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THE VASCULAR AND BRYOPHYTE FLORA OF THE NATURE MONUMENT VRELO UNE

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During growing seasons 2018-2019 and in winter 2021, the flora of vascular plants and bryophytes of the Nature Monument Vrelo Une in southern Croatia was studied. The previous floristic data available for this area, covering 9.58 ha, are sparse, and this study recorded 219 taxa of vascular plants from 59 families. The species-richest families are Compositae (10.5%), Fabaceae (8.2%), Poaceae (7.8%), and Lamiaceae (6.4%). Additionally, 64 bryophyte species (14 liverworts and 50 mosses) were recorded. The spectrum of biogeographic elements of vascular plants places the study area in the Euro-Siberian region, at the meeting point of two vegetation sub-zones within the European broadleaf deciduous forests zone – thermophilic, sub-Mediterranean forests of the class *Quercetea pubescentis* and mesic forests of the class *Carpino-Fagetea sylvaticae*. The species of the South-eastern European and Illyrian elements give a local distinctiveness to the flora. The biogeographic elements of bryophytes are less sensitive but reflect the same biogeographical pattern. Since most of the researched area is covered by forests and thickets, the largest number of species of vascular plants are associated with these particular habitats, while rocks and aquatic habitats are the most important for bryophyte diversity. In terms of the IUCN categories, four species are classified as near threatened, three as least concern and three as data deficient. Invasive species have not been recorded.

Key words: southern Croatia, biogeographical elements, habitat types, endangered species, protected species, mosses, liverworts

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Tokom sezona 2018.-2019. i zimi 2021. istraživane su vaskularne biljke i mahovine Spomenika prirode Vrelo Une u južnoj Hrvatskoj. Za ovo područje, koje zauzima 9,58 ha, prethodni floristički podaci su rijetki, a ovim istraživanjem zabilježeno je 219 vrsta vaskularnih biljaka koje pripadaju u 59 porodica. Vrstama najbogatije porodice su Compositae (10,5%), Fabaceae (8,2%), Poaceae (7,8%) i Lamiaceae (6,4%). Nadalje, zabilježene su 64 vrste mahovina (14 jetrenjarki i 50 pravih mahovina). Spektar biogeografskih elemenata vaskularnih biljaka smješta istraživano područje u Eurosibirsku regiju, na susretište dvaju podzona europske zone širokolisnih bjelogoričnih šuma – termofilnih, submediteranskih šuma razreda *Quercetea pubescentis* i mezofitnih šuma razreda *Carpino-Fagetea sylvaticae*. Vrste jugoistočnoeuropskog i ilirskog flornog elementa flori daju lokalni značaj. Biogeografski elementi mahovina manje su geografski osjetljivi, no odražavaju isti biogeografski uzorak. S obzirom da je istraživano područje većinom pokriveno šumama i šikarama, tu se nalazi i najveći broj vrsta vaskularnih biljaka, dok su stijene i vodena staništa najvažnija za raznolikost mahovina. Prema IUCN-ovim kategorijama, četiri vrste su gotovo ugrožene, tri su najmanje zabrinjavajuće i za tri nema dovoljne količine podataka. Invazivne vrste nisu zabilježene.

Ključne riječi: južna Hrvatska, biogeografski elementi, stanišni tipovi, ugrožene vrste, zaštićene vrste, prave mahovine, jetrenjarke

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INTRODUCTION

The Una River is a 212 km long karst river, more than of which half flows either in Croatia (120 km) or along the border with Bosnia and Herzegovina. It springs in the Lika Region, a hundred kilometres away from the town Zadar, in Donja Suvaja, near the settlement Srb. The spring is located at 396 meters above sea level, in a very narrow canyon below the slopes of the mountains Plješevica and Stražbenica. The spring is in the form of a round, calm, blue-green lake with a known depth of 205 meters, expected, however, to be much deeper. The spring of the Una River, along with the 150 m of its canyon, was protected in 1968 as a hydrological natural monument with an area of 9.58 ha (Bioportal, 2023) (Fig. 1).

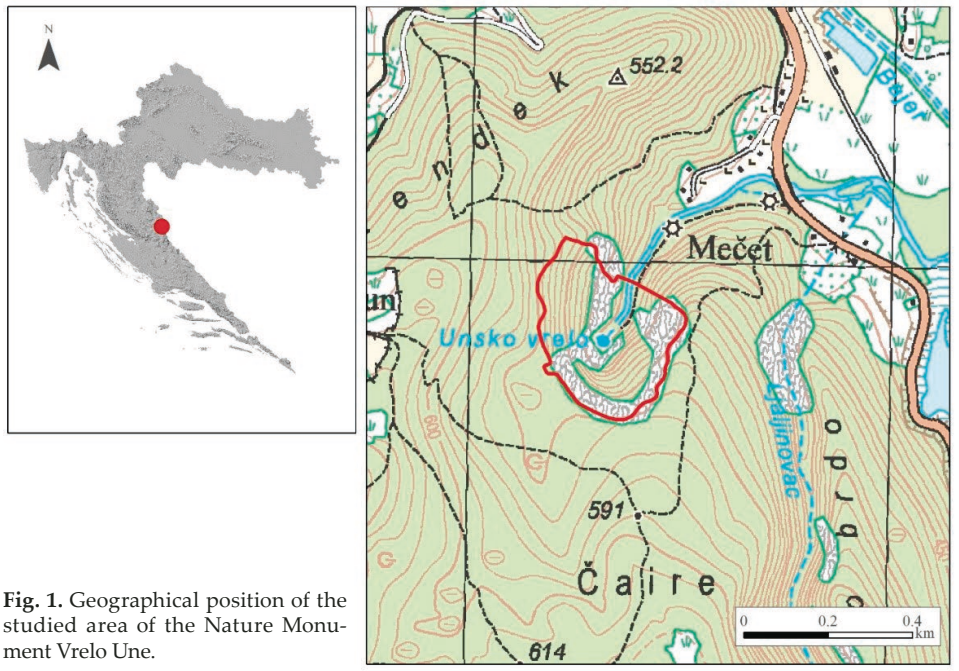

Fig. 1. Geographical position of the studied area of the Nature Monument Vrelo Une.

Vrelo Une (the Una River Spring) is located in the zone of temperate deciduous forests, at the meeting point of sub-Mediterranean and continental vegetation, i.e. thermophilic forests with downy oak (class *Quercetea pubescentis* Doing-Kraft ex Scamoni et Passarge 1959) and mesic forests of oaks and beech trees (class *Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968). However, as Vrelo Une is surrounded by steep and drained limestone rocks, and as it is located at a low altitude, it is completely surrounded by thermophilic thickets and forests, which are dominated by two tree species, the eastern hornbeam (*Carpinus orientalis*) and the hop-hornbeam (*Ostrya carpinifolia*).

So far, no thorough floristic and vegetation research has been carried out in the area of Vrelo Une. However, the first floristic notes did occur very early, dating back to the 19th century. Reichardt (1867) reports on the field trip of the assistant curator Zelebor from the Natural History Museum in Vienna, who visited mountains Plješevica and Kremen, the settlement Martinbrod and Vrelo Une in August and September 1863 and

then in 1865, collecting abundant herbarium material. In this material there were two mosses from Vrelo Une, *Chiloscyphus polyanthos* and *Fontinalis antipyretica*, which can still be found there today. The flora of the surroundings of Vrelo Une was subsequently explored by the famous Croatian botanist Ljudevit Rossi (1913) as part of extensive research into Mt Lička Plješevica. The next botanist to publish data related to Vrelo Une was Ivo Horvat (1932), who listed seven bryophyte species (in recent nomenclature: *Pellia endiviifolia*, *Cinclidotus aquaticus*, *Plagiopus oederianus*, *Alleniella besseri*, *Homalia lusitanica*, *Palustriella commutata* and *Syntrichia ruralis*), of which only the first three were confirmed in the present research. After that, Šugar & Plazibat (1988) published a general overview of the vegetation of the Gornje Pounje region, but without specifying Vrelo Une. At Vrelo Une, Kranjčev recorded the orchid *Cephalanthera damasonium* in 2001, while Dubravko Šincek recorded *Epipactis helleborine* and *Digitalis laevigata* in 2008 (Nikolić, 2005-onwards). The same year, 93 plant species were recorded within the project of the Biology Student Association (BIUS), which focused on the area of the upper course of the Una River.

The objectives of this research were to create a list of vascular and bryophyte flora of Vrelo Une based on field observations and collected herbarium materials, perform a taxonomic and phytogeographic analysis of the flora, as well as the analysis of the proportion of threatened, alien and invasive taxa.

MATERIAL AND METHODS

Field research was performed in 2018-2019 and in 2021, in multiple field visits to record plant species and their distribution. Species that could not be identified in the field, including all bryophyte species, were collected and herbarized for subsequent identification. The standard identification keys and iconographies were used, while the nomenclature and systematics of taxa follow the internet database Euro+Med PlantBase (Euro+Med, 2006-onwards) for vascular plants and Hodgetts *et al*. (2020) for bryophytes.

The system of floristic elements (biogeographic elements) groups species according to the similarity of their distribution ranges. In this paper, the system proposed by Horvatić (1963) and Horvatić *et al.* (1967–68) was used for vascular plants, with some of the categories being revised and updated according to newer studies (Aeschimann *et al*., 2004; Landolt *et al*., 2010; Simon *et al*., 1992; Flora Web, 2023). The floristic element categories used are:

1. plants of the general Mediterranean floristic element
2. plants of the Illyrian (Illyrian-Balcan and Illyrian-Adriatic) floristic element
3. plants of the Southern European floristic element
4. plants of the Atlantic floristic element
5. plants of the Eastern European-Pontian floristic element
6. plants of the South-eastern European floristic element
7. plants of the Central European floristic element
8. plants of the European floristic element
9. plants of the Eurasian floristic element
10. plants with a circumholarctic distribution
11. plants with a wide distribution, cosmopolitan
12. neophytes, cultivated and adventitious plants.

Furthermore, each bryophyte species is assigned the category of biogeographic elements according to Hill *et al*. (2007), where the major biome element (E1) and eastern limit category (E2) are distinguished.

For each species, the habitat type in which it was recorded was noted as well, with the following categories used for vascular plants habitats (Fig. 2):

1. mesophytic *Ostrya carpinifolia* forest around the spring
2. mostly thermophilic *Carpinus orientalis-Ostrya carpinifolia* shrubs and low forest
3. alluvial gallery forest and scrub
4. rocks and rock crevices (shaded and open)
5. aquatic and riparian habitats
6. ruderal habitats.

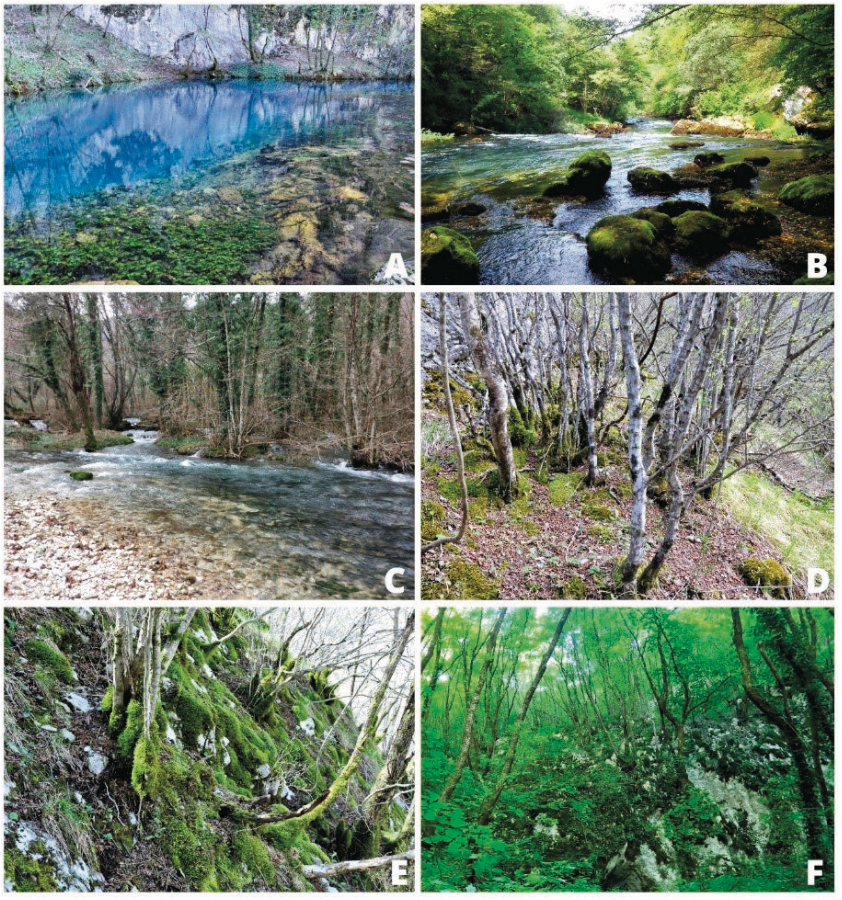

Fig. 2. Main habitat types in the studied area: A – aquatic and riparian habitats, B – emerged rocks in riverbed, C – alluvial gallery forest, D – thermophilic *Carpinus orientalis* shrub, E – steep rocky slope and F – mesophytic *Ostrya carpinifolia* forest.

Since bryophytes occupy ecological niches in a somewhat different way from vascular plants, the following habitat types were used:

1. forests
2. rocks and rock crevices (mostly shaded)
3. tree bark
4. aquatic and riparian habitats.

Data on conservation status were taken from the Red Book of the Vascular Flora of Croatia (Nikolić & Topić, 2005), and updated according to the on-line Red Book (Nikolić, 2023), while data on the legal protection in Croatia were taken from the Ordinance on strictly protected species (Narodne novine, 2013, 2016).

RESULTS

Vascular flora

Within this study 219 vascular plant species from 59 families (Appendix 1) were recorded. Among these were ten fern species (Pteridophyta) and 209 angiosperm species, which included 175 dicotyledons (Magnoliopsida) and 34 monocotyledons (Liliopsida). Gymnosperms were not recorded. In terms of species numbers, the most represented families were Compositae (10.5%, i.e. Asteraceae 5.9% and Cichoriaceae 4.6%), Fabaceae (8.2%), Poaceae (7.8%) and Lamiaceae (6.4%) (Fig. 3).

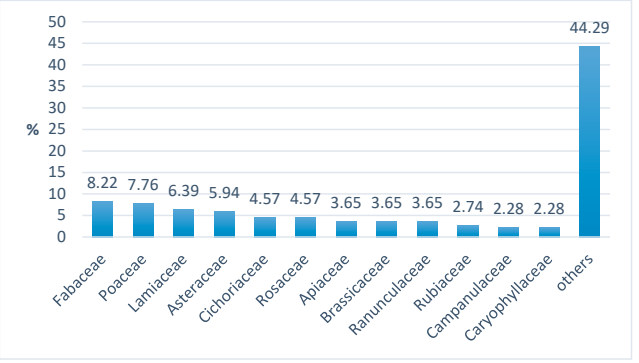

Fig. 3. Percentage shares of vascular plant families represented with more than five species.

The recorded taxa were grouped into the 12 main categories of biogeographic (floristic) elements depending on their distribution ranges (Fig. 4). The highest number of taxa in the study area belonged to the Eurasian element (41.47%), followed by the Southern European (17.51%) element, which included seven species of the Southern-Central European element (*Cyclamen purpurascens*, *Euonymus latifolius*, *Galanthus nivalis*, *Pilosella hoppeana*, *Moehringia muscosa*, *Saxifraga rotundifolia* and *Valeriana tripteris*). These were followed by the Central European (8.76%) and European element (8.29%), while the South-eastern European element amounted to 6.45% of the total flora. The Mediterranean element amounted to 5.53%, and the Illyrian-Balkan to 4.61%. Though these percentages are relatively low, the presence of the two latter categories is quite important for the phytogeographic characterisation of the study area. The absence of adventitious species indicates the naturalness of the flora and stresses the conservation value of the area.

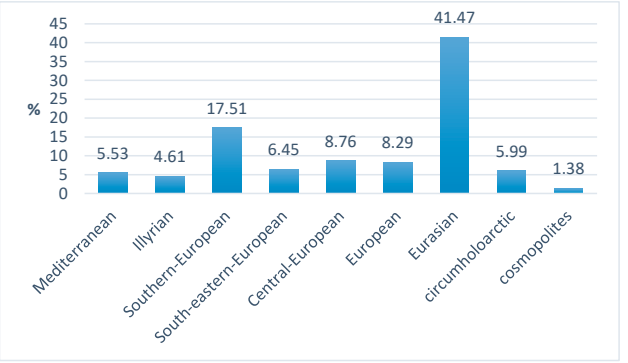

Fig. 4. Spectrum of biogeographic elements for vascular flora.

The species richness was highest in the low forest and shrubs of *Carpinus orientalis* and *Ostrya carpinifolia*, which cover most of the investigated area. Here, up to 43.38% of species were recorded (Fig. 5). This was followed by other forest types – higher and more mesophytic *Ostrya carpinifolia* forest (16.44%) and alluvial gallery forest and scrub (15.98%). Different rocky habitats harboured 9.13% of the species, while ruderal habitats at the entrance to the protected area harboured a high 10.5% of the recorded species. On the other hand, in aquatic and riparian habitats, only 4.57% of species occurred.

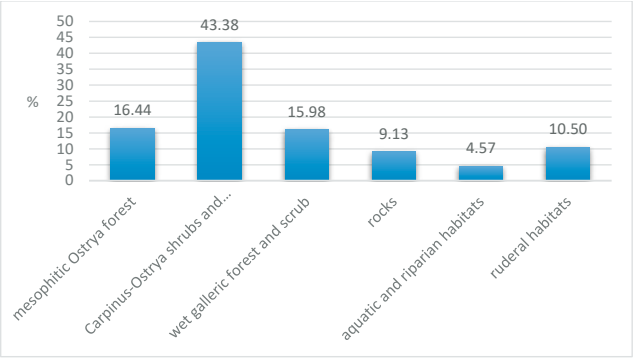

Fig. 5. The proportion of vascular plant species in main habitat types.

Bryophyte flora

In all, 64 bryophyte species were recorded, including 14 liverworts and 50 mosses (Appendix 2). Considering their distribution across the major biomes (Fig. 6), three biogeographic elements stand out: Boreo-temperate (36.51%), Temperate (22.22%) and Southern-temperate (17.46%). All other categories were much less represented, with fewer than 10% of species each.

Similarly, when the eastern limit categories were considered, two biogeographic elements dominated – circumpolar (47.62%) and European (39.68%). Furthermore, suboceanic elements amounted to 7.94%, while the shares of other elements were considerably lower (Fig. 7).

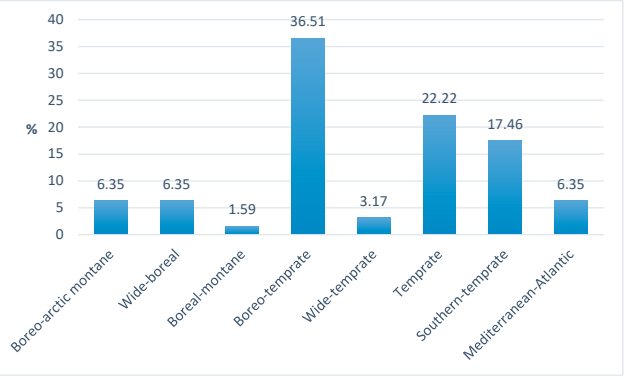

Fig. 6. Spectrum of biogeographic elements for bryophyte flora regarding major biomes.

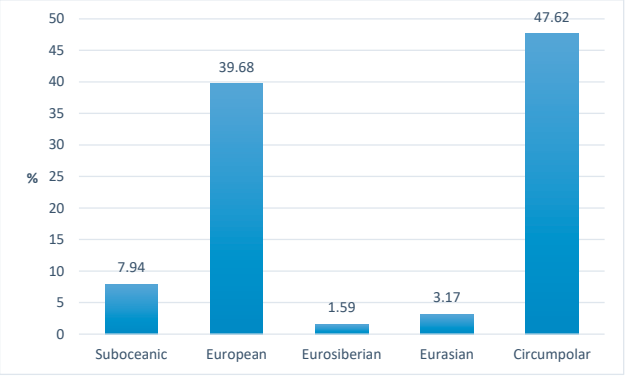

Fig. 7. Spectrum of biogeographic elements for bryophyte flora regarding eastern limit category.

Regarding the main habitat types, the bryophyte species were more evenly distributed (Fig. 8). On mostly shaded rocks and larger stones within the forest, 37.33% of species were found, followed by 28.00% of species recorded in aquatic and riparian habitats and 24.00% on the forest ground. On tree bark, 10.67% of species occurred.

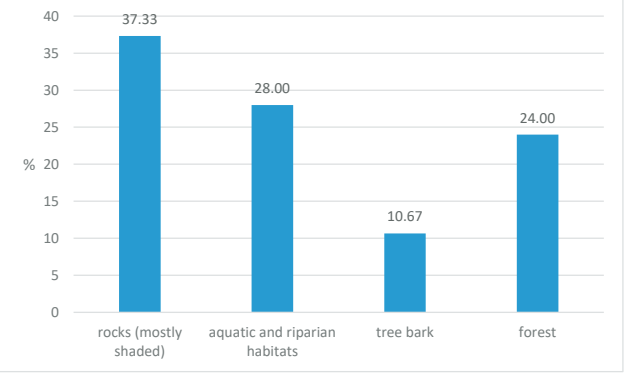

Fig. 8. The proportion of bryophyte species across main habitat types.

Conservation value of the flora

Ten out of 219 (4.6%) vascular plant species were strictly protected: *Achnatherum calamagrostis*, *Achillea virescens*, *Cephalanthera damasonium*, *Cephalanthera longifolia/rubra*, *Epipactis helleborine*, *Neottia nidus-avis*, *Peltaria alliacea*, *Seseli kochii*, *Seseli montanum* subsp. *tommasinii* and *Trifolium dalmaticum*.

It was not possible to identify the exact species of *Cephalanthera* due to the lack of flowers.

Furthermore, 10 (4.6%) species were assigned one of IUCN categories (NT, LC and DD) (Tab. 1), while no truly threatened species were found.

Tab. 1. Species listed in the Red Book of Croatian Vascular Flora (NT – near threatened, LC – least concern and DD – data deficient).

NT	*Asparagus tenuifolius*
	Cephalanthera longifolia/rubra
	Cyclamen europaeum
	Peltaria alliacea
LC	*Galanthus nivalis*
	Melica ciliata
	Saxifraga rotundifolia
DD	*Veronica anagalis-aquatica*
	Achnatherum calamagrostis
	Campanula trachelium

DISCUSSION

This study is the first comprehensive floristic study of the Nature Monument Vrelo Une, especially regarding the bryophytes, which are generally underexplored in the whole Croatian territory (Sabovljević *et al.*, 2011).

The phytogeographic analysis showed that the flora is dominated by plants with a Eurasian distribution, which reflects its affiliation to the Euro-Siberian/North American phytogeographic region at the broadest scale. The high ratio of the Southern European element indicates the existence of thermophilic habitats that enable the survival of plants that are primarily distributed in the sub-Mediterranean zone. If we look at the Central European and European elements together, they have almost the same percentage of species as the Southern European element. This ideally describes the phytogeographical position of the researched area, which is located at the meeting point of two vegetation sub-zones within the European broadleaf deciduous forests zone – thermophilic, sub-Mediterranean forests of the class *Quercetea pubescentis* and mesic forests of the class *Carpino-Fagetea sylvaticae*. Although woody species of sub-Mediterranean forests dominate in the researched area (*Carpinus orientalis*, *Ostrya carpinifolia*, *Quercus cerris*, *Acer obtusatum*), the surrounding mountains belong to the belt of Dinaric beech forests (alliance *Aremonio-Fagion* (Horvat 1950) Borhidi in Török et al. 1989). This "fagetal" influence can not be observed in the tree layer, but it is clearly reflected in the herb layer by species such as *Aremonia agrimonoides*, *Cardamine bulbifera*, *Chaerophyllum temulum*, *Euphorbia dulcis*, *Hordelymus europaeus*, *Inula conyza*, *Lactuca muralis*, *Mercurialis perennis*, *Ranunculus lanuginosus* and others.

The proportion of the Southeastern-European element is quite low but still high enough to indicate the position of the researched area in the eastern context of South Europe. Some of the species belonging to this element are very abundantly represented in the vegetation of the area and significantly contribute to the general vegetation physiognomy or are characteristic species in phytosociological system (e.g. *Carpinus orientalis*, *Coronilla emerus* subsp. *emeroides*, *Viburnum lantana*, *Cotinus coggygria*, *Peltaria alliacea*, *Inula hirta*). The plants of the Mediterranean element are quite rare, despite the relative proximity of the Adriatic Sea. This is a result of complex geomorphology and relief, with mountain ranges preventing intrusion of the Mediterranean climate and consequently of Mediterranean plants.

The narrowest phytogeographic characterization of the area is seen in the plants of the Illyrian floristic element (which in this study included both Illyrian-Balkan and Illyrian-Adriatic elements). This group includes some of the older species of the European flora, which gone extinct in central and northern Europe, while surviving the glacial periods in the refugia of North-western Balkans.Today, these species are mostly endemic to this area, and significantly contribute to the wealth and distinctiveness of the flora and vegetation (Trinajstić, 1995). In the researched area, ten species belonging to the Illyrian-Balkan floristic element were recorded (*Acer obtusatum*, *Achillea virescens*, *Aremonia agrimonoides*, *Campanula pyramidalis*, *Digitalis laevigata*, *Frangula rupestris*, *Micromeria thymifolia*, *Pseudofumaria alba*, *Seseli kochii* and *Trifolium dalmaticum*).

Bryophytes are phylogenetically significantly older than vascular plants, so their species generally have comparatively large distribution areas. Therefore, bryophytes can not phytogeographically characterize the area as accurately as vascular plants. Nevertheless, the analysis of biogeographic elements of bryophytes revealed trends similar to those seen in vascular plants within our study. Besides the Boreo-temperate element consisting of species widespread in the conifer and broadleaf forest zones, high proportions of the Temperate and Southern-temperate elements characterize the researched area. This perfectly corresponds to the position of the area at the meeting point of thermophilic, sub-Mediterranean forests and mesic forests as was indicated by the composition of vascular plants as well. As was the case with the vascular plants, the proportion of the Mediterranean element was low among bryophyte species. Considering the eastern limit category, the dominant circumpolar and European elements were followed by the Suboceanic one, while the Eurosiberian and Eurasian elements were very poorly represented. All this indicated that the bryophyte flora of the investigated area is characterized by species adapted to a temperate climate under the maritime influence, without large annual extremes and a small amount of precipitation, characteristic of the continental climate. However, bryophyte distribution ranges, due to the previously explained reason, cannot precisely delineate the specific position of the area in southeastern Europe, i.e. in the Northwestern Balkans.

Since most of the researched area is covered by forests and thickets, it is to be expected that the largest number of species will be associated precisely with those habitat types. However, *Carpinus orientalis-Ostrya carpinifolia* low forests and thickets were inhabited by a significantly higher number of species than the taller and more mesic *Ostrya carpinifolia* forests. The most probable reasons for the observed difference are a larger amount of light and a higher number of microhabitats in *Carpinus orientalis-Ostrya carpinifolia* stands than in the monotone, shaded *Ostrya carpinifolia* forest, with the ground covered with a dense litter layer. On the other hand, alluvial gallery forests

and scrub have a specific set of species specialized for wet habitats, although they occupy a very small proportion of the investigated area. Similarly, a set of ecologically highly specialized species was characteristic of aquatic habitats and rocks, while the entrance into the protected area was characterized by a quite high number of ruderal species as a consequence of human impact.

Bryophytes occupy different ecological niches than vascular plants. Thus, the largest number of species is confined to the rocks, especially those that are shaded, which provide more moist, stable and constant environmental conditions. Additionally, forest ground is not particularly suitable for bryophytes due to the litter layer, so the number of species and their cover depends on the presence of rocks and patches of open soil. However, aquatic habitats are very favourable for bryophytes. Here, they thrive completely submersed or they inhabit rocks and boulders emerging from the water, as well as the periodically flooded bank zone where there is low competition from vascular plants.

The area of the Nature Monument Vrelo Une, although small, has a rich and well-structured flora of vascular plants and bryophytes that reflects both the phytogeographic position and ecological conditions of the habitats. Ten species from the Red List also contribute to the conservation value of the area.

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Appendix 1. Vascular flora of the Nature Monument Vrelo Une. Biogeographical elements (biogeog.): 1 – Mediterranean, 2 – Illyrian, 3 – Southern European, 5 – Eastern European-Pontian, 7 – Central European, 8 – European, 9 – Eurasian, 10 – circumholoarctic and 11 – cosmopolitan. Habitats: 1 – *Ostrya carpinifolia* forerst, 2 – *Carpinus orientalis-Ostrya carpinifolia* shrubs and low forest, 3 – alluvial gallery forest and scrub, 4 – rocks and rock crevices, 5 – aquatic and riparian habitats and 6 – ruderal habitats.

	biogeog.	habitat
Pteridophytina		
Polypodiidae		
Aspleniaceae		
Asplenium ceterach L.	3	4
Asplenium ruta-muraria L.	10	4
Asplenium scolopendrium L.	10	1
Asplenium trichomanes L.	11	4
Dryopteridaceae		
Dryopteris filix-mas (L.) Schott	10	1
Polystichum aculeatum (L.) Roth	9	1
Polystichum setiferum (Forssk.) Woyn.	9	1
Polypodiaceae		
Polypodium vulgare L.	9	4
Woodsiaceae		
Cystopteris fragilis (L.) Bernh.	11	4
Equisetidae		
Equisetaceae		
Equisetum arvense L.	10	6
Spermatophytina		
Dicotyledonae		
Aceraceae		

	biogeog.	habitat
Acer campestre L.	9	3
Acer monspessulanum L.	3	2
Acer obtusatum Willd.	2	2
Acer pseudoplatanus L.	7	3
Adoxaceae		
Adoxa moschatellina L.	10	1
Anacardiaceae		
Cotinus coggygria Scop.	5	2
Apiaceae		
Berula erecta (Huds.) Coville	10	5
Chaerophyllum temulum L.	8	3
Cnidium silaifolium (Jacq.) Simonk.	3	2
Oenanthe fistulosa L.	9	5
Pastinaca sativa subsp. *urens* (Godr.) Čelak.	9	6
Sanicula europaea L.	9	1
Seseli kochii Breistr. (=*S. elatum* Gouan subsp. *gouani* (Koch) P. W. Ball)	2	2
Seseli montanum L. subsp. *tommasinii* (Rchb. f.) Arcang.	5	2
Araliaceae		
Hedera helix L.	9	3
Aristolochiaceae		
Asarum europaeum L.	9	1
Asclepiadaceae		
Vincetoxicum hirundinaria Medik.	9	2
Betulaceae		
Alnus glutinosa (L.) Gaertn.	9	3
Boraginaceae		
Myosotis scorpioides L.	10	5
Myosotis sparsiflora Pohl	9	2
Symphytum tuberosum L.	3	1
Brassicaceae		
Aethionema saxatile (L.) R. Br.	3	2
Arabis turrita L.	3	2
Cardamine bulbifera (L.) Crantz	7	1
Cardamine enneaphyllos (L.) Crantz	3	1
Cardamine hirsuta L.	9	6
Erophila verna (L.) DC.	10	6
Erysimum odoratum Ehrh.	5	2
Peltaria alliacea Jacq.	5	4
Campanulaceae		
Campanula persicifolia L.	9	2
Campanula pyramidalis L.	2	4
Campanula rapunculoides L.	9	2
Campanula rotundifolia agg.		4
Campanula trachelium L.	9	1
Caprifoliaceae		
Lonicera caprifolium L.	5	2
Sambucus nigra L.	9	3
Viburnum lantana L.	5	2

	biogeog.	habitat
Caryophyllaceae		
Moehringia muscosa L.	3, 7	4
Petrorhagia saxifraga (L.) Link	3	4
Silene latifolia Poir. subsp. *alba* (Mill.) Greuter et Bourdet	9	3
Silene nutans L.	9	2
Silene vulgaris (Moench) Garcke	7	2
Celastraceae		
Euonymus latifolius (L.) Mill.	3, 7	1
Euonymus verrucosa Scop.	5	2
Cistaceae		
Helianthemum nummularium (L.) Mill. subsp. *obscurum* (Čelak.) Holub	7	2
Clusiaceae		
Hypericum montanum L.	9	2
Hypericum perforatum L.	9	2
Compositae - Asteraceae		
Achillea millefolium L.	9	3
Achillea virescens (Fenzl) Heimerl	2	2
Artemisia vulgaris L.	9	6
Bellis perennis L.	7	6
Buphthalmum salicifolium L.	7	2
Carlina vulgaris L.	7	2
Centaurea deusta Ten. subsp. *concolor* (DC.) Hayek	3	2
Eupatorium cannabinum L.	9	3
Inula conyza DC.	7	1
Inula hirta L.	5	2
Petasites hybridus (L.) P. Gaertn., B. Mey. et Schreb.	9	5
Tanacetum corymbosum (L.) Sch. Bip.	8	2
Tussilago farfara L.	9	6
Compositae - Cichoriaceae		
Cichorium intybus L.	9	6
Cirsium vulgare (Savi) Ten.	9	6
Crepis biennis L.	7	3
Pilosella hoppeana (Schult.) F. W. Schultz & Sch. Bip.	3, 7	2
Pilosella bauhini (Schult.) Arv.-Touv.	5	2
Hieracium sabaudum L.	7	2
Leontodon crispus Vill.	3	2
Leontodon hispidus L. ssp. *hispidus*	8	3
Lactuca muralis (L.) Gaertn.	7	4
Taraxacum sect. *Taraxacum* F. H. Wigg.	9	6
Cornaceae		
Cornus mas L.	3	2
Cornus sanguinea L.	8	3
Corylaceae		
Carpinus orientalis Mill.	5	2
Corylus avellana L.	8	1
Ostrya carpinifolia Scop.	3	1, 2
Crassulaceae		
Sedum ochroleucum Chaix	3	4

	biogeog.	habitat
Sedum sexangulare L.	8	4
Sedum telephium L. subsp. *maximum* (L.) Krock.	8	4
Dipsacaceae		
Knautia arvensis (L.) Coult.	9	2
Euphorbiaceae		
Euphorbia cyparissias L.	9	2
Euphorbia dulcis L.	7	1
Mercurialis perennis L.	8	1
Fabaceae		
Colutea arborescens L.	3	2
Coronilla emerus L. subsp. *emeroides* Boiss. et Spruner	5	2
Securigera varia (L.) Lassen	9	6
Dorycnium germanicum (Gremli) Rikli	3	2
Genista januensis Viv.	5	2
Lotus corniculatus L. subsp. *hirsutus* Rothm.	9	2
Medicago falcata L.	9	6
Medicago lupulina L.	9	6
Ononis spinosa L.	8	2
Trifolium campestre Schreber	1	2
Trifolium dalmaticum Vis.	2	2
Trifolium incarnatum L.	3	3
Trifolium pratense L.	9	3
Trifolium repens L.	9	6
Trifolium scabrum L.	1	2
Trifolium stellatum L.	1	2
Vicia grandiflora Scop.	5	3
Vicia hirsuta (L.) Gray	9	2
Quercus cerris L.	3	2
Fumariaceae		
Corydalis cava (L.) Schweigg. & Körte	9	1
Pseudofumaria alba (Mill.) Lidén	2	4
Geraniaceae		
Erodium cicutarium (L.) L. Hér.	1	2
Geranium columbinum L.	9	2
Geranium lucidum L.	1	3
Geranium robertianum L.	10	4
Lamiaceae		
Acinos arvensis (Lam.) Dandy	1	2
Ajuga reptans L.	9	3
Clinopodium vulgare L.	10	2
Lamium galeobdolon (L.) Crantz	9	1
Lamium maculatum L.	9	2
Melittis melissophyllum L.	7	2
Mentha longifolia (L.) L.	9	5
Micromeria thymifolia (Scop.) Fritsch	2	4
Prunella vulgaris L.	9	1
Salvia glutinosa L.	9	1
Salvia pratensis L.	8	2

	biogeog.	habitat
Satureja montana L.	3	4
Teucrium chamaedrys L.	3	2
Thymus pulegioides L.	9	2
Linaceae		
Linum catharticum L.	9	2
Lythraceae		
Lythrum salicaria L.	9	5
Oleaceae		
Fraxinus angustifolia Vahl	5	3
Fraxinus ornus L.	3	2
Ligustrum vulgare L.	9	1
Papaveraceae		
Chelidonium majus L.	9	6
Plantaginaceae		
Plantago major L. subsp. *intermedia* (Gilib.) Lange	9	3
Plantago major L. subsp. *major*	9	6
Plantago media L.	9	2
Primulaceae		
Cyclamen purpurascens Mill.	3, 7	1
Primula vulgaris Huds.	8	1
Ranunculaceae		
Anemone ranunculoides L.	9	2
Caltha palustris L.	10	5
Clematis vitalba L.	7	3
Ficaria verna Huds.	8	3
Isopyrum thalictroides L.	9	1
Ranunculus acris L.	9	3
Ranunculus lanuginosus L.	7	1
Ranunculus repens L.	9	3
Rhamnaceae		
Frangula alnus Mill.	9	3
Frangula rupestris (Scop.) Schur.	2	2
Rhamnus cathartica L.	9	3
Rosaceae		
Aremonia agrimonoides (L.) DC.	2	1
Crataegus monogyna Jacq.	9	2
Fragaria vesca L.	9	2
Geum urbanum L.	9	3
Potentilla micrantha Ramond ex DC.	3	2
Rosa canina agg.	9	6
Rubus fruticosus agg.		6
Sanguisorba minor Scop. subsp. *muricata* Briq.	9	2
Sorbus aria (L.) Crantz	8	2
Sorbus torminalis (L.) Crantz	9	2
Rubiaceae		
Asperula cynanchica L.	8	4
Galium aparine L.	9	6
Galium corrudifolium Vill.	1	2

	biogeog.	habitat
Galium divaricatum Pourr. ex Lam.	1	2
Galium lucidum All.	3	2
Galium mollugo L.	9	3
Rutaceae		
Ruta graveolens L.	3	2
Salicaceae		
Salix caprea L.	9	3
Salix eleagnos Scop.	3	3
Salix purpurea L.	9	3
Saxifragaceae		
Saxifraga rotundifolia L.	3, 7	1
Scrophulariecae		
Digitalis laevigata Waldst. et Kit.	2	2
Melampyrum nemorosum L.	9	2
Verbascum thapsus L.	9	2
Veronica anagallis-aquatica L.	9	5
Tiliaceae		
Tilia platyphyllos Scop.	7	3
Ulmaceae		
Ulmus minor Mill.	8	2
Urticaceae		
Parietaria officinalis L.	3	1
Urtica dioica L.	11	6
Valerianaceae		
Valeriana officinalis L.	7	3
Valeriana tripteris L.	3, 7	1
Violaceae		
Viola alba Besser subsp. *dehnhardtii* (Ten.) W. Becker	7	2
Monocotyledonae		
Alliaceae		
Allium carinatum L.	8	2
Allium sphaerocephalon L.	1	2
Amaryllidaceae		
Galanthus nivalis L.	3, 7	1
Araceae		
Arum italicum Mill.	1	2
Asparagaceae		
Anthericum ramosum L.	7	2
Asparagus tenuifolius Lam.	3	2
Polygonatum multiflorum (L.) All.	10	2
Polygonatum odoratum (Mill.) Druce	9	2
Cyperaceae		
Carex digitata L.	9	2
Carex hallerana Asso	1	2
Carex hirta L.	9	3
Carex humilis Leyss.	9	2
Juncaceae		
Juncus articulatus L.	10	5

	biogeog.	habitat
Orchidaceae		
Cephalanthera damasonium (Mill.) Druce	3	2
Cephalanthera longifolia (L.) Fritsch / *rubra* (L.) Rich.		2
Epipactis helleborine (L.) Crantz	9	1
Neottia nidus-avis (L.) Rich.	9	1
Poaceae		
Achnatherum calamagrostis (L.) P. Beauv.	3	4
Agrostis stolonifera L.	9	5
Anthoxanthum odoratum L.	9	2
Brachypodium rupestre (Host) Roem. & Schult.	3	2
Brachypodium sylvaticum (Huds.) P. Beauv.	9	1
Cynosurus cristatus L.	9	3
Dactylis glomerata L.	9	6
Elymus repens (L.) Gould	9	6
Festuca valesiaca Schleich. ex Gaudin	9	2
Hordelymus europaeus (L.) Harz	8	1
Lolium perenne L.	8	6
Melica nutans L.	9	1
Melica ciliata L.	1	2
Poa bulbosa L.	9	2
Poa compressa L.	9	2
Poa trivialis L.	9	3
Sesleria autumnalis (Scop.) F. W. Schultz	3	2

Appendix 2. Bryophyte flora of the Nature Monument Vrelo Une. Biogeographical elements – E1: 1 – Arctic-montane, 2 – Boreo-arctic montane, 3 – Wide boreal, 4 – Boreal-montane, 5 – Boreo-temperate, 6 – Wide-temperate, 7 – Temperate, 8 – Southern-temperate and 9 – Mediterranean-Atlantic; E2: 2 – Suboceanic, 3 – European, 4 – Eurosiberian, 5 – Eurasian and 6 – Circumpolar. Habitats: 1 – forests, 2 – rocks and rock crevises (mostly shaded), 3 – tree bark and 4 – acquatic and riparian habitats.

	E1	E2	habitat
Marchantiophyta			
Apopellia endiviifolia (Dicks.) Nebel & D.Quandt	8	6	4
Chiloscyphus pallescens (Ehrh.) Dumort.	5	6	4
Cololejeunea calcarea (Lib.) Steph.	5	2	2, 3
Frullania tamarisci (L.) Dumort.	5	2	2, 3
Jungermannia atrovirens Dumort.	3	3	2
Lophocolea coadunata (Sw.) Mont.	7	3	4
Marchantia polymorpha L. subsp. *monsvagans* Bischl. & Boissel.-Dub.	5	3	4
Marchantia quadrata Scop.	2	6	2
Mesoptychia collaris (Nees) L.Söderstr. & Váňa	4	6	2
Pedinophyllum interruptum (Nees) Kaal.	7	3	2, 4
Plagiochila porelloides (Torr. ex Nees) Linden.	5	6	2
Radula complanata (L.) Dumort.	5	6	3
Reboulia hemisphaerica (L.) Raddi	8	6	4
Scapania aspera M. Bernet & Bernet	5	3	2
Bryophyta			
Abietinella abietina (Hedw.) M. Fleisch.	2	6	1
Alleniella complanata (Hedw.) S.Olsson, Enroth & D.Quandt	5	3	1, 3

	E1	E2	habitat
Anomodon viticulosus (Hedw.) Hook. & Taylor	5	6	2
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen	7	6	2
Brachythecium rivulare Schimp.	5	6	4
Brachythecium rutabulum (Hedw.) Schimp.	7	3	1
Brachythecium salebrosum (Hoffm. ex F. Weber & D. Mohr) Schimp.	3	6	2
Brachythecium tommasinii (Sendtn. ex Boulay) Ignatov & Huttunen			2
Campylophyllopsis calcarea (Crundw. & Nyholm) Ochyra	7	3	2
Chionoloma tenuirostre (Hook. & Taylor) M.Alonso, M.J.Cano & J.A.Jiménez	5	6	2
Cinclidotus aquaticus (Hedw.) Bruch & Schimp.	9	3	4
Cinclidotus fontinaloides (Hedw.) P. Beauv.	8	3	4
Cratoneuron filicinum (Hedw.) Spruce	6	6	4
Ctenidium molluscum (Hedw.) Mitt.	5	3	1
Dicranum scoparium Hedw.	3	6	1
Didymodon acutus (Brid.) K. Saito	8	6	2
Didymodon fallax (Hedw.) R.H. Zander	8	6	2
Didymodon insulanus (De Not.) M.O. Hill	8	5	2
Didymodon rigidulus Hedw.	5	6	1
Didymodon spadiceus (Mitt.) Limpr.	7	3	2
Encalypta streptocarpa Hedw.	5	5	1
Exsertotheca crispa (Hedw.) S.Olsson, Enroth & D.Quandt	7	3	2, 3
Fissidens crassipes Wilson ex Bruch & Schimp.	8	3	4
Fissidens dubius P. Beauv.	7	3	2
Flexitrichum flexicaule (Schwägr.) Ignatov & Fedosov	5	6	1, 2
Fontinalis antipyretica Hedw.	5	6	4
Homalothecium lutescens (Hedw.) H. Rob.	8	3	1
Homalothecium sericeum (Hedw.) Schimp.	8	4	1
Hypnum cupressiforme Hedw.	6	6	1, 3
Lewinskya striata (Hedw.) F.Lara, Garilleti & Goffinet	5	3	3
Microeurhynchium pumilum (Wilson) Ignatov & Vanderp.	9	2	4
Mnium stellare Hedw.	5	6	4
Orthothecium intricatum (Hartm.) Schimp.	2	3	2
Orthotrichum pallens Bruch ex Brid.	5	3	3
Oxyrrhynchium hians (Hedw.) Loeske	7	6	2, 4
Plagiomnium rostratum (Schrad.) T.J. Kop.	5	3	1, 4
Plagiomnium undulatum (Hedw.) T.J. Kop.	7	3	1, 4
Plagiopus oederianus (Sw.) H.A. Crum & L.E. Anderson	2	6	2
Plasteurhynchium striatulum (Spruce) M.Fleisch.	9	2	1
Pseudoscleropodium purum (Hedw.) M. Fleisch.	7	3	1
Ptychostomum capillare (Hedw.) D. T. Holyoak & N. Pedersen	5	6	4
Ptychostomum pseudotriquetrum (Hedw.) J.R.Spence & H.P.Ramsay ex Holyoak & N.Pedersen	3	6	4
Rhizomnium punctatum (Hedw.) T.J. Kop.	5	6	2
Rhynchostegium riparioides (Hedw.) Cardot	8	6	4
Schistidium crassipilum H.H. Blom	8	3	2
Thamnobryum alopecurum (Hedw.) Gangulee	7	3	4
Thuidium recognitum (Hedw.) Lindb.	7	6	1
Thuidium tamariscinum (Hedw.) Schimp.	7	3	1
Tortella tortuosa (Hedw.) Limpr.	5	6	1, 2
Trichostomum brachydontium Bruch	9	2	2