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BRYOPHYTE FLORA OF THE SIGNIFICANT LANDSCAPE "LOWER KAMENJAK AND MEDULIN ARCHIPELAGO" (ISTRIA, CROATIA) WITH NEW AND NOTEWORTHY NATIONAL RECORDS

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Bryophyte flora of the Significant Landscape Lower "Kamenjak and Medulin Archipelago" in Istria (western Croatia) was studied from 2019 to 2021. The study resulted in a list of 14 liverwort and 60 moss taxa. *Tortula pallida*, *Bryum gemmilucens*, *Microbryum davallianum* var. *conicum* and *Microbryum muticum* are new national records. The prevalence of Mediterranean-Atlantic, temperate and southern-temperate chorotypes corresponds well with the biogeographical characteristics of the studied area. The turf life-form and colonist life strategy, predominantly represented by small Pottiaceae species, prevailed within the study. They mostly inhabited periodically moist soil of open habitats in olive groves, maquis and garrigues. This study aimed to address the significant lack of current data on bryophytes in coastal parts of Croatia.

Key words: life-forms, liverworts, maquis, Mediterranean, mosses, new national record, olive groves, Pottiaceae

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Od 2019. do 2021. proučavana je flora mahovina Značajnog krajobraza "Donji Kamenjak i Medulinski arhipelag" u Istri (zapadna Hrvatska), čime je utvrđeno 14 svojti jetrenjarki i 60 svojti pravih mahovina. Svojte *Tortula pallida*, *Bryum gemmilucens*, *Microbryum davallianum* var. *conicum* i *Microbryum muticum* zabilježene su po prvi put za Hrvatsku. Dominacija mediteransko-atlantskog, tempratnog i južno-tempratnog flornog elementa odgovara biogeografskim karakteristikama proučavanog područja. Mahovine koje rastu u čupercima, kao prevladavajući životni oblik te kolonizatori kao prevladavajuća životna strategija, zastupljene brojnim malim vrstama iz porodice Pottiaceae, uglavnom naseljavaju periodički vlažna tla otvorenih staništa u maslinicima, makijama i garizima. Ovo istraživanje doprinos je poznavanju mahovina obalnog područja Hrvatske, za koje nedostaju recentni podaci.

Ključne riječi: životni oblici, jetrenjarke, makija, Sredozemlje, prave mahovine, nove svojte, maslinici, Pottiaceae

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INTRODUCTION

Croatia has a quite long history of bryological research, predominantly conducted by foreign researchers with the majority of investigations being performed along the Adriatic coast and across the islands (Alegro *et al*., 2012). However, after the fruitful research period of the turn of the 19th and 20th centuries, further research into the bryophytes of the Adriatic coast was almost completely discontinued until modern times, except for the survey of hepatics of Bischler & Jovet-Ast (1973). Moreover, the majority of the recent bryophyte inventories compiled during the last 15 years (e.g. Papp *et al*., 2013a, b, 2016; Alegro *et al*., 2014, 2015; Rimac *et al*., 2019) are focused on inland Croatia, since this area was historically extremely data deficient compared to the Mediterranean region. In the Mediterranean, at least some historic data existed (Alegro & Šegota, 2018–onwards), therefore this area was neglected in recent surveys. This resulted in a very uneven distribution of recent information on bryophytes, which motivated our research into the bryoflora of Rt Kamenjak.

The study area lies in southern Istria, Croatia's largest peninsula situated in the northern Adriatic. Rt Kamenjak represents the southernmost point of Istria, reaching approximately 4 km southwards from the village Premantura in the form of a small, elongated peninsula, with width svarying up to 1.6 km (Fig. 1). This small peninsula is characterized by a well-indented, rocky coast, encompassing a land area consisting of alternating valleys and hills not higher than 50 m a.s.l.

The history of land use includes centuries of traditional agriculture, which caused changes in the natural vegetation, ultimately resulting in a mosaic of semi-natural habitats. Due to long-term human activities related to agriculture, the native forest vegetation of ass. *Fraxino orni-Quercetum ilicis* Horvatić (1956) 1958 was gradually transformed into its degradation stages: maquis, garrigue and dry rocky grasslands. As a result, the current vegetation of Rt Kamenjak is mostly a mixture of woody vegetation (littoral evergreen forests and maquis and anthropogenic forest stands), dry sub-Mediterranean grasslands (*Scorzoneretalia villosae* Kovačević 1959), agricultural land and ruderal vegetation (Ljubičić *et al*., 2020).

The heterogeneous habitats of the area offer diverse options for various and interesting flora. Rt Kamenjak is known for its floristic richness; over 600 plant taxa have been recorded on this small piece of land (Topić & Šegulja, 2000). Some of these plants are rare, endemic, endangered and protected by law (Topić, 1994; Topić *et al*. 1997, 1998; Perko 1998; Vuković, 2010; Vuković *et al*., 2013; Brana *et al*., 2014). Accordingly, Rt Kamenjak and the 12 nearby islets have been protected since 1996 due to their great floristic and landscape richness, today in the category of Significant Landscape, the "Lower Kamenjak and Medulin Archipelago". During the 20th century, changes in the way of life and the development of tourism led to agriculture ceasing to be the primary form of human activity in the area. For this reason, vegetation succession is actively ongoing, while open, grassland areas are rapidly returning to shrubby vegetation.

Southern Istria has a very long history of botanical research. It was a subject of detailed botanical studies in historical times, especially by Freyn (1878, 1881, 1900), Tommasini (1873) and Neugebauer (1875). After the southernmost part was legally protected, botanists became increasingly interested in the area (Topić, 1994; Topić *et al*., 1997, 1998; Perko, 1998; Topić & Šegulja, 2000; Vuković *et al*., 2011, 2013; Brana *et al*., 2014; Rottensteiner, 2014; Ljubičić *et al*. 2020) and as a result, the vascular flora of the area is relati-

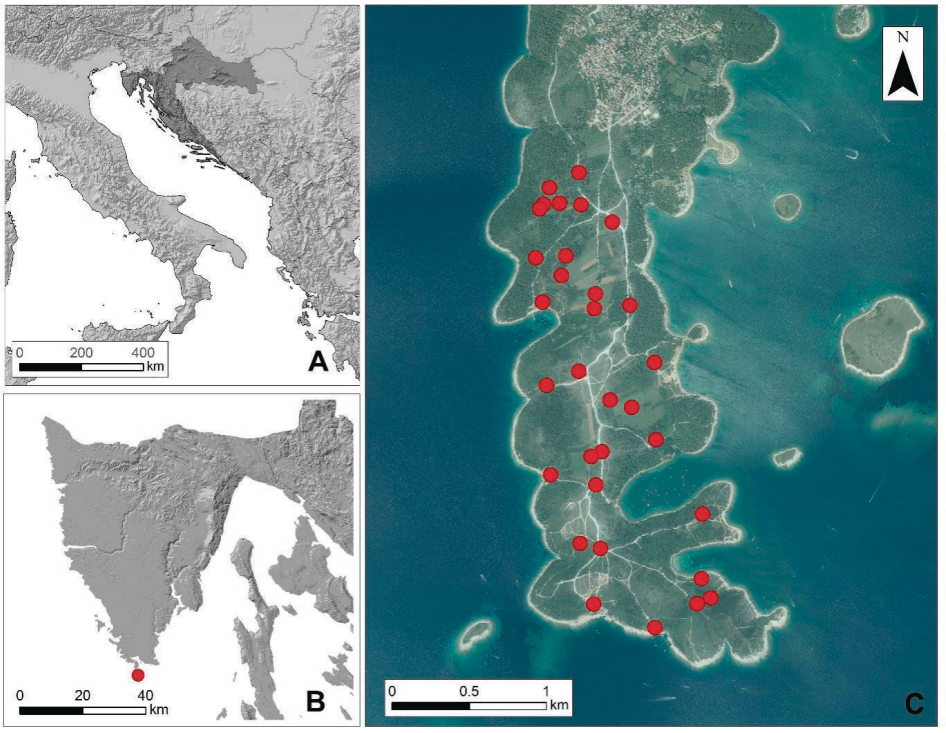

Fig. 1. Study area: A–position of Croatia, B–position of Rt Kamenjak in Istria, C–investigated localities on Rt Kamenjak.

vely well studied. In contrast, data about the bryophytes of Rt Kamenjak are remarkably poor. All known data about bryophytes in Croatia are publicly available through the national Flora Croatica Database (Alegro & Šegota, 2018-onwards). These records, however, mostly refer to old, historical data from the 19th century (Pavletić, 1955), which were later incorporated into various modern checklists as literature data. Recent field findings are scarce, due to the long-term lack of bryologists, leading to decades without data collection. Prior to this survey, the only literature note about bryophytes on Rt Kamenjak was the finding of the moss *Aloina aloides* (Koch ex Schultz) Kindb., dating from the second half of the 19th century (Freyn, 1878). However, according to our knowledge, the area is extremely rich in bryophytes. This is particularly obvious during the winter months, when ephemeral taxa emerge and occur in high coverage, and large areas become covered with thick, green, bryophyte mats. Given the contrast between the literature data and the situation in the field, we aimed to broaden knowledge about the bryophytes of Rt Kamenjak and produce the most recent inventory of taxa.

METHODS

Specimens were collected from eight random sites spread over Rt Kamenjak during the first preliminary field trip in December 2019. During a two-day field trip in January 2020, the whole area of Rt Kamenjak was surveyed, and ten additional sites were selected, where new bryophyte material was collected. In February 2021, altogether 14 sites

were surveyed and new material was collected. In total, 32 sites were surveyed on Rt Kamenjak (Fig. 1, Appendix 1). The sites were selected in such a way as to cover the area evenly. At each site, all bryophyte taxa were recorded, collected and photographed over approximately 100 m^2.

To ensure that all available habitats are represented, the material was collected from open grasslands, forests, edges of paths, stonewalls, olive groves etc., and from different substrates (soil, bark, stones and walls), in order to collect the largest possible number of taxa. In all sites, GPS coordinates were recorded with a Garmin device.

Specimens were identified using a stereomicroscope, light microscope and the following referencess: Smith, 1996; Paton, 1999; Atherrton *et al.*, 2010; Frahm & Frey, 2004; Smith, 2004; Frey *et al.*, 2006; Erzberger & Schröder, 2013; Hedenäs, 2015; Lüth, 2019; Erzberger, 2021. Following the identification, distribution maps of recorded taxa were prepared using ArcMap 10.5 software. Bryophyte nomenclature follows Hodgetts *et al.* (2020). The chorological analysis of bryophyte flora based on major biomes was carried out according to Hill & Preston (1998). The analysis of life-form spectra was done using the classification given in Hill *et al.* (2007), while the life strategies were defined according to During (1992), given in Dierssen (2001).

RESULTS AND DISCUSSION

The field inventory resulted in 14 liverwort and 60 moss taxa (Appendix 2) belonging to 22 families, with Pottiaceae being the most represented (28 taxa, 37.8%), followed by Bryaceae and Brachytheciaceae (8 taxa, 10.8% each), Ricciaceae (5 taxa, 6.8%) and Fissidentaceae (4 taxa, 5.4%) (Fig. 2). The most common species were *Dicranella howei* (18 records), *Rhynchostegium megapolitanum* and *Tortella squarrosa* (13 records each), *Fissidens taxifolius* and *Microbryum rectum* (12 records each), *Fissidens incurvus* and *Riccia beyrichiana* (11 records each) (Fig. 3).

New and noteworthy records

Among the recorded taxa, several were singled out as new, rare and noteworthy national records and are discussed below:

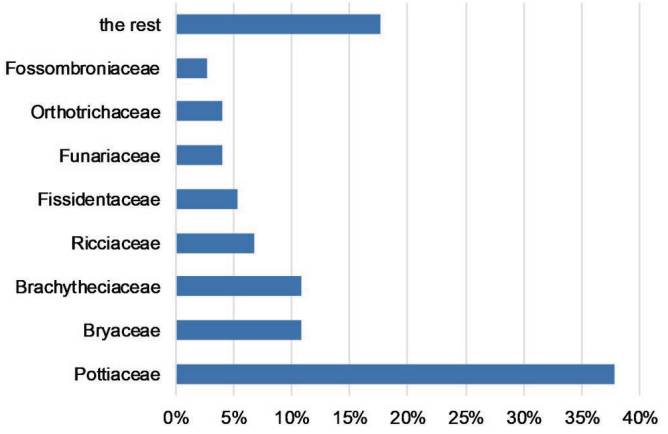

Fig. 2. The most represented families in the bryoflora of Rt Kamenjak.

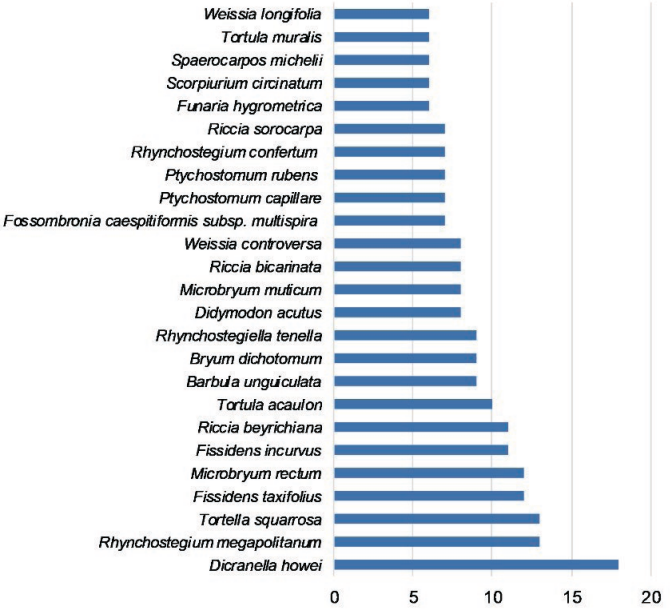

Fig. 3. The most common taxa in the studied area (> 5 localities).

Acaulon muticum (Hedw.) Müll.Hal.

This southern-temperate species has been rarely recorded in Croatia. Historical records refer to the island of Rab (Loitlesberger, 1909; Latzel, 1931) and the vicinity of Dubrovnik (Latzel, 1931), while the only recent record is from Čorkova Uvala in the Plitvice Lakes National Park (Alegro *et al*., 2014). On Rt Kamenjak, we recorded the species in two localitiess, representing the second recent finding of this species in Croatia.

Bryum barnesii J.B.Wood ex Schimp.

This species is morphologically quite similar to *B. dichotomum*, with which it has been frequently synonymized (e.g. Smith, 2004; Hodgetts *et al*., 2020). Both taxa, independently of their taxonomic status, were recorded in the studied area: *B. dichotomum* more often (in nine localities), and *B. barnesii* in only one locality in the SW part of the studied area (Fig. 4). As a terricolous species, it was found on bare soil in the Pinižula locality. *Bryum barnesii* was usually regarded as a distinct species in Central Europe (e.g. Demaret & Wilczek, 1976, 1980; Wilczek & Demaret, 1976, 1980; Demaret, 1993), but many plants and populations intermediate between *B. barnesii* and *B. dichotomum* do occur (Smith & Whitehouse, 1978; Holyoak, 2003, 2004). Both species belong to the complex of forms allied to *B. bicolor* Discks. in which six taxa are recognized (Wilczek & Demaret, 1976). A review of the *B. bicolor* complex in North America by Vanderpoorten & Zartman (2002) made a distinction between species with numerous bulbils per leaf axil (including *B. barnesii*) and those with 1(-2) bulbils per leaf axil (including *B. dichotomum*). Although Shaw (1990) demonstrated that the number of bulbils per plant in *B. bicolor* agg. can vary according to environmental conditions, there does not

appear to be any further evidence that the number of bulbils per leaf is susceptible to modification under different growth conditions (Holyoak, 2003). Moreover, Dolnik (2006), discovered, while studying gemma development under controlled conditions, that the number of bulbils per leaf axil in *B. barnesii* was constant. Hence, although further study of a wide range of plant material is needed, including molecular analyses, this character may justify retaining *B. barnesii* as a separate species, even if one of still uncertain status and distribution (Holyoak, 2003; Dolnik, 2006). We present a record of specimens with numerous large axillary bulbils, accordingly identified as *B. barnesii*. This is the second known locality of this taxon in Croatia as it was previously recorded in 2017 on the banks of the Zrmanja River in the southern part of the country (Dalmatia Region) (Rimac *et al.*, 2022).

Bryum gemmilucens R.Wilczek & Demaret

This is a taxonomically accepted species of the *Bryum bicolor* agg., distinguished by bright yellow bulbils that almost lack leaf primordia. Bulbils are quite large (100–200 μm), numerous, usually ca. 5 per leaf axil. The plants are tiny, measuring 1 to 8 mm in height and growing most often in small but dense tufts (Erzberger & Schröder, 2013; Smith, 2004). The species is a European Temperate element, however, to this day rarely recorded in southeastern Europe (Hodgetts & Lockhart, 2020), known so far only from Greece (including Crete). It was discovered on sandstone outcrops in calcareous grassland and open soil in saline grassland in neighbouring Hungary, where it is regarded as being highly rare and endangered (Erzberger & Schröder, 2013). Furthermore, it is known to occur on arable fields, roadsides and woodland roads (Smith, 2004). This is the first record of the species in Croatia. It was found in five localities, on patches of bare soil within the garrigue and maquis (Fig. 4).

Cheilothela chloropus (Brid.) Broth.

This Mediterranean species has seven known localities in Croatia so far, exclusively in the Mediterranean part of the country (towns of Poreč, Rovinj and Pula and the islands of Cres, Sušac, Lastovo and Šipan) (Głowacki, 1902, 1913; Forenbacher, 1911; Hruby, 1912; Baumgartner, 1916; Latzel, 1931; Pavletić, 1955). However, all these findings were from before 1930 and were not confirmed subsequently. Our recent records of *C. chloropus* in five localities on Rt Kamenjak are the first confirmation of this species in Croatia for 90 years.

Ephemerum serratum (Hedw.) Hampe

Ephemerum serratum is an extremely rare or more likely insufficiently studied ephemeral moss in Croatia – it has been found on the island of Rab (Düll, 1999), in Vrhovinsko Polje (Alegro *et al.*, 2014) (listed as *E. minutissimum* Lindb.), on the island of Molat and in southern Istria (Alegro *et al.*, 2019). During our research, we found *E. serratum* in two locations on patches of bare soil in olive groves.

Gymnostomum viridulum Brid.

So far, only four localities with this species have been reported in Croatia, with the earliest record from 1913 from the town of Dubrovnik (herbarium specimen collected by J. Podpera – ZA 66046) (Alegro & Šegota, 2018-onwards). In more recent times *G.*

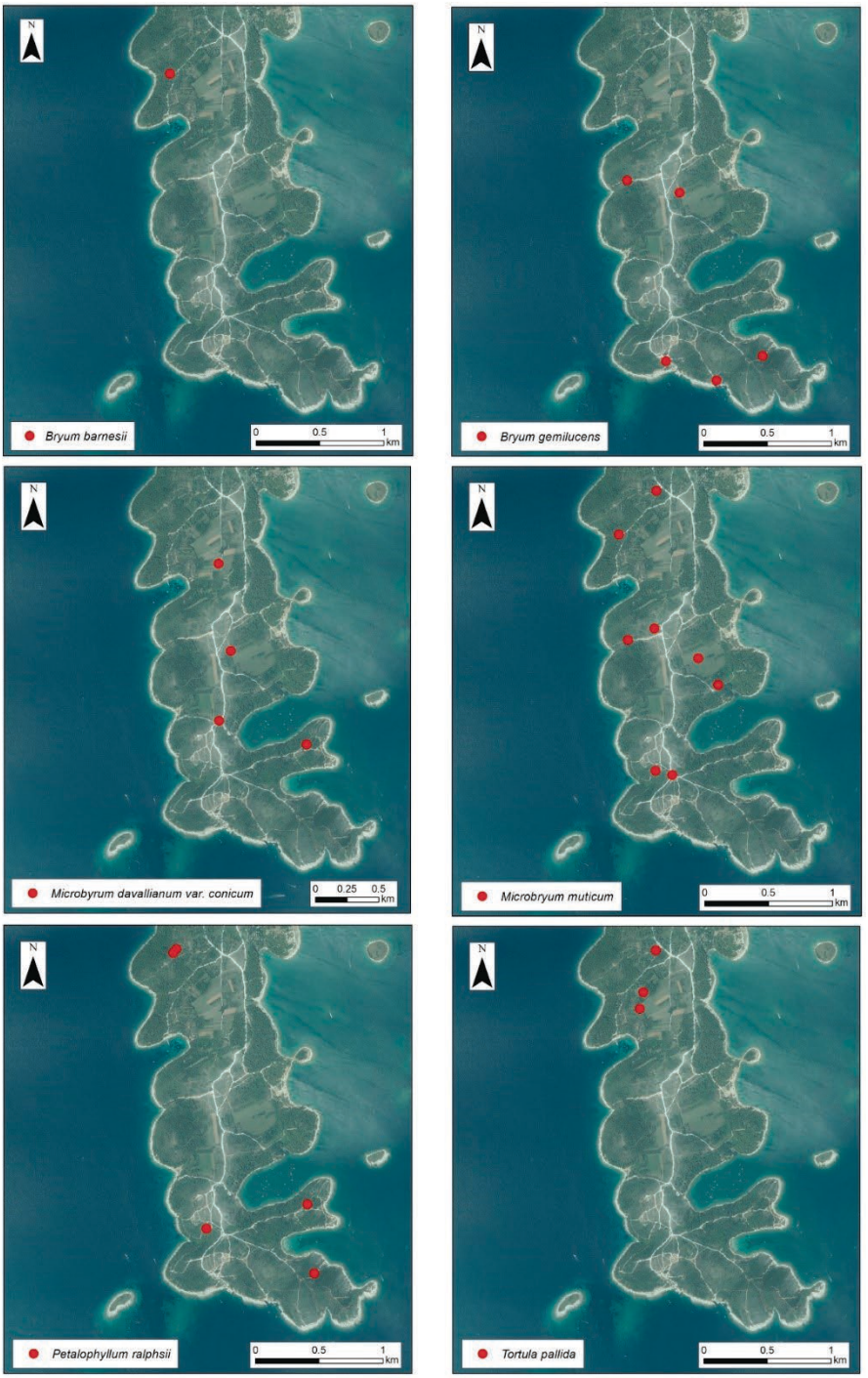

Fig. 4. Distribution maps of new and noteworthy taxa of Croatian bryoflora recorded in Rt Kamenjak.

viridulum was recorded in eastern Istria (Düll, 1999), Žumberačko Gorje (Alegro *et al.*, 2015) and the islet of Rava (Sabovljević *et al.*, 2018). On Rt Kamenjak, we found the species in three localities, making a valuable addition to the knowledge of this understudied species in Croatia.

Microbryum davallianum (Sm.) R.H.Zander var. *conicum* (Schleich. ex Schwägr.) R.H.Zander

Although there are sufficient morphological differences to recognize *M. davallianum* var. *conicum* at the variety level and the taxon has been recognized in several identification keys and checklists (Frahm & Frey, 2004; Lüth, 2019; Hodgetts & Lockhart, 2020; Hodgetts *et al.*, 2020), it has not been recorded as such in Europe so far, except in the Netherlands (Hodgetts & Lockhart, 2020; BLWG, 2023). Although molecular studies are still not available and its status is still uncertain, it was accepted by e.g. Blockeel *et al.* (2021) as having enough morphological definition to merit varietal status. The appearance of ripe capsules distinguishes this variant from ordinary *M. davallianum* var. *davallianum*. The latter species has capsules that, when opened, have a widened mouth with the greatest width just below the mouth and which are about as long as they are wide, while var. *conicum* has capsules that have the greatest width about the middle and are longer than wide. The additional identification characters are 1–4 rows of small, differentiated cells immediately below the mouth and either rudimentary or absent peristome and spores with short spines, papillae or tubercles on the surface (Pilkington, 2022). Our records are the first in Croatia and this taxon was registered in four localities, occurring on patches of bare soil within the garrigue and maquis (Fig. 4).

Microbryum muticum (Venturi) T.Mahévas, C.Schneider, T.Schneider, D. Cartier & T.Géhin

A dubious taxon placed mainly within the variability of the *Microbryum starckeanum* (e.g. Ros & Werner, 2006) or *M. davallianum* (e.g. Frey *et al.*, 2006). Some European bryologists consider it as an additional variety of *M. davallianum* with the distinction based on capsule shape, the number of rows of differentiated cells below the peristome mouth and degree of papillosity of upper leaf cells (Pilkington, 2022). The spores are wavy in outline with round or spinous apical processes (papillose to echinate) (Ros *et al.*, 1996), somewhat more pronounced than in *M. davalianum* and *M. starchkeanum*. German bryologists even place this taxon on a specific level (e.g. Frahm & Frey, 2004; Lűth, 2019; Nebel & Philippi, 2000; Erzberger, 2021). We have identified several samples as *Microbryum muticum,* the first record in Croatia, found in eight localities (Fig. 4) on patches of bare soil within the garrigue and maquis.

Petalophyllum ralfsii (Wilson) Nees & Gottsche

Petalophyllum ralfsii is a very distinctive liverwort, with leaf-like ridges, resembling miniature lettuce and growing solitarily in rosettes (Hill *et al.*, 2007). It has a Mediterranean-Atlantic distribution (Hill *et al.*, 1991, 2007; Hill & Preston, 1998), with the largest known populations in the British Isles (Campbell *et al.*, 2015). The Mediterranean part of its European distribution area stretches from Portugal and Spain (Balearic Islands), through Italy and Malta to Greece and Cyprus (Paton, 1999; Söderstrom *et*

al., 2002). The species has been generally regarded as rare, especially in the Mediterranean part of its distribution area, where many records are old and unconfirmed. There are only two known sites on the Balkan Peninsula, both on the Peloponnese (Greece) (Schiffner & Baumgartner, 1919; Preston, 1981; Blockeel, 1991). However, more localities are known from the island of Crete (Düll & Düll-Hermanns, 1973; Bischler & Jovet-Ast, 1979; Preston, 1981; Papp *et al.*, 1998; Biel, 2020) and the islands of Gavdopoula, Gavdos and Euboea (Bergmeier *et al.*, 2011; Biel, 2020). *Petalophyllum ralfsii* prefers lower and more maritime positions on the Atlantic coast, while Mediterranean populations favor higher and more inland locations (Šegota *et al.*, 2020). The species has been listed in Annex II of the EU Habitat Directive (European Commission, 1992; Evans & Arvela, 2011). Due to its specialized ecology and the fragility of its habitat, the species is potentially threatened by many negative pressures. Despite performing a detailed search across the suitable microhabitats and during the early winter period, we have found this taxon only in five localities (Fig. 4), on patches of bare soil within the garrigue and maquis or near the forest edges.

Sphaerocarpos michelii **Bellardi**

This rare liverwort has been previously recorded in Croatia only twice. The first record dates from the first half of the 20th century (Horvat, 1932) and refers to the area of Zagreb. Later, this finding was cited by Pavletić (1955) and this quote was afterwards transferred to several checklists (Düll *et al.*, 1999; Sabovljević, 2003; Sabovljević & Natcheva, 2006; Ros *et al.*, 2007), but the record was never confirmed again in the field. As much as 87 years later a new record of this species in Croatia was made (Alegro *et al.*, 2019), from the area of the town of Slatina in eastern Croatia. We have found *S. michelii* in six localities in Rt Kamenjak. It typically inhabited patches of bare and moist soil at the foot of olive trees in olive groves, sometimes in very abundant populations. The population from Rt Kamenjak represents the third record in Croatia and the first record of this species in the Mediterranean part of Croatia.

Tortula pallida **(Lindb.) R.H.Zander**

Tortula pallida is a southern European species that is recorded relatively rarely in Europe (Hodgetts & Lockhart, 2020). In the Balkans, it is so far known only from Greece (including Crete). It grows in small tufts, up to 0.5 cm tall, in coastal habitats with a saline influence (Bosanquet, 2021) although populations from inland salt marshes have recently been found in eastern Germany (Müller, 2017). The species is characterized by obtuse to rounded leaf apices, generally yellowish to orange, sometimes reddish seta with cylindrical or ellipsoidal urn up to 1.7 mm long. Findings on Rt Kamenjak represent the first national records of this species in Croatia and the species was found in three localities (Fig. 4).

Zygodon conoideus **(Dicks.) Hook. & Taylor**

This Atlantic-Mediterranean epiphytic acrocarpous moss was found very recently for the first time in Croatia - on the islet of Rava in northern Dalmatia (Sabovljević *et al.*, 2018) and on Mt Velebit (Šegota, 2022.). These were so far the only known findings of this species in the Balkan Peninsula (Hodgetts & Lockhart, 2020). Thus, our findings from two localities on Rt Kamenjak represent the third record of this species in Croatia and the Balkans.

Phytogeographical and biological analysis of the recorded flora

The chorological analysis of the bryophytes collected on Rt Kamenjak showed the predominance of the Mediterranean-Atlantic chorotype (32.4%), followed by the temperate (23.0%) and southern-temperate (21.6%) chorotype (Fig. 5). This corresponds well with the biogeographical characteristics of the studied area, as well as with main features of Mediterranean climate, characterized by hot and dry summers, and mild and rainy winters (Beck *et al.*, 2018). Similarly, the relevance of Mediterranean and temperate elements was reported for the Mediterranean maquis on Crete (Papp *et al.*, 1998).

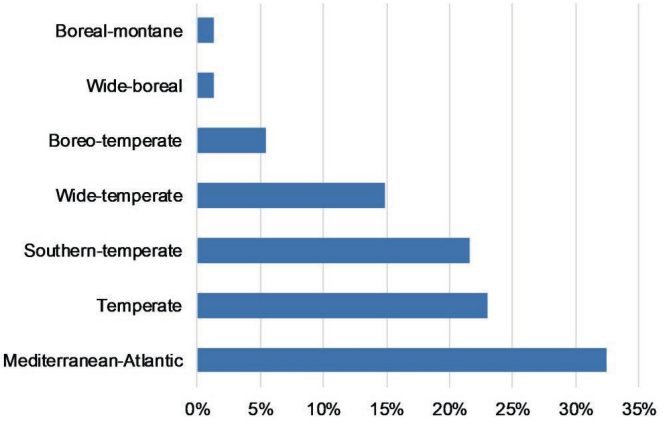

Fig. 5. Chorological spectrum of bryoflora of Rt Kamenjak based on major biomes.

Turfs dominated the life-form spectrum, accounting for 55.0% (41 taxa) of the documented species (Fig. 6). These were mostly represented by numerous small Pottiaceae species, as well as by several Fissidentaceae and Bryaceae species inhabiting moist soil of open habitats in olive groves, maquis and garrigues. The predominance of this life-form is expected in the Mediterranean, since these species produce relatively dense colonies of many loosely or closely packet vertical stems with limited branching, enabling the survival in xeric environments. Such forms can better store water in capillary spaces between the stems and additionally, the evaporative water loss is lower since this form is likely to become enveloped in a laminar boundary layer (Proctor, 1981, 1982; Bates, 1998). The overall predominance of Pottiaceae representatives is furthermore in line with the array of their anatomical and morphological adaptations to a xerothermic environment (e.g. smaller cells, recurved leaves, papillose laminae) which promote the water uptake and storage, as well as reduce water loss. Turfs were followed by rough mats and solitary thalloids, each accounting for 10.8% (8 taxa) out of 74 recorded taxa within the study. The solitary thalloid category was represented by five *Riccia* species, among which *Riccia beyrichiana*, *R. bicarinata* and *R. sorocarpa* were the most frequent. This xerotolerant thalloid liverwort family is typical for the Mediterranean vegetation, its occurrence being limited to more humid parts of the year (spring, winter) (Papp *et al.*, 1998). In the rough mat category, species such as *Rhynchostegium megapolitanum*, *R. confertum*, *Rhynchostegiella tenella*, and *Scorpiurium circinatum* were

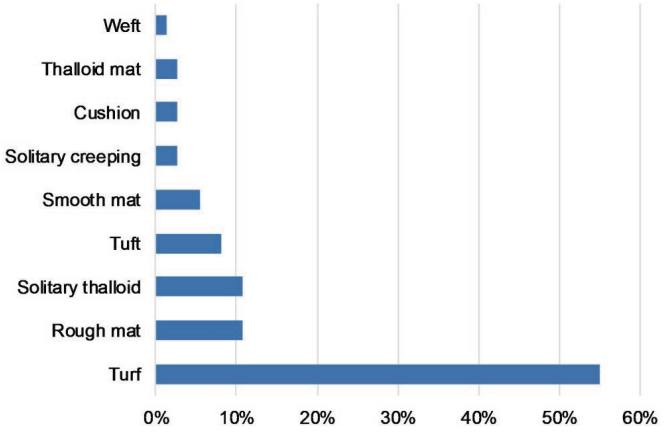

Fig. 6. Life-form spectrum of bryoflora of Rt Kamenjak.

the most common, inhabiting diverse substrates – rocks, soil and tree bark and more shaded habitats within the investigated area.

The analysis of the life strategy spectrum revealed the dominance of colonists, which amounted to 49.2% (29 taxa) (Fig. 7) of the recorded taxa, the majority of them being turfs. Colonists are known to predominate on open soil and paths in the Mediterranean maquis (Papp *et al.*, 1998), as well as in olive groves and are regarded as indicators of the Mediterranean climate (Maccherini *et al.*, 2013). Colonists are stress tolerant species, which successfully tolerate extremes and quickly occupy new environments, which usually last long enough to enable the development of a few generations, i.e. for several years (During, 1979). Colonist species mostly correspond with the turf category of life-form scheme. This is true for annual-shuttle species as well, the second most represented strategy (29.7%, 22 taxa) within the bryoflora of Rt Kamenjak. These ephemeral species finish their life cycle within the very short suitable period, which in the Mediterranean corresponds with the most humid period of the year since the limi-

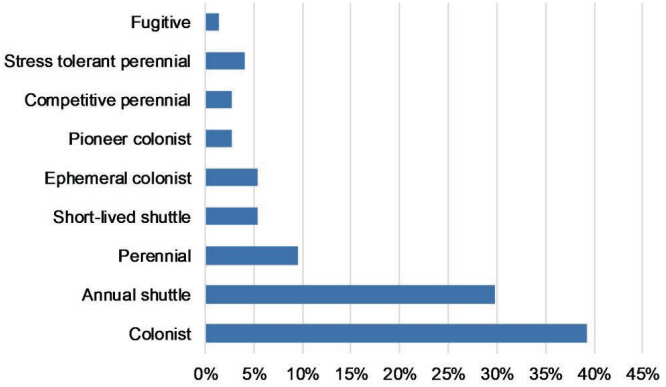

Fig. 7. Life strategy spectrum of bryoflora of Rt Kamenjak.

ting factor for bryophytes is water availability. These species rely on a high production of large and highly resilient spores, which give rise to new individuals when suitable conditions reappear within the same locality or in the vicinity (During, 1979; Kürschner, 2004). These species were mostly found within olive groves and paths passing through the maquis. They included minute taxa such as that of genera *Ephemerum*, *Microbryum*, *Tortula* and *Riccia*, as well as *Acaulon muticum*, *Entosthodon fascicularis*, *Fossombronia caespitiformis*, *Physcomitrium pyriforme* and *Sphaerocarpos michelii*.

The majority of the recorded species were collected from olive groves, as well as from open soil along the paths through maquis and garrigues and on Mediterranean grasslands (Fig. 8). These habitats are already known to host xerotolerant acrocarpous mosses and thalloid liverworts, as well as certain rare and endangered bryophyte species (Papp *et al.*, 1998; Maccherini *et al.*, 2013; Šegota *et al.*, 2020). However, changes in land-use, primarily the abandonment of the land and traditional agriculture over the past five decades, negatively affected these habitats all over the Mediterranean. Abandonment of traditional agriculture (olive groves and domestic animal grazing) led to

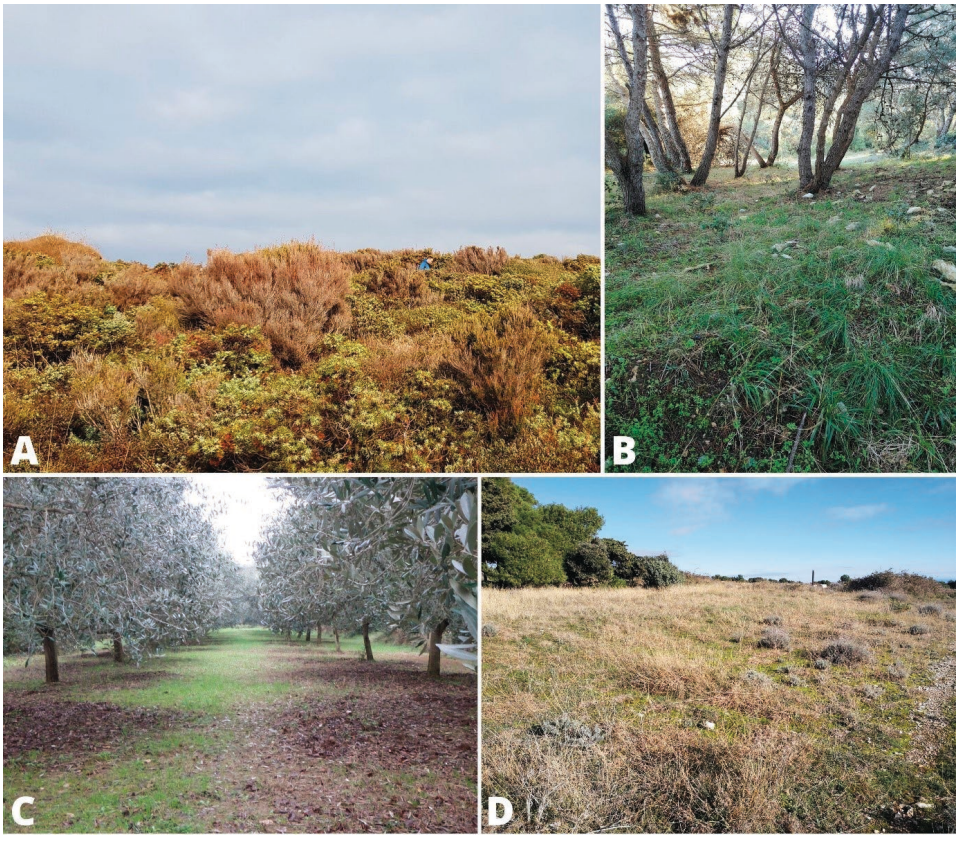

Fig. 8. Habitats promoting the bryophyte diversity on Rt Kamenjak: A–maquis, B–forest edges, C–olive groves, D–grasslands.

the encroachment of woody species on the Mediterranean grasslands and paths through maquis and garrigues. Finally, secondary succession resulted in the loss of both habitat heterogeneity and biodiversity (Myers *et al.*, 2000; Biondi *et al.*, 2006; Maccherini, 2013; Plieninger *et al.*, 2014). These processes can be observed in Croatia, although the situation is somewhat more satisfactory on Rt Kamenjak. This quite small area is protected as a significant landscape and appropriate effort is continuously invested in monitoring and management of the area, considering its biodiversity, with its olive groves, Mediterranean grasslands and open patches in maquis supporting considerable bryophyte diversity.

CONCLUSIONS

This study aims to fill a significant gap in current bryophyte data in Croatia's coastal areas. A significant number of species were discovered on this little, isolated tip of Istria, including numerous new and noteworthy national records, considerably enhancing our understanding of bryophytes in this region. This study paved the way for future inventories of bryophytes throughout the eastern Adriatic coast.

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Appendix 1. GPS coordinates of locations of bryophyte collection in WGS84.

No.	X	Y	No.	X	Y	No.	X	Y
1	13.90836 °E	44.79474 °N	12	13.90503 °E	44.78971 °N	23	13.91574 °E	44.76840 °N
2	13.91287 °E	44.78712 °N	13	13.90861 °E	44.79288 °N	24	13.91913 °E	44.76987 °N
3	13.90886 °E	44.78318 °N	14	13.90572 °E	44.78713 °N	25	13.92025 °E	44.77024 °N
4	13.91095 °E	44.77854 °N	15	13.90719 °E	44.78872 °N	26	13.91149 °E	44.78156 °N
5	13.90682 °E	44.77710 °N	16	13.90750 °E	44.78988 °N	27	13.91328 °E	44.78118 °N
6	13.91109 °E	44.77291 °N	17	13.91009 °E	44.77824 °N	28	13.91001 °E	44.78772 °N
7	13.91068 °E	44.76966 °N	18	13.91122 °E	44.79193 °N	29	13.90996 °E	44.78685 °N
8	13.91943 °E	44.77134 °N	19	13.90685 °E	44.79293 °N	30	13.91504 °E	44.78383 °N
9	13.91936 °E	44.77510 °N	20	13.90598 °E	44.79381 °N	31	13.90942 °E	44.77316 °N
10	13.91056 °E	44.77659 °N	21	13.90555 °E	44.79283 °N	32	13.91534 °E	44.77934 °N
11	13.90626 °E	44.78231 °N	22	13.90524 °E	44.79256 °N			

Appendix 2. List of bryophytes recorded in Rt Kamenjak

Liverworts:

Calypogeiaceae

1. Calypogeia fissa (L.) Raddi

Fossombroniaceae

2. Fossombronia caespitiformis (Raddi) De Not. ex Rabenh. subsp. *caespitiformis*

3. Fossombronia caespitiformis (Raddi) De Not. ex Rabenh. subsp. *multispira* (Schiffn.) J. R. Bray & Cargill

Lunulariaceae

4. Lunularia cruciata (L.) Lindb.

Marchantiaceae

5. Marchantia polymorpha L.

Oxymitraceae

6. Oxymitra incrassata (Brot.) Sérgio & Sim-Sim

Petalophyllaceae

7. Petalophyllum ralphsii (Wilson) Nees & Gottsche

Ricciaceae

8. Riccia beyrichiana Hampe

9. Riccia bicarinata Lindb.
10. Riccia glauca L.
11. Riccia nigrella DC.
12. Riccia sorocarpa Bisch.

Southbyaceae
13. Southbya nigrella (De Not.) Henriq.

Sphaerocarpaceae
14. Sphaerocarpos michelii Bellardi

Mosses:

Brachytheciaceae
15. Brachythecium rutabulum (Hedw.) Schimp.
16. Oxyrrhynchium hians (Hedw.) Loeske
17. Plasteurhynchium striatulum (Spruce) M.Fleisch.
18. Pseudoscleropodium purum (Hedw.) M.Fleisch.
19. Rhynchostegiella tenella (Dicks.) Limpr.
20. Rhynchostegium confertum (Dicks.) Schimp.
21. Rhynchostegium megapolitanum (Blandow ex F.Weber & D.Mohr) Schimp.
22. Scorpiurium circinatum (Bruch) M.Fleisch. & Loeske

Bryaceae
23. Bryum argenteum Hedw.
24. Bryum barnesii J.B.Wood ex Schimp.
25. Bryum dichotomum Hedw.
26. Bryum gemmilucens R.Wilczek & Demaret
27. Bryum ruderale Crundw. & Nyholm
28. Ptychostomum capillare (Hedw.) Holyoak & N.Pedersen
29. Ptychostomum rubens (Mitt.) Holyoak & N.Pedersen
30. Ptychostomum torquescens (Bruch & Schimp.) Ros & Mazimpaka

Ditrichaceae
31. Cheilothela chloropus (Brid.) Broth.

Dicranellaceae
32. Dicranella howei Renauld & Cardot

Funariaceae
33. Entosthodon fascicularis (Hedw.) Müll. Hal.

Fissidentaceae
34. Fissidens dubius P.Beauv.
35. Fissidens incurvus Starke ex Röhl
36. Fissidens taxifolius Hedw.
37. Fissidens viridulus (Sw.) Wahlenb.

Funariaceae
38. Funaria hygrometrica Hedw.
39. Physcomitrium pyriforme (Hedw.) Bruch & Schimp.

Grimmiaceae
40. Grimmia orbicularis Bruch ex Wilson

Hypnaceae
41. Hypnum cupressiforme Hedw.

Mniaceae
42. Plagiomnium affine (Blandow ex Funck) T.J.Kop.

Orthotrichaceae
43. *Orthotrichum diaphanum* Brid.
44. *Zygodon conoideus* (Dicks.) Hook. & Taylor
45. *Zygodon rupestris* Schimp. ex Lorentz

Pottiaceae
46. *Acaulon muticum* (Hedw.) Müll.Hal.
47. *Aloina aloides* (Koch ex Schultz) Kindb.
48. *Aloina ambigua* (Bruch & Schimp.) Limpr.
49. *Barbula unguiculata* Hedw.
50. *Didymodon acutus* (Brid.) K.Saito
51. *Didymodon cordatus* Jur.
52. *Didymodon fallax* (Hedw.) R.H.Zander
53. *Didymodon vinealis* (Brid.) R.H.Zander
54. *Ephemerum cohaerens* (Hedw.) Hampe
55. *Ephemerum recurvifolium* (Dicks.) Boulay
56. *Ephemerum serratum* (Hedw.) Hampe
57. *Gymnostomum viridulum* Brid.
58. *Microbryum curvicollum* (Hedw.) R.H.Zander
59. *Microbryum davallianum* (Sm.) R.H.Zander var. *conicum* (Schleich. ex Schwägr.) R.H.Zander
60. *Microbryum muticum* (Venturi) T.Mahévas, C.Schneider, T.Schneider, D.Cartier & T.Géhin
61. *Microbryum rectum* (With.) R.H.Zander
62. *Microbryum starckeanum* (Hedw.) R. H. Zander
63. *Streblotrichum convolutum* (Hedw.) P.Beauv.
64. *Syntrichia ruralis* (Hedw.) F.Weber & D.Mohr
65. *Tortella squarrosa* (Brid.) Limpr.
66. *Tortella tortuosa* (Hedw.) Limpr.
67. *Tortula acaulon* (With.) R.H.Zander
68. *Tortula muralis* Hedw.
69. *Tortula pallida* (Lindb.) R.H.Zander
70. *Tortula truncata* (Hedw.) Mitt.
71. *Weissia condensa* (Voit) Lindb.
72. *Weissia controversa* Hedw.
73. *Weissia longifolia* Mitt.

Pylaisiaceae
74. *Homomallium incurvatum* (Schrad. ex Brid.) Loeske