the sedge *Carex hispida*, which grows at the edge of the river. Other species are *Althaea officinalis*, *Eupatorium cannabinum*, *Cirsium creticum* subsp. *triumfettii* and *Equisetum telmateia*.

Ecology: sedge-bed marsh vegetation in mesotrophic to dystrophic habitats. This community is found along the Sordo River in flat areas (i.e. “Le Piane” depression) where organic, periodically flooded, hydromorphic soils occur. Further away from the riverbanks and onto the first river terrace, the *Caricetum hispidae* fades into *Molinio-Arrhenatheretea* meadows.

Syntaxonomy: the *Caricetum hispidae* association was first described by Brullo and Ronsisvalle (1975) in western Sicily. Venanzoni et al. (2018) also recognized this association in their revision of the *Phragmito-Magnocaricetea* whereas Landucci et al. (2020) considered the *Caricetum hispidae* as a synonym p.p. of the *Cladio marisci-Caricetum hispidae* O. Bolòs 1967 (*Bolboschoenion*). In our opinion, the two associations (*Cladio-Caricetum hispidae* and *Caricetum hispidae*) have different ecological ranges, as the *Cladio-Caricetum* is a community that develops in sub-saline environments, whereas the *Caricetum hispidae* was described in a freshwater context. In our study we referred to *Caricetum hispidae* with some relevés (6–9 in Suppl. material 1: table S16) giving rise to a hygro-nitrophilous variant characterized by the presence of *Eupatorium cannabinum*, *Equisetum telmateia*, and *Urtica dioica*.

92/43/EEC Habitats Directive: no

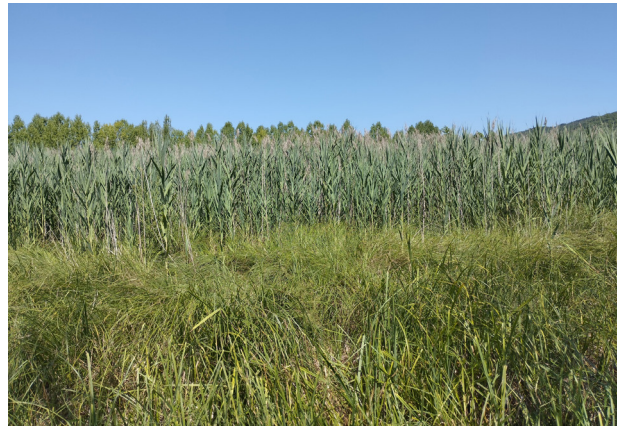


Figure 8. *Caricetum hispidae* in the foreground and *Phragmitetum australis* in the background, along the Sordo River (photo P. Fortini, June 2024).

HYDROPHYTIC VEGETATION

(*Potamogetonetea*; *Potamogetonetalia*; *Potamogetonion*, *Batrachion fluitantis*, *Ranunculion aquatilis*)

***Veronico-Callitrichetum stagnalis* (Kaiser 1926) Müller 1962** (Suppl. material 1: table S17, relevés 1–2)

Floristic characterization: dense paucispecific community dominated by *Callitriche stagnalis*, with *Veronica anagallis-aquatica* subsp. *anagallis-aquatica*, *Sparganium neglectum* and *Helosciadium nodiflorum* subsp. *nodiflorum* occurring less frequently.

Ecology: a hydrophytic community located in the lentic waters of the Sordo River.

Syntaxonomy: Passarge (1992) recognized the *Veronico-Callitrichetum stagnalis* (Kaiser 1926) Müller 1962 in a flowing water environment and included it in the *Lemno-Callitrichion* Passarge 1992. This alliance includes the communities dominated by *Callitriche* sp. pl. and *Lemna* sp. pl., as well as the communities dominated by *Callitriche* and *Veronica* sp. pl. According to Mucina et al. (2016) *Lemno-Callitrichion* was invalidly described and is therefore reported under the new name *Ranunculion aquatilis* Passarge ex Theurillat in Theurillat et al. 2015, which is a typical alliance of stagnant freshwaters. This classification is consistent with that proposed in the Prodrome of the Italian vegetation although in that case the reference is to *Ranunculion aquatilis* Passarge 1964, a name considered invalid in Theurillat et al. (2015).

92/43/EEC Habitats Directive: 3260 – Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation.

***Zannichellietum peltatae* ass. nov.** (Table 1; relevés 1–6 reported also in Suppl. material 1: table S18; Fig. 9).

Floristic characterization: dense, monospecific community of *Zannichellia peltata*.

Ecology: hydrophytic community found along Biferno River in flowing waters.

Syntaxonomy: the *Zannichellietum peltatae* ass. nov. is described hoc loco. Holotypus: rel. 6 Table 1. Date: 10/07/2024, Geographic location: stretch of river along the SS 647 road (Lucito municipality, Campobasso Province), Coordinates (WGS84) 41.722694°N, 14.724556°E. Characteristic species: *Zannichellia peltata* Bertol. Alliance: *Batrachion fluitantis* Neuhausl 1959.

Table 1. *Zannichellietum peltatae* ass. nov. The asterisk indicates a diagnostic species, and ^T indicates the type relevé.

Relevé number	1	2	3	4	5	6 ^T
Plot size (mq)	4	2	1	1	4	4
Total vegetation cover (%)	50	50	90	80	80	90
<i>Zannichellietum peltatae</i> ass. nov.						
<i>Zannichellia peltata</i> *	3	3	5	5	5	5
<i>Batrachion fluitantis</i> , <i>Potamogetonetalia</i> , <i>Potamogetonetea</i>						
<i>Potamogeton crispus</i>	.	.	.	.	.	+
<i>Molinio-Arrhenatheretea</i>						
<i>Paspalum distichum</i>	+	.	.	.	.	.
<i>Phragmito-Magnocaricetea</i>						
<i>Veronica beccabunga</i> subsp. <i>beccabunga</i>	+	.	.	.	.	.

Prior to this study, only *Z. palustris* of the five species in the *Zannichellia* genus present in Italy had been reported in Molise (Lucchese 1995; Bartolucci et al. 2018; Galasso et al. 2025), and no phytosociological relevés or bibliographic references had ever been published. The new association *Zannichellietum peltatae* differs from *Zannichellietum palustris* in that it is essentially a monophytic community, with only a sporadic presence of other species, such as *Paspalum distichum*, *Potamogeton crispus*, and *Veronica beccabunga*. Furthermore, the *Zannichellietum peltatae* here described was found in fast-flowing shallow water rather than in eutrophic environments with more stable waters, which are typical of the *Zannichellietum palustris*. However, although Lang (1973) described a *Zannichellietum palustris sparganietosum* as being typical of fast-flowing shallow waters too (see Van Vierssen 1982), the fast-flowing water environment in which our relevés were performed suggests that they should be referred to *Batrachion fluitantis* instead.

92/43/EEC Habitats Directive: 3260 – Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation.

Groenlandietum densae Segal ex Schipper et al. in Schaminée et al. 1995 (Suppl. material 1: table S19, relevé 1)

Floristic characterization: dense community composed of *Groenlandia densa*, *Potamogeton crispus* and *Nasturtium officinale*.

Ecology: heliophilous or hemi-sciaphilous hydrophytic community located along Sordo River dominated by *Groenlandia densa*. This community is typical of slow-flowing waters with clean, clear and nutrient-rich waters with a constant temperature.



Figure 9. *Zannichellietum peltatae* patches in the middle of the Biferno riverbed, in a relatively shallow and fast-flowing water environment (photo D. Viciani, June 2024).

Syntaxonomy: the reference in terms of association is the *Groenlandietum densae* which is reported for Central and Southern Europe (Schaminée et al. 1995; Šumberová 2011). There is scarce information on this association in southern Italy, so its occurrence is restricted to a few areas, especially in Sicily (Brullo et al. 1994; Caldarella et al. 2021) where the *Groenlandietum densae* is classified in the alliance *Potamogetonion* and the order *Potamogetonetalia*.

92/43/EEC Habitats Directive: 3260 – Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation.

Potamogetonetum crispum von Soó 1927 (Suppl. material 1: table S19, relevés 2–3)

Floristic characterization: dense community of *Potamogeton crispus*, *Sparganium neglectum*, *Helosciadium nodiflorum* subsp. *nodiflorum*, *Veronica anagallis-aquatica* subsp. *anagallis-aquatica* (r. numb. species: 5).

Ecology: in the study area this association occurs in form of a hydrophytic community characterizing lotic and freshwater environments.

Syntaxonomy: the association *Potamogetonetum crispum* is widely distributed and is generally found in both lentic and lotic waters, under eutrophic, hypertrophic or polluted conditions (Šumberová 2011). It is included in the alliance *Potamogetonion*.

92/43/EEC Habitats Directive: 3260 – Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation.

Stuckenietum pectinatae Carstensen ex Hilbig 1971 nom. mut. nov. (Suppl. material 1: table S19, relevés 4–6)

Floristic characterization: dense monospecific stand of *Stuckenia pectinata*.

Ecology: in the study area this hydrophytic community was exclusively found at the mouth of the Biferno River in low-flowing water.

Syntaxonomy: The *Potamogetonum pectinati* was described invalidly for Germany rivers (Carstensen 1955) and subsequently validated in Hilbig (1971). This is a common association in central Europe (Schubert et al. 1995; Matuszkiewicz 2005; Šumberová 2011), as well as in peninsular Italy and major islands (Biondi and Bagella 2005; Sburlino et al. 2008; Caldarella et al. 2021). While the classification of *Potamogetonum pectinati* within the higher syntaxonomic ranks is beyond doubt, the nomenclature could be reviewed. In fact, the name *Potamogeton pectinatus* L. serves as the basionym for the name *Stuckenia pectinata* (L.) Börner (see Kaplan 2008). The latter is currently considered the valid and accepted name for this taxon in the main international and national floras and checklists (see Tropicos 2025; IPNI 2026). In particular, the name *Potamogeton pectinatus* L. is no longer accepted in at least two floras covering its geographical distribution (see Bartolucci et al. 2018). Accordingly, we propose hoc loco the name *Stuckenietum pectinatae* Carstensen ex Hilbig 1971 as *nomen mutatum novum* (Art. 45).

92/43/EEC Habitats Directive: 3260 – Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitriche-Batrachion* vegetation.

***Potamogetonum denso-nodosi* O. de Bolòs 1957** (Suppl. material 1: table S19, relevés 7–10, Fig. 10)

Floristic characterization: dense stands of *Potamogeton nodosus*, occasionally accompanied by *Zannichellia peltata*.

Ecology: this hydrophytic community was found along the Biferno River near its mouth in Campomarino.

Syntaxonomy: in this paper we refer to the association *Potamogetonum denso-nodosi*, although, in its typical form, this association should be characterized by the co-dominance of *Myriophyllum spicatum*. Some authors classify the *Potamogeton nodosus* communities in the *Batrachion fluitantis* (sub *Ranunculion fluitantis*) (e.g. Hrivnák 2002) due to the rheophilic characteristics exhibited by the guide species. Our sampling in a river environment with relatively mobile waters, as opposed to stagnant or weakly flowing waters, has likely resulted in the floristic impoverishment of the association, which is often in contact with *Zannichellietum peltatae*, as evidenced by the presence of *Zannichellia peltata* as the primary companion species.

92/43/EEC Habitats Directive: 3260 – Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitriche-Batrachion* vegetation.

PLEUSTONIC VEGETATION

(*Lemnetea minoris*; *Lemnetalia minoris*; *Lemnion minoris*)

***Lemnetum minoris* von Soó 1927** (Suppl. material 1: table S20, relevés 1–2)

Floristic characterization: a dense community of aquatic macrophytes floating on the water's surface, mainly consisting of *Lemna minor*, with *Nasturtium officinale* and *Sparganium neglectum* also present.



Figure 10. *Potamogetonum denso-nodosi* in the Biferno River (photo D. Viciani, June 2024).

Ecology: found along the Sordo River in areas of still or slow-moving water protected by the other hydrophytic or helophytic vegetation.

92/43/EEC Habitats Directive: no

Discussion

As well as being an essential resource for the development of agricultural, tourism, and industrial activities, the Molise region's water system also represents a primary ecological corridor characterized by high biodiversity at taxonomic, ecological, and landscape scales. Currently, the available vegetation database for the study area contains very few phytosociological references, which are almost exclusively related to vegetation types other than riverbed vegetation (Blasi and Paura 1995; Taffetani and Biondi 1989; Stanisci and Conti 1990; Blasi et al. 2005). Accordingly, the most significant result of this study was the identification and georeferencing of several hydrophilous and hygrophilous communities in areas that were currently lacking information.

Alongside new regional records of communities that are rare on the Italian peninsula (e.g. *Groenlandietum densae*), we provided the first regional phytosociological data for communities that are widely distributed in the context of European macrophytic vegetation (e.g. *Lemnetum minoris*, *Stuckenietum pectinati*, and *Helosciadietum nodiflori*, etc.). Due to the high specialization of the taxa which are normally found in hydrophilous and hygrophilous communities, the vegetation mosaic tends to be very similar across different geographic areas. However, some

peculiarities also emerged in the study area that required the description of new communities or that laid the foundation for a future syntaxonomic revision for several types of vegetation.

Regarding the class *Potamogetonetea*, this paper introduces a new association, *Zannichellietum peltatae* ass. nov. The species of the genus *Zannichellia* exhibit only partially overlapping ecological niches and often do not co-occur in macrophytic communities. Giving the overwhelming presence of *Zannichellia peltata* in our relevés and the absence of other related species, the proposal of a new association appeared to us to be the only viable option. A secondary option that was considered was to refer to *Zannichellietum palustris* s.l. communities such as *Parvo-Potamo-Zannichellietum pedicellatae* De Soó 1947 (= *Zannichellietum palustris* Nordhagen 1954, *Zannichellietum palustris* Lang 1967). However, in the absence of the association's guide species (*Z. palustris*), this would have been a methodologically incorrect choice. In addition, the two communities have a rather different ecology because the *Zannichellia palustris* communities are more widespread in eutrophic to hypertrophic ponds and pools and tolerate strong water fluctuations (Hrivnák 2002; Šumberová 2011), whereas *Z. peltata* shows a marked preference for clear, fast-flowing waters. The *Zannichellietum peltatae* may be present in other areas of central Italy where the species has recently been recorded (see Di Pietro et al. 2022), but specific phytosociological studies have not yet been conducted in these regions. As emphasized in the results, the most significant uncertainty relates to the selection of the reference alliance for the *Zannichellietum peltatae*. The choice is between *Potamogetonion* Libbert 1931 and *Batrachion fluitantis* Neuhausl 1959, since these two alliances have a partially different ecological diagnosis. According to Mucina et al. (2016) the *Potamogetonion* is defined as a broad alliance comprising rooted and floating macrophytes that inhabit nutrient-rich waters, whereas the *Batrachion fluitantis* is characteristic of nutrient-poor shallow waters. The sampled areas where the association was found (the shallow flowing waters of the middle course of the Biferno), suggest that the *Zannichellietum peltatae* should be assigned to the *Batrachion fluitantis*. This highlights a significant difference in the interpretation of this community between the EuroVegChecklist and the Prodrome of the Italian vegetation, despite both referring to the same syntaxonomic class (i.e. *Potamogetonetea*). In Mucina et al. (2016) the *Batrachion fluitantis* is included in the order *Callitricho hamulatae-Ranunculetales aquatilis* Passarge ex Theurillat in Theurillat et al. 2015. However, Biondi et al. (2014) argue that this alliance, along with the *Potamogetonion* Lippert 1931 (sub *Potamion pectinati* (W. Koch 1926) Libbert 1931) should be classified within the *Potamogetonetalia* order (sub *Potametalia pectinati* Koch 1926). The *Callitricho hamulatae-Ranunculetales aquatilis* order was proposed following the publication of the Prodrome of the Italian vegetation. Consequently, it could not be taken into consideration by the latter. However, the

order's original definition "vegetation of rooted macrophytes in shallow moving freshwaters of Europe", suggests that classifying the *Zannichellietum peltatae* within the *Callitricho hamulatae-Ranunculetales aquatilis* is ecologically appropriate.

In addition to the case just mentioned, our study also highlights other syntaxonomical mismatches between the Prodrome of the Italian Vegetation and the EuroVegChecklist (e.g. *Molinio-Arrhenatheretea* vs. *Bidentetea* for the classification of the *Polygono-Paspalietum*, or vs. *Agrostietea stoloniferae* for the *Cirsio-Eupatorietum*; *Epilobietea angustifolii* vs. *Filipendulo-Convolvuletea* vs. *Galio-Urticetea* for the *Phalarido-Petasitetum* and *Convolvulo-Epilobietum*; *Apion nodiflorii* vs. *Glycerio-Sparganion* for the *Nasturtietum officinalis*). These differences in syntaxonomic classification are normally due to a different interpretation of the original ecological and biogeographic diagnosis of the syntaxa in issue. However, in other cases, the mismatch is due to syntaxa nomenclature not being updated, either because the Code of phytosociological nomenclature was not applied correctly in the past, or because it was not applied at all (see the case of *Potamogetonetea* vs. *Potametea*). The recent publication of the new code (Theurillat et al. 2021), which introduces significant changes (particularly about the retroactivity of certain articles) necessitates an update to the syntaxonomic frameworks at both the European and Italian levels. As has been emphasized repeatedly, it is impossible to consider the syntaxonomic aspects of a community, or groups of communities, in isolation from the nomenclatural ones. Accordingly, the correct application of the names is pivotal in fostering stability within the syntaxonomic framework of the European vegetation (Terzi et al. 2021) and facilitates a more precise and fruitful exchange of information among researchers from diverse disciplines.

During this study, several issues relating to divergent classification were identified in other syntaxonomic classes. One such issue is the *Polypogono viridis-Paspalietum distichi*, nomen inversum. Our decision to classify the *Polypogono-Paspalietum* in the class *Molinio-Arrhenatheretea* rather than in the *Bidentetea tripartitae* is based on a physiognomic criterion. This criterion states that a perennial humid meadow cannot be classified in a class which is primarily characterized by therophytic communities.

The most complex situation that emerges at the syntaxonomic class level probably concerns the classification of tall-herb semi-natural perennial communities on nutrient-rich riparian fringes. In this instance, the two communities in question are the *Phalarido-Petasitetum* and the *Convolvulo-Epilobietum hirsuti*. The decision to designate the class *Epilobietea angustifolii* for communities that develop at relatively low altitudes alongside river stretches bordering a town, which are therefore subject to human disturbance may be met with concerns. However, in our opinion, the floristic composition of the sampled communities did not demonstrate sufficient nitrophily to justify the classification in the class *Galio-Urticetea*. Furthermore, *Galio-Urticetea* is currently synonymized

with *Epilobietea angustifolii* itself in the EuroVegChecklist. It has been suggested that a more suitable choice would have been the class *Filipendulo ulmariae-Convulvuletea sepium*, supported by the assertion that this class is described in the Prodrome of the Italian vegetation as having a broad ecological and bioclimatic spectrum (i.e. vegetation of primary or secondary megaforbs perennials, of environments from very humid to periodically flooded, on eutrophic to mesotrophic mineral soils, from plain to mountainous areas, both in the Mediterranean and temperate macrobioclimate). However, according to Mucina et al. (2016) the class *Filipendulo ulmariae-Convulvuletea sepium* was described invalidly by Géhu and Géhu-Franck (1987) and has not yet been validated. This is probably due to the controversial ecological and syntaxonomic position of the order *Convulvuletalia sepium* Tx. ex Moor 1958 (see also Theurillat et al. 1995; Dengler et al. 2007; de Foucault 2011), which is disputed between the classes *Galio-Urticetea* (of which it represents the nomenclatural type), the *Filipendulo-Convulvuletea*, and the *Epilobietea angustifolii*. In confirmation of this syntaxonomic plurality of the order *Convulvuletalia sepium*, as syntaxonomic box capable of accommodating diverse vegetation types, it is worth noting that it also extends towards some types of wet meadows of *Molinio-Arrhenatheretea*. This is exemplified by the *Cirsio triumfetti-Eupatorietum cannabini*, an association which could be classified either in the *Filipendulo-Convulvuletea* or the *Molinio-Arrhenatheretea* depending on the size and shape of its stands, the extent of its linear development along the edge of watercourses, and the degree of human disturbance to which it is subjected.

Regarding the association originally designated as *Polygono-Xanthietum italicum*, a detailed examination has been conducted from both nomenclatural and coenological perspectives. In terms of nomenclature, the new name *Persicario lapathifoliae-Xanthietum orientalis* nomen mutatum novum has been proposed here. From a coenological perspective the present study has analysed the extent to which the dominance of *Xanthium orientale* could influence the ecological amplitude of the *Persicario-Xanthietum*. This analysis assumes that this association is highly heterogeneous from a floristic perspective and that its floristic composition is strictly dependent on the frequency and intensity of “unpredictable” events, such as flood waves. In the original table by Pirola and Rossetti (1974), the dominant species for specific cover index is *Persicaria lapathifolia*, followed by *Xanthium italicum* (recte *Xanthium orientale*). During our sampling on the sandy-pebbly shores, we observed two distinct situations regarding the prevalence of *Xanthium orientale*. On the one hand, one relevé was characterized by the very high dominance of *Xanthium*, while on the other hand, four relevés were marked by the sporadic presence of *Xanthium*. Accordingly, it was decided to include only the relevé in which *Xanthium orientale* was effectively dominant in the *Polygono-Xanthietum*, while the other four were assigned to a different community (*Polypogon monspeliensis* and *Persicaria lapathifolia* community).

Finally, this study raises some points for discussion regarding the long-standing problem of how ecologically different a community must be from another to be classified as an autonomous association, and the extent to which the growth form of the community’s dominant species (even in the context of the hemicryptophytic life form) can play a diagnostic role at the alliance or order level. The first case concerns the *Caricetum hispidae*, which according to this paper possesses a separate ecological significance from the *Cladio marisci-Caricetum hispidae*. Nevertheless, it has been considered a syntaxonomic synonym of the latter in recent large-scale revisions (Landucci et al. 2020). The second case concerns the *Nasturtietum officinalis*, which we propose should be classified within an alliance including communities dominated by prostrate species, such as *Apion nodiflori*, rather than within an alliance dominated by erect helophytes, such as *Glycerio-Sparganion*. In addition to the physiognomic-structural criterion, there is also a partial different ecology between *Glycerio-Sparganion* and *Apion nodiflori*, highlighted in the prodrome of the French vegetation (Bardat et al. 2004; Ferrez et al. 2011) which, like the Italian Prodrome, keeps these two alliances separate. These points for discussion may be taken more consistently into consideration in subsequent, larger-scale contributions based on a more extensive dataset of relevés.

In terms of Habitat identification and conservation implications, several plant communities identified within the study area are currently classified as habitats of conservation interest (Evans 2006, 2010; Biondi et al. 2009, 2012; Angiolini et al. 2017; Gigante et al. 2018). However, attributing vegetation types to specific habitats included in the Annex I of the Manual of Interpretation of the Habitats Directive 92/43/EEC is not always straightforward. In some cases, the link between recorded vegetation and habitat is clearly established; for example, riparian communities of poplar and willow, which are undoubtedly attributable to code 92A0. In other cases, a reasoned and broad interpretation is needed. For instance, communities that are ecologically similar to those included in the habitat 6430 should be included in that habitat even if the syntaxa they belong to are not expressly mentioned in the reference documents. This is the case of the *Cirsio triumfetti-Eupatorietum cannabini*, *Phalarido-Petasitetum hybridi* and *Convolvulo-Epilobietum hirsuti*, three communities that occur alongside watercourses, on moist, cool soils. From an ecological and topological perspective, they should be assigned to habitat code 6430. However, this is not so clear when we analyse these cases from a syntaxonomic perspective. In fact, since its description, the *Cirsio triumfetti-Eupatorietum cannabini* has been placed in syntaxa gravitating towards the class *Molinio-Arrhenatheretea* which do not closely correspond to the reference syntaxa for habitats included in the 92/43/EEC directive. Nevertheless, we believe that attributing a community to a conservation-interest habitat should be more properly linked to the ecosystem context covered by the community than to its syntaxonomic classification, which can vary over time and depending (especially at the order or

class level) on subjective interpretation. Accordingly, given its ecological characteristics, the *Cirsio triumfetti-Eupatorium cannabini* community should be attributed to habitat 6430, as should also be the *Phalarido-Petasitetum hybridi* and *Convolvulo-Epilobietum hirsuti*.

Another open question is how to attribute hydrophytic communities to one habitat or another when they significantly overlap from an ecological and floristic point of view. For example, the correct distinction between codes 3150 (Natural eutrophic lakes with *Potamogetonion* or *Stratition*) and 3260 (Watercourses of plain to montane levels with the *Ranunculion aquatilis* and *Batrachion fluitantis* vegetation), which share a great number of diagnostic and representative species (see Biondi et al. 2014; Biondi and Blasi 2025). Within the study area itself, hydrophytic communities were identified whose dominant species suggest their inclusion in habitat code 3150 (*Groenlandietum densae*, *Potamogetonietum crispum*, *Potamogetonietum densonodosi*, *Stuckenietum pectinatae* and *Lemnetum minoris*; see Biondi et al. 2009). However, from an ecological perspective, the river environment in which these communities grow clearly indicates their classification within the habitat code 3260. This is because, when distinguishing between habitats 3150 and 3260, the ecological criterion should take precedence over the floristic one (Rivieccio et al. 2021; Viciani et al. 2022). The second question, as highlighted by Biondi and Blasi (2025), concerns the interaction between strictly hydrophytic communities and some helophytic communities which sometimes occupy ecological spaces normally characterized by true aquatic species and communities. A typical case study involves communities dominated by small helophytes, such as *Helosciadium nodiflorum* and *Nasturtium officinale*, which are found in moderately flowing and shallow waters. These communities are in close spatial contact with, and share the habitat of, more typical hydrophytic communities, such as the *Veronico-Calthitrichetum*. Both *Helosciadium nodiflorum* and *Nasturtium officinale* are indeed species that can live in a submerged state as true hydrophytes (see Sburlino et al. 2008) and are consequently well adapted to occur in floating stream banks (Haslam 1978). In accordance with Biondi and Blasi (2025), our classification of the *Helosciadium nodiflorum* and *Nasturtium officinale* in the *Apion nodiflorum* alliance aims to highlight the fact that these species give rise to communities that occupy the inner areas of rivers and streams with shallow water conditions, as well as the periodically flooded riverbanks. From this perspective, our reference to Habitat code 3260 for the *Helosciadium nodiflorum* and *Nasturtium officinale* communities seems appropriate.

A slightly different case is that involving the *Lemnetum minoris*. As mentioned in previous paragraphs, we detected this community as being protected by the other hydrophytic or helophytic vegetation in the form of a complex coenological mosaic which characterizes slow-moving waters. Lemnids are not usually indicative of running water environments. In our case, the presence of the *Lemnetum minoris* is in fact linked to a “refuge” environment where other hydrophytic and helophytic communities that have already been attributed to habitat 3260 occur, providing a

protected environment for *Lemna minor*. Therefore, while the partially unexpected presence of *Lemnetum minoris* fragments is interesting and increases the site's ecosystem diversity, they cannot individually indicate the presence of habitat code 3260 (which is still present thanks to the surrounding communities), or code 3150 (normally associated with other types of humid areas).

Botanists often emphasize the difficulty of identifying habitats of conservation interest that are physiognomically dominated or co-dominated by invasive alien plants, such as *Paspalum distichum* or *Xanthium orientale* (codes 3270 and 3280). This is probably still an unresolved issue and obviously we are all aware of the risks of the introduction or proliferation of alien species. However, it is important to remember that vegetation physiognomy sometimes serves the unique purpose of delineating a territory that may contain other features, such as a specific micro- and macrofauna or ecological functions, which the European legislator has deemed worthy of protection (see also Bolpagni 2013).

Finally, it should be noted that, although some communities do not constitute habitats of interest under Directive 92/43/EEC, they are nevertheless of great importance in the Southern European-Mediterranean biogeographic context, as they are rare and characteristic of environments that are subject to numerous pressures and threats (Lastrucci et al. 2014; Angiolini et al. 2017; Gigante et al. 2018). This applies to some communities of rushes (*Juncus fontanesii*) and *Schenoplectus* spp. and *Phragmites* reed beds, as well as communities of the *Glycerio-Sparganion* alliance, all of which are present here. According to regional biodiversity legislation, these communities are considered of regional interest in certain Italian regions, such as Tuscany. This is particularly true for communities of large sedges (e.g. those included in the alliances *Caricion gracilis* and *Magnocaricion*), one of which, the *Caricetum hispidae* association, was detected here. These communities are of such high conservation interest in the Italian peninsula that a Proposal to improve Annex I of Directive 92/43/EEC has also been formulated (Casavecchia et al. 2021).

Syntaxonomic scheme

SALICETEA PURPUREAE Moor 1958

SALICETALIA PURPUREAE Moor 1958

Salicion albae Soò 1951

Rubo ulmifolii-Salicetum albae Allegrezza, Biondi et Felici 2006

ALNO GLUTINOSAE-POPULETEA ALBAE

P. Fukarek et Fabijanić 1968

POPULETALIA ALBAE Br.-Bl. ex Tchou 1948

Carici remotae-Fraxinion oxycarpae Pedrotti ex

Pedrotti, Biondi, Allegrezza et Casavecchia in Biondi, Allegrezza, Casavecchia, Galdenzi, Gasparri, Pesaresi, Vagge ex Blasi 2014

Dioscoreo communis-Populetum nigrae Poldini et Vidali in Poldini, Sburlino et Vidali 2017

MOLINIO-ARRHENATHERETEA Tx. 1937
POTENTILLO-POLYGONETALIA AVICULARIS Tx. 1947
Potentillion anserinae Tx. 1947
Cirsio triumfetti-Eupatorietum cannabini Brullo et Spampinato 1990
Juncus fontanesii community
HOLOSCHOENETALIA VULGARIS Br.-Bl. ex Tchou 1948
Polypogono viridis-Paspalion distichi Br.-Bl. in Br.-Bl., Roussine et Nègre 1952 nom. invers. et mut. Lastrucci et Viciani 2025
Polypogono viridis-Paspaletum distichi Br.-Bl. in Br.-Bl., Gajewski, Wraber et Walas 1936 nom. invers. et mut. Lastrucci et Viciani 2025

BIDENTETEA TRIPARTITAE Tüxen, Lohmeyer et Preising ex Von Rochow 1951
BIDENTETALIA TRIPARTITAE Br.-Bl. et Tuxen ex Klika in Klika et Hadac 1944
Chenopodium rubri (Tx. in Poli et J. Tx. 1960) Hilbig et Jage 1972
Persicario lapathifoliae-Xanthietum orientalis Pirola et Rossetti 1974 nom. mut. nov.
 [= *Polygono lapathifolii-Xanthietum italicum* Pirola et Rossetti 1974]
Polypogon monspeliensis and *Persicaria lapathifolia* community

EPILOBIETEA ANGUSTIFOLII Tx. et Preising ex von Rochow 1951
CONVOLVULETALIA SEPIUM Tx. ex Moor 1958
Senecionion fluviatilis Tx. ex Moor 1958
Phalarido-Petasitetum hybridum Schwick. 1933
Convolvulo-Epilobietum hirsutum Hilbig, Heinrich et Niemann 1972

PHRAGMITO AUSTRALIS-MAGNOCARICETEA ELATAE Klika in Klika et Novák 1941
BOLBOSCHOENETALIA MARITIMI Hejný in Holub et al. 1967
Scirpion maritimi Dahl et Hadač 1941
Bolboschoeno maritimi-Schoenoplectetum tabernae-montani Bueno Sánchez et Prieto in Bueno Sánchez 1997 nom. mut. nov.
 [= *Bolboschoeno compacti-Scirpetum tabernaemontani* Bueno Sánchez et Prieto in Bueno Sánchez 1997]

NASTURTIO OFFICINALIS-GLYCERIETALIA FLUITANTIS Pignatti 1953
Glycerio-Sparganion Br.-Bl. et Sissingh in Boer 1942
Glycerio-Sparganietum neglectum Koch 1926
Apion nodiflori Segal in Westhoff et Den Held 1969
Nasturtietum officinalis Gilli 1971
Helosciadietum nodiflori Maire 1924
PHRAGMITETALIA COMMUNIS W. Koch 1926
Phragmition communis W. Koch 1926
Typhetum latifoliae Nowiński 1930
Phragmitetum australis Savič 1926 nom. corr.
MAGNOCARICETALIA Pignatti 1953
Magnocaricion W. Koch 1926
Caricetum hispidae Brullo et Ronsisvalle 1975

POTAMOGETONETEA Klika in Klika et Novák 1941
Potamogetonalia Koch 1926
Potamogetonion Libbert 1931
Groenlandietum densae Segal ex Schipper et al. in Schaminée et al. 1995
Potamogetontum crispum von Soó 1927
Potamogetonietum denso-nodosum O. de Bolòs 1957
Stuckenietum pectinatae Carstensen ex Hilbig 1971 nom. mut. nov.
 [= *Potamogetetum pectinati* Carstensen ex Hilbig 1971]
Ranunculion aquatilis Passarge ex Theurillat in Theurillat et al. 2015
Veronico-Callitrichetum stagnalis (Kaiser 1926) Müller 1962
Batrachion fluitantis Neuhausl 1959
Zannichellietum peltatae ass. nov.

LEMNETEA MINORIS O. de Bolòs et Masclans 1955
LEMNETALIA MINORIS O. de Bolòs et Masclans 1955
Lemnion minoris O. de Bolòs et Masclans 1955
Lemnetum minoris von Soó 1927

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI.

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Author contributions

Conceptualization: PF, LL, DV; Formal analysis and investigation: LL, DV, PF, RDP, PDM, IM, Statistical analysis and graphics: PF, PDM, IM; writing—original draught preparation: RDP, PF; writing—review and editing: RDP, PF, LL, DV; PDM. All authors have read and agreed to the published version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Phytosociological tables of the riverine vegetation of the Biferno and Sordo rivers in the Molise region; complete list of the syntaxa quoted in the text and phytosociological tables; geographical coordinates (WGS84) and date of the phytosociological relevés

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Data type: docx

Explanation note: This supplementary file is divided into three different sections. In the first section the phytosociological tables of the riverine vegetation of the Biferno and Sordo rivers (Molise Region, Italy) are reported, in order: table S1 = *Rubus ulmifolii-Salicetum albae*; table S2 = *Dioscoreo communis-Populetum nigrae*; table S3 = *Juncus fontanesii* community; table S4 = *Cirsio triumfetti-Eupatorium cannabini*; table S5 = *Polypogono-Paspaleto distichi* nom. invers. (*Paspalo distichi-Polypogonetum viridis*); table S6 = *Persicario lapathifoliae-Xanthietum orientalis*; table S7 = *Polypogon monspeliensis and Persicaria lapathifolia* community; table S8 = *Phalarido-Petasitetum hybridi*; table S9 = *Convolvulo-Epilobietum hirsuti*; table S10 = *Bolboschoeno compacti-Scirpetum tabernaemontani*; table S11 = *Glycerio-Sparganietum neglecti*; table S12 = *Nasturtietum officinalis*; table S13 = *Helosciaditum nodiflori*; table S14 = *Typhetum latifoliae*; table S15 = *Phragmitetum australis*; table S16 = *Caricetum hispidae*; table S17 = *Veronico-Callitrichetum stagnalis*; table S18 = *Zanichellietum peltatae*; table S19 = *Groenlandietum densae, Potamogetonetum crispum, Potamogetonetum denso-nodosi, Potamogetonetum pectinati*; table S20 = *Lemnetum minoris*. The second section reports a complete list of the syntaxa quoted in the text and phytosociological tables. The third section contains all the information relating to the geographical coordinates (WGS84) and the date of the phytosociological relevés.

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