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Research article

NEW RECORDS TO THE BRYOFLORA OF THE E SLOPE OF MT. KENYA

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Abstract: The first author studied the bryophyte communities on the East slope of Mt. Kenya through the forest belt between 1600 and 3000 m elevations. Seven sampling plots were selected at each 200 m altitudinal interval. At each sampling plot microclimate data measurements were carried out for six months between July and December 2020 using dataloggers and the composition of epiphyllous communities was studied in details with special reference to the host plants. Tamás Pócs and his team (Bence Együd, Judit Havasi and Mária Szegedi) joined to this research during the August of 2021, to help in further collection and identification work. The collected specimens are deposited in the herbaria of EA and EGR. Majority of the collections have already been identified. The discovery of the only mainland African occurrences of the Lemurian *Microlejeunea inflata* and *Leptodon fuciformis* are outstanding results. Other species are new for Kenya: *Cololejeunea platyneura*, *Cyclodyction subbrevifolium*, *Diplasiolejeunea deslooveri*, *Fissidens intramarginatus* and *Telaranea coactilis.* The last author visited the same sites 2004 with his late wife, Sarolta Czímer, guided by Min S.Chuah-Petiot from Nairobi University and from their collection *Gemmabryum subapiculatum*, *Orthotrichum denticulatum*, *Lophocolea fragrans* and *Lophocolea muricata* proved to be new to Kenya.

Keywords: Africa, endemism, Kenya, Lemurian element

INTRODUCTION

Mount Kenya (Kirinyaga) is the highest mountain in Kenya and the second highest of Africa, with its 5199 m elevation. It lies just at the S side of Equator and was formed by tertiary volcanic activity. Protected as a national park, since 1949, spreading over 120 km diameter, at 71500 ha area, quite isolated by the surrounding lowland (Bennun and Njoroge 2000).

Mount Kenya attracted many botanists but its bryological exploration started relatively late. The first bryophyte collectors were probably R. E. and Th. C. E. Fries in 1922 (Vanden Berghen 1951). Three later publications contained the majority of records. O.Hedberg's afroalpine collections (including many records from Mt. Kenya) were identified and pulished by Potier de la Varde (1955) and by S. Arnell (1956). M. S. Chuah-Petiot carried out intensive fieldwork in the mountains for several years. She reported 194 bryophyte species of which 38 species were new to Mt. Kenya and 30 others for the whole country (Chuah-Petiot 1995). Apart from these many publications contain scattered records from the mountains.

The first author made a comprehensive documentation of the epiphytic bryophyte communities along the Chogoria Trail, located SW of Meru town, on the East, windward slope of Mt. Kenya. The permanent sampling plots (PSPs) were spread through the whole forest belt between 1600 and 3000 m elevations, at each approximately 200 m altitudinal interval. Mugambi and Patel were instrumental in site selection and description.

The sampling plots are marked by the following abbreviations:

Nt: 1640 m. Degraded submontane rainforest dominated by *Anthocleista grandiflora–Diospyros abyssinica,* mixed with *Strombosia scheffleri, Agelaea pentagyna* and *Allophylus abyssinicus*.

Ch1: 1800 m. S 00°13.95', E 37°32.11'. Disturbed montane rainforest dominated by *Zanthoxylum gilletii - Harungana madagascariensis,* with *Tabernaemontana stapfiana, Elaeodendron buchananii, Xymalos monospora* and *Strombosia scheffleri.*

Ch2: 2000 m. S 00°14'.09", E 37°33'.05". Montane rainforest dominated by *Anthocleista grandiflora, Cassipourea malosana, Macaranga kilimandscharica,* intermixed with *Podocarpus latifolius* and *Xymalos monospora.*

Ch3: 2200 m. S 00°14'09", E 37°33'.05"'.Montane rainforest dominated by *Kuloa usambarensis, Afrocarpus falcatus, Cassipourea malosana,* mixed with *Galiniera saxifraga, Xymalos monospora* and *Podocarpus latifolius.*

Ch4: 2400 m. S 00°12'29", E 37°30'02". Upper montane rainforest dominated by *Afrocrania volkensii*, *Schefflera volkensii*, mixed with *Nuxia congesta*, *Cassipourea. malosana* and *Podocarpus latifolius.*

Ch5: 2600 m. S 00°11'23", E 37°28'34". Bamboo (*Yushania alpina*) forest with scattered and emergent *Nuxia congesta* trees.

Ch6: 2800–2950 m. S 00°10'04"', E 37°28'08". *Juniperus procera* forest intermixed with *Afrocarpus falcatus, Hagenia abyssinica* and *Yushania alpina.*

During our recent trip we collected only in the plots No. Ch2, Ch3, Ch4 and Ch6 and at 2100 m, between Ch2 and Ch3: **Ch2.2** and at 2300 m, between Ch3 and Ch4: **Ch3.2**. The spot numbers with boldface are used in the enumeration of records.

MATERIAL AND METHODS

Tamás Pócs and his team (Bence Együd, Judit Havasi and Maria Szegedi) joined to this research during the August of 2021, to help in the collection and identification work. Pócs visited the same route earlier, in February 2004 with his wife, Sarolta Czímer, guided by Min Chuah-Petiot from Nairobi University. The collected and already identified specimens from both collections are deposited in the herbaria of EA and EGR.

RESULTS

The records new to Kenya or the whole of continental Africa, according to Wigginton (2018) and to O'Shea (2006), are enumerated below:

Liverworts

Cololejeunea platyneura (Spruce) A.Evans occurs between 2000 and 3000 m in Guinea, Sierra Leone, Nigeria, DR Congo, Rwanda, Tanzania, Malawi and Madagascar (Fischer 2013, Wigginton 2018). Epiphyllous in montane forests. – *Malombe et al.*, at 2200 (**Ch3**) and 2900 m (**Ch6**).

Diplasiolejeunea deslooveri Vanden Berghen distributed in DR Congo, Rwanda, Kenya, Zimbabwe, Mozambique, South Africa. Epiphyllous or epiphytic in montane forest, 2500 m (2200 m in Mt Kenya, **Ch3**).

Lophocolea fragrans (Moris et De Not.) Gottsche, Lindenb. et Nees. is a species with very scattered (or unknown) distribution from the oceanic and Mediterranean parts of Europe, from Costa Rica, East China and from a few localities in Africa (Paton 1999, Wigginton 2018). Not yet known from Kenya. – *Pócs & Chuah-Petiot* 04003/A, at 2300 m, corticolous, the same locality, as **Ch3.2**.

Lophocolea muricata (Mitt.) Schiffn. is a Pantropical-oceanic temperate species widespread in Africa but hitherto was unpublished from Kenya (Grolle 1959, Wigginton 2018). *Pócs & Chuah-Petiot* 04010/F, at 2180 m, on decaying log, the same, as **Ch3.**

Microlejeunea inflata Steph. (*Figure 1*). KENYA: **Ch4**, Epiphyllous on *Podocarpus latifolius* leaves.The extension of its known distribution to mainland Africa is remarkable. The species hitherto was known only from the Indian Ocean Islands (Grolle 1995). Good illustration of the species is done by Pócs (2002: 18, fig. 6). Type: from MADAGASCAR: without closer indication of locality: *Forsyth Major* 1000, in Stephani 1915), later published from the Antsiranana Prov., Réserve spéciale de Manongarivo (Pócs and Geissler 2002) furthermore there are three unpublished records from Madagascar: Toamasina Prov., Maromizaha forest S of Andasibe National Park at 1200 m, epiphyllous on *Pandanus* leaves, *S. Pócs* 9890/CL; Antsiranana Prov., Marojezy National Park, 780–1050 and 1830 m, epiphyllous, *Pócs et al.* 90113/EC and 90114/KA. From COMORO Islands: Ndzouani Island, first reported by Pócs (1993, confirmed by Grolle 1995), from Mayotte Island also became known (Chongui peak, 300-500 m, epiphyllous, *Pócs & Magill* 9287/AD, det. Grolle; Dapani, Réserve Forestière des Crêtes, 110-210 m, on roots, *S. & T. Pócs* 05080/G, NW du village Chembényoumba, 34 m, on roots, *S. & T.Pócs* 05090/G (all Mayotte records unpublished). It is known from many localities in RÉUNION Island (fully enumerated by Ah-Peng *et al.* 2010). New to the SEYCHELLES, Mahé Island, Morne Seychellois Nat. Park, summit ridge of Morne Blanc in mossy elfin forest dominated by *Northea seychellarum* and *Roscheria melanochaetes.* 600-667 m, epiphyllous. *Pócs 00102/Q and 01539/R* and Mahé Island, Grand Bois, on leaves of *Vateriopsis seychellarum,* J. Gerlach s.n. 2 Aug. 2002, det. Pócs.

Telaranea coactilis (Spruce) J.J.Engel & G.L.Merr. (*Figure 2*). Among other bryophytes. Earlier this species was treated as *Arachniopsis diacantha* (Mont.) Howe, with tropical African-American distribution (Gradstein *et al.* 1984). Engel & Smith Merrill (2004) in their revision of genus *Telaranea* distinguished two species formerly known as *Arachniopsis diacantha* under the binomials of *Telaranea diacantha* (Mont.) Engel & Merr. and *Telaranea coactilis* (Spruce) Engel & Merr., giving good distinguishing characters between the two in the shape and size and cell number leaf segments. Although both species were recorded from Africa, *T. coactilis* was not known from Kenya (Wigginton 2018). **Ch3**, on decaying log in the cushion of *Syrrhopodon asper* Mitt.

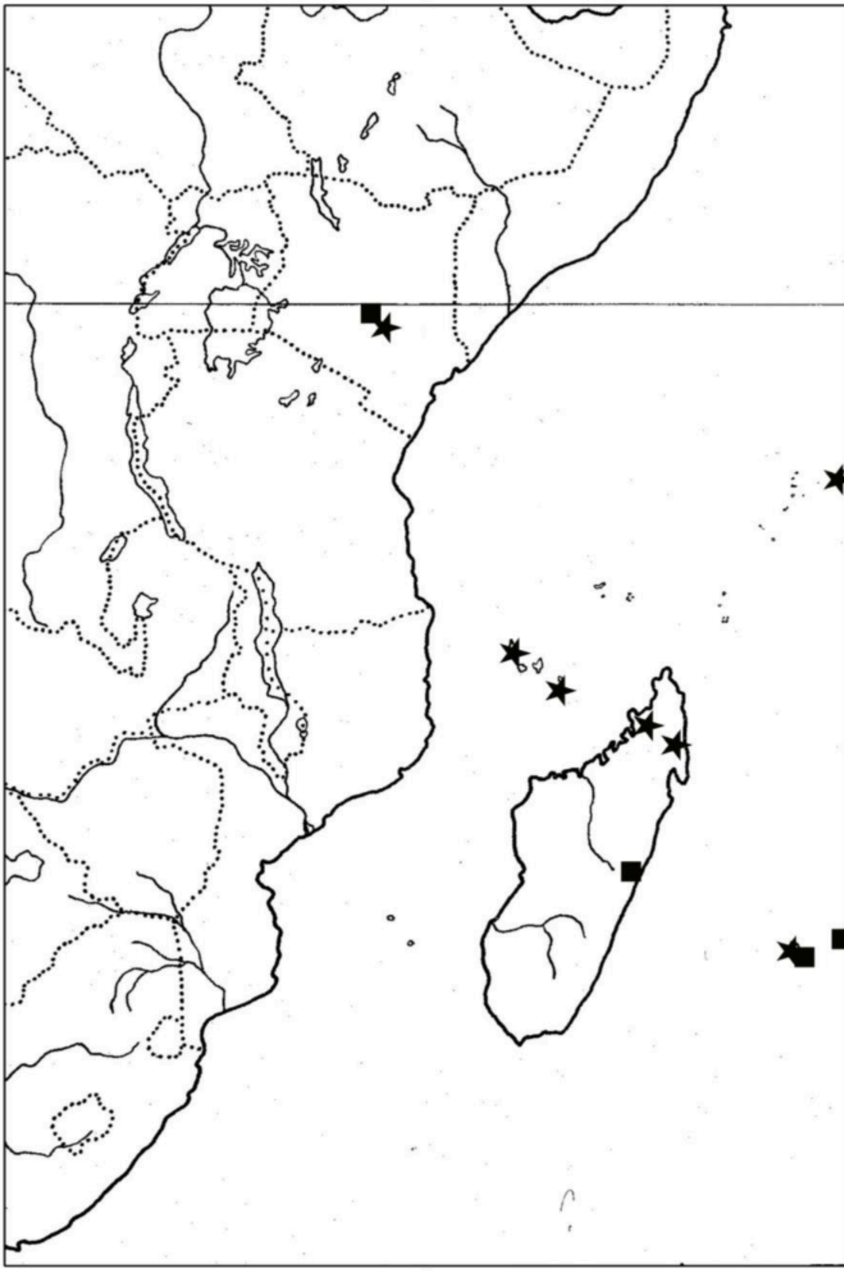

Figure 1. Distribution of *Microlejeunea inflata* Steph. (asterisk) and of *Leptodon fuciformis* (Brid.) Enroth.

Mosses

Cyclodictyon subbrevifolium Broth. (*Figures 3–4*). A species described and till now known only from Tanzania, Mt.Kilimanjaro along the Marangu Route at about 2800 m. New to Kenya: **Ch3.** Typical characters are the broad ovate leaves with acuminate apex and subentire or entire 2-seriate margin, with obsolete teeth (Demaret and Potier de la Varde 1951).

Fissidens intramarginatus (Hampe) A.Jaeger. An Afro-American disjunct widespread in tropical Africa, but new to Kenya: **Ch3**, on decaying log. The specific characters are the limbidia extending the whole length of vaginal laminae and the pluripapillose leaf cells with low and blunt papillae (Bruggeman-Nannenga 2006).

Gemmabryum subapiculatum (Hampe) J. R. Spence & H. P. Ramsay. Syn.: *Bryum subapiculatum* Hampe. A cosmopolitan species hitherto known in East Africa only from Tanzania (Bizot et al. 1979), new to Kenya. On shady rock in bamboo forest, *Pócs & Chuah-Petiot* 04008/P, same locality as **Ch5**.

Leptodon fuciformis (Brid.) Enroth (See *figures 1* and *5–8*). The species was hitherto considered to be an Indian Ocean Islands endemic known under the name of *Pinnatella fuciformis* (Brid.) Touw. and known only from Madagascar, Mauritius and Réunion. It is related to *Leptodon smithii* (Hedw.) F.Weber & D.Mohr, widespread also in the drier montane forests of continental Africa. But well differs by the hanging habit bipinnately branching at its lower and remotely and irregularly branched upper part with tapering branches which are not inrolled even in dry state (Enroth 1992). **Ch6.** Epiphyte hanging from *Juniperus procera* twigs.

Orthotrichum denticulatum Lewinsky. A rare East African montane epiphyte only known from Ethiopia, Rwanda and Tanzania occurring between 1700 and 2700 m.It is recognized by ovato-lanceolate leaves with broadly recurved margin and hyaline, denticulate apex, strongly 8-ribbed theca with cryptopore stomata. (Lewinsky 1978). New to Kenya: *Pócs & Chuah-Petiot* 04008/A (same as **Ch5**), on bamboo (*Yushania alpina*) twigs.

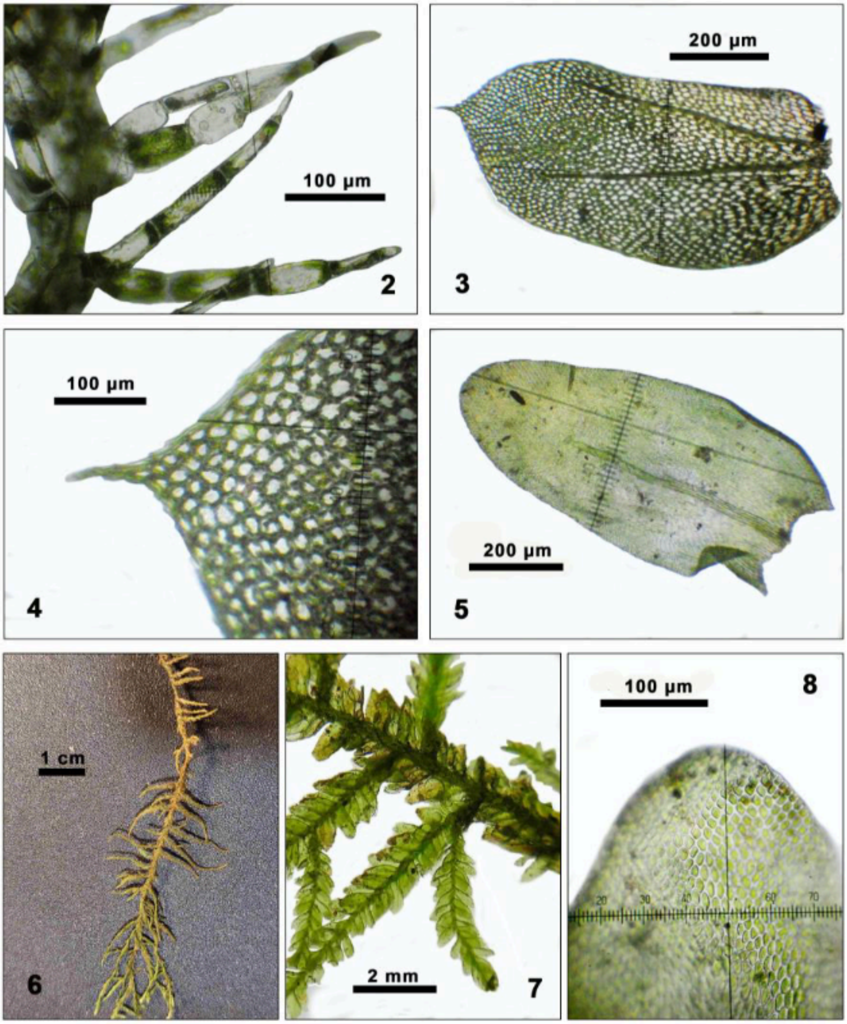

Figure 2. *Telaranea coactilis* (Spruce) J.J.Engel & G.L.Merr., part of shoot, dorsal, view (from *T. Pócs et al. Ch3.CA*). **Figures 3–4.** *Cyclodictyon subbrevifolium* Broth., leaf and leaf apex (from *Ch3.A*). **Figures 5–8.** *Leptodon fuciformis* (Brid.) Enroth, leaf, habit of hanging specimen, shoot with side branches and leaf apex (from *Ch.6A*).

DISCUSSION

As from the above examples can be seen, even the best investigated areas of Kenya can provide new records, what calls attention to the still inadequately searched Kenyan bryoflora, waiting for new discoveries. The enumerated bryophytes are either widespread but overlooked taxa or rare species hitherto known only from their type locality or new to the continent. Also, some Lemurian (mostly on Indian Ocean islands distributed) species, atlhough are concentred in mainland Africa to the Eastern Cristalline Arc mountains, can occur also on some isolated volcanoes in Kenya, like *Microlejeunea inflata* and *Leptodon fuciformis.* In particular, the study and dicovery of epiphyllous bryophytes from the entire range of afromontane and montane forests in Mt Kenya lays a formidable baseline for monitoring biodiversity shifts underscored by the impacts of climate change.

Acknowledgement – The first author thanks the National Geographic Society for the generous funding on the exploration of the first comprehensive epiphyllous bryophyte diversity in Mt Kenya. He also humbly acknowledges facilitation by the National Museums of Kenya, Meru University of Science and Technology, Kenya Forest Service, National Council for Science, Technology and Innovation and Kenya Wildlife Service. The local community representatives through the Community Forest Association are also recognised for their active participation during the field studies. The second author and his team are very grateful to Dr. Itambo Malombe, organising transport and guiding to his permanent research plots in three regions of Kenya and to Dr. Min Chuah-Petiot organizing a course at Nairobi University and within its frame taking Tamás Pócs and his wife to Mt. Kenya along the Chogoria trail. The authors acknowledge the careful review of the paper by Dr. Andrea Sass-Gyarmati and Dr. Sándor Orbán.

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BRYOPHYTE COLLECTIONS OF ESZTERHÁZY KÁROLY CATHOLIC UNIVERSITY (EGR): THE DIGITAL DATABASE OF MALAGASY SPECIMENS

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Abstract: The paper describes the Malagasy collections in the cryptogamic herbarium of the Eszterházy Károly Catholic University (EGR), Eger (Hungary), according to its condition in 2022. All specimens were documented: all data from the labels were entered into MS Excel spreadsheet, and in the case of type material digital photographs are also taken. The oldest Malagasy specimens hosted in the herbarium are the isotypes of *Brachymenium borgenianum* Hampe and *Bryum subargenteum* Hampe, both specimens collected by M. Borgen in 1870. The main aim was to digitalize and publish information on the cryptogam herbarium in order to provide an easier access to the data. The digital photographs and the database are property of the Department of Botany and Plant Physiology of Eszterházy Károly Catholic University. Data of Madagascar specimens database are summarized in an electronic appendix including: catalogue number, taxon name, collector, locality, date of gathering and file name of the documentary photograph. Further data can be required from the curator of the herbarium.

Keywords: biological collections, herbarium digitization, Madagascar bryophytes

INTRODUCTION

The herbarium of the Eszterházy Károly Catholic University (acronym: EGR) is the second largest herbarium in Hungary (Takács *et al.* 2014), consisting of two main parts. The cryptogam collection, which is one of the largest in Central Europe (consisted by 200.000 identified bryophytes, and 8000 lichenized and moss parasitic fungi) is widely known among bryologists. It has gained an international reputation for the collections of Prof. Tamás Pócs and his colleagues, who studied and collected bryophytes all over the tropics. This collection comprises lichens mainly from Europe and Africa, but the main part are the bryophytes collected predominantly in the tropical regions of Africa, India, Indonesia, Vietnam, Papua New Guinea, Australia, Fiji, Cuba, Peru and Venezuela. The vascular collection is quite small in number, but not negligible (Sass-Gyarmati and Vojtkó 2010; Pénzesné Kónya *et al.* 2013). It is mainly valued for the age and collectors of its specimens, dating back to the early 19th century. It stores the collections of significant Hungarian botanists of that time, providing information about their trips and interests in certain regions or taxa. The vascular collection includes vouchers collected primarily in the territory of present-day Hungary and the neighboring countries (mainly in the Carpathian Basin), but there are specimens from the Alps, Silesia, the Balkan and from the coastal regions of the Adriatic Sea as well. The vascular collection has been digitized (E. Vojtkó *et al.* 2014), followed by digitization of the *Sphagnum* (peat moss) specimens, as well as the first batch of the cryptogam collection (Kapi and Sass-Gyarmati 2020).

Digitization and analysis of the cryptogamic herbarium is still an actual challenge for us. Digitization process of the Malagasy bryophytes started in 2020. The aim was to create a database of the Malagasy species belonging to the cryptogamic collection of EGR, including all main attributes of each herbarium specimen, accompanied by digital photos of the type specimens. Currently, some other Hungarian herbaria are being processed similarly, e.g. BP (Hungarian Natural History Museum) (Papp and Rajczy 1998), DE (Szarvas *et al.* 2010).

MATERIAL AND METHODS

The database comprises the material collected until 2018. Methods of digitization and database building process mostly followed Molnár V. *et al.* (2012) and Takács *et al.* (2014). The nomenclature of the species follows Söderström *et al.* (2016), Wigginton (2018) for the liverworts and hornworts and O'Shea (2006) for the mosses. First the information on the labels was entered into Ms Excel spreadsheet, where rows correspond to individual records and columns represent attributes of the collected specimens. The following attributes were recorded: (1) taxon name on the label, (2) collector (or collectors) name, (3) collecting number (4) identifier person name (5) data of gathering and (6) detailed locality data. One record of the database represents specimen(s) of the same taxon collected from the same locality at the same time on one capsule. If a herbarium capsule contains specimens of different taxa, they are treated as same records, the species name are included in brackets. Thus, the number of records (= rows in the database) could represent sometimes more than one species. In the case of type material, digital photographs were taken from the label of each capsules. The digital photos were taken using '.jpg extension, and their average size is 1.5–2 MB. In the case if collecting dates were given as intervals (very often in case of foreign collections) we record the earlier data. Data of the Malagasy database are summarized in an electronic appendix https://uni-eszterhazy.hu/biology/m/egr/database. Further data can be required directly from the curator of the herbarium.

RESULTS AND DISCUSSION

Representations of the Malagasy species and floristically significant records

The database contains 2004 records (evidence based on: 2022) of which 435 species, 14 subspecies and 26 varieties are recorded of more than 100 collectors. The most important are the 115 type specimens (29 holo-, 27 iso-, 4 topo-, 3 isoparatype-, 51 paratype and one specimen with „type" mention). Specimen labels collected from Madagascar, written by typing machine or computer and are easily readable. Anyway, a few problems occured with those written in Chinese.

The oldest Malagasy specimens are from the 19th century, the isotypes of *Brachymenium borgenianum* Hampe and *Bryum subargenteum* Hampe. Both specimens were collected by M. Borgen in Madagascar with no specification or details of the precise location. These specimens arrived as exchange material (*Figure 1*). All other specimens are collected from 20th and 21th century.

Figure 1. Isotypes of *Brachymenium borgenium* Hampe and *Bryum subargenteum* Hampe, the oldest specimens collected from Madagascar, held in Eger (photos: A. Sass-Gyarmati).

The Malagasy specimens of EGR under study were collected between 1870 and 2018. The intensity of collecting was very uneven, as the vast majority of specimens were obtained between 1990–1999. The collection of the specimens from Madagascar can be dated from the first half of the 1990's and from 2004, when travel and financial conditions made this possible. Professor Tamás Pócs participated in altogether four times (1990, 1994, 1998, 2004), members of the Botanical Department accompanied him once time and collected on the 1994 Madagascar research trip. Before and after this period, materials were sent to our herbarium mainly by gift or exchange. In 2018, another opportunity was opened to collect moss on the island on behalf of the French Museum of Natural History, this time by Andrea Sass-Gyarmati in the frame of „Madbryo" Project. A decade-long breakdown shows that most of the samples, numerically 1520, came from the period 1990–1999 (*Figure 2*).

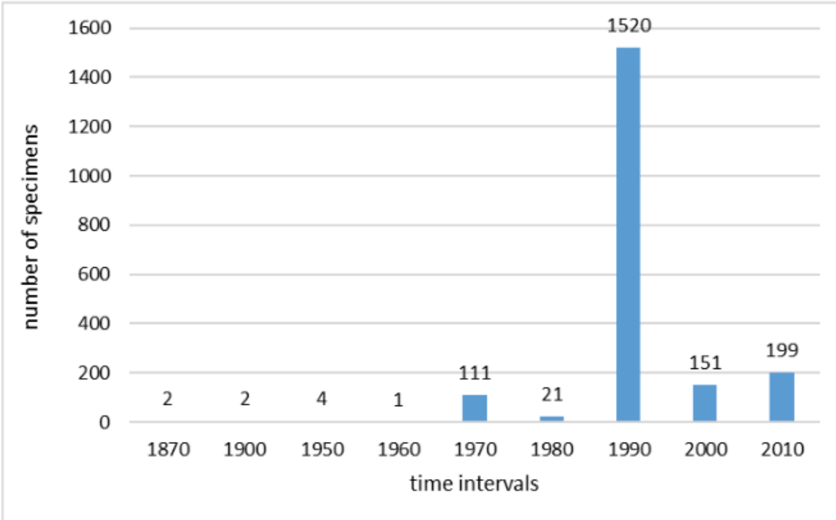

Figure 2. The number of collected specimens by time intervals.

The majority of the specimens belongs to the largest families. The best represented genera are shown in the table below (*Table 1*).

Table 1. The best represented genera in Madagascar, by number and percentage.

Genera	*nr.*	*percentage*
Plagiochila	241	11.99%
Diplasiolejeunea	186	9.25%
Bazzania	149	7.41%
Frullania	104	5.17%
Syrrhopodon	107	5.32%
Cololejeunea	89	4.43%
Sphagnum	83	4.13%
Drepanolejeunea	80	3.98%
Radula	66	3.28%
Calymperes	62	3.09%

The species of genera listed in the table are the most numerous also in the other tropics, belonging to the families among others of Lejeuneaceae, Lepidoziaceae, Frullaniaceae, Radulaceae, Calymperaceae, which account for more than 2/3 of the data set. In fact the identification of many specimens or entire genera is still pending, being in boxes at the stage as they were collected. In some cases researchers are working on them in the present time (eg. *Bazzania, Cololejeunea, Plagiochila*, *Radula, Bryaceae, Campylopus, Leucoloma* and *Sphagnum*) and hopefully their results will be published soon. So the larger collections of the nineties of past century has only been partially identified and databased. Since the 2000s onwards, the increasingly strict rules for issuing exploration permits and transfer of specimens to their specialists practically slowed down further collections on the island.

Representation of Malagasy collections in the herbarium – important collectors

Table 2. Summary of the collections of Hungarian collectors.

Hungarian collectors	*nr. of collected specimens*
Tamás Pócs	313
Sándor Orbán	119
András Vojtkó	89
Gabriella Kis	73
Andrea Sass-Gyarmati	42
Sarolta Pócs	10
Tamás Pócs, Sarolta Pócs & András Szabó	103
Tamás Pócs & András Szabó	79
Kata, Sarolta, Tamás Pócs & András Szabó	24
Tamás Pócs & András Vojtkó	2
Tamás Pócs & Sarolta Pócs	49

Table 2 summarizes the activity of Hungarian collectors. Where there are several collectors included on the label this means that they were together at a particular collecting site, however, the name of the collector at that time not always clear, so these combinations appear on the original labels according to the table. Tamás Pócs also participated on several occasions as member of foreign granted projects, so his name appears in 57.4% of the labels.

Important foreign collectors who contributed substantially to the collections enrichment are: C. Lafarge-England, R.E. Magill, P. Geissler, Lü, A. Randrianasolo, M. Onraedt., R. Ranaivojaona and D. A. Callaghan (*Table 3*).

Table 3. Important foreign collectors from Madagascar.

Foreign collectors	*Nr. of collected specimens*
T. Pócs, C. Lafarge-England & R.E. Magill	272
P. Geissler	152
D. A. Callaghan	127
Lü	57
M. Onraedt	45
P. Tixier	16
D. J. Mabberley	10

Geographical coverage

Based on collected specimen data our results are in concordance with the vegetational diversity of Madagascar (*Figure 3*).

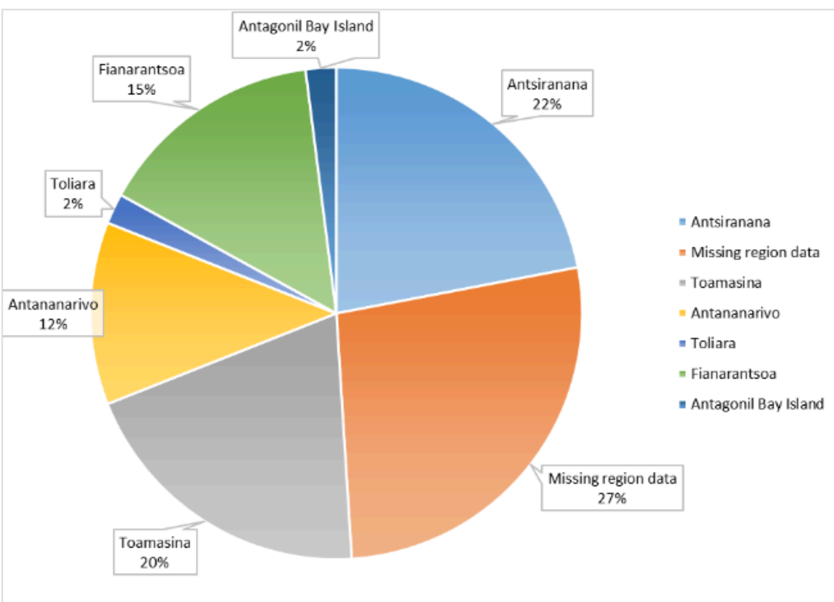

Figure 3. The number of collected specimens and their geographical representation in the regions of Madagascar.

The highest number of specimens occurs in the province of Antsiranana which is justified by the presence of the Reserve Integrale Nationale de Marojejy and the Reserve Speciale de Manongarivo in the province, which are characterized by the relative easy availability and the very high diversity of vegetation and the outstanding number of endemisms. A key target for researchers is to make collections here, but this is facing serious difficulties these days, making them one of the most valuable specimens in our collection. There are two priority areas in the province of Toamasina: one in Andasibe-Perinet, which may be popular due to its proximity to the capital, and all researchers visiting Madagascar visit this National Park. Similarly, special habitats can be found in the same province in the Mananara Nord Biosphere Reserve and National Park, from where we have very rich material. The third well-explored area is the Ranomafana National Park, located in the province of Fianarantsoa and due to its diverse habitats and endemisms, remains a priority area for exploration. In the case of the southern province of Toliara, where the rainy season decreases and dry thorn bush develops, where bryophytes are present in smaller amount and diversity, it is justified that lesser bryophytes were collected from here. In spite of their difficault approach the Masoala Peninsula and Marojezy National Park poved to be very promising areas for future exploration.

CONCLUSIONS

In our herbarium the Malagasy specimens are in the the same storage cabinets with other tropical bryophytes. About 75 % of the Malagasy specimens were collected by Hungarian botanists, mainly by members of the Botany Department (Madagascar 1994, 1996, 1998, 2004, 2018), and the other specimens came in exchange or as gift materials to the herbarium from foreign researchers. The greatest significance of the completed database is that the Malagasy collection of the Herbarium is now electronically searchable, which facilitates the research work and more efficient management of the collection. Based on the database, which is also available online, the species, collector name and year are now searchable. For more detailed data contact of the herbarium curator (the Author of this paper) is required, who can assign additional data and borrow the material (except for types) if necessary. Domestic and foreign herbariums can also access the data, which can promote the loans between herbaria and provide more detailed information on our specimens.

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Research article

LOW UNDERSTORY CONDITION IN AN OAK FOREST IN HUNGARY, 1972 AND 2022 – SÍKFŐKÚT PROJECT IS 50 YEARS OLD

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Abstract: Serious oak decline was first detected in 1979-80 in a mixed sessile oak–Turkey oak forest (*Quercetum petraeae-cerridis* Soó 1963). This decline resulted important structural changes in the understory shrub layer. Despite of this, relatively few studies deal with shrub communities and shrub layer dynamics after oak death. The goals of this research were to determine the conditions of low shrubs and analyse the possible changes in this layer after 5 decades from the beginning of Síkfőkút research. Specimens which were lower than 1.0 m in height were categorized as low shrubs in the shrub community. In 1972 and in 2022, 16-17 native low shrub species were observed in the understory; 15 species were present continuously in the forest. The density of low shrubs was 87401 and 17317 specimen ha^{-1}. The most common low shrub species was *Ligustrum vulgare* and 5 decades later *Quercus petraea* with 24.1% and 37.8% ratio. The mean height and mean diameter of low shrub species changed among 10.3-67.0 cm and 1.5-7.5 mm. The mean cover of these shrubs fluctuated between 35 cm^2 and 2026 cm^2 based on the two measured year. Our results suggest that the low shrub layer responded negatively to the biotic and abiotic factors under 5 decades; this is especially true to the density, cover and diversity indices of species.

Keywords: low shrub layer, oak decline, density, mean size, foliage cover

INTRODUCTION

Oak decline has been described as a widespread and complex phenomenon in many countries (Tomiczek 1993, Sonesson and Drobyshev 2010). An increase in the death of oak species has been observed in many regions of Hungary since 1978 (Igmándy 1987). In the Síkfőkút research stand (*Quercetum petraeae-cerridis* Soó 1963) species composition of the canopy was stable until 1979 and the healthy *Quercus petraea* Matt. L. (sessile oak) and *Quercus cerris*

L. (Turkey oak) also remained constant. Serious oak decline was first reported in 1979–80 (Kotroczó *et al.* 2005) and by 2017, 62.9% of the oaks had died (Misik and Kárász 2020). This decline resulted many significant changes in the condition of shrub layer on Síkfőkút (Misik *et al.* 2013, 2014).

Understory and overstory relationships are complex and mutual but are dominated by the canopy structure and condition (Burrascano *et al*. 2011, Burton *et al*. 2011, Cutini *et al.* 2015). Shrub layers of forest ecosystems change dynamically and respond sensitively to the environmental changes (Chipman and Johnson 2002, Rees and Juday 2002). They are strongly related to the composition and structure of the overstory (Palik and Engstrom 1999, Chianucci *et al.* 2016). Shrub species play a major role in the cycles of some essential nutrients, including the dynamics of nitrogen, potassium and carbon (Gilliam 2007, Juhos *et al.* 2021). The shrub layers are directly contributes to forest biodiversity (Kerns and Ohmann 2004, Aubin *et al.* 2009), including compositional and structural diversity, enhancing the aesthetics of forest ecosystems and helping to protect watersheds from erosion (Alaback and Herman 1988, Halpern and Spies 1995, Muir *et al.* 2002). Shrubs provide food and habitat, among others, for song-birds, forest ungulates and arthropoda (González-Hernández *et al.* 1998, Yanai *et al.* 1998), can mitigate forest decline and influence forest regeneration through affecting light availability (Kunstler *et al.* 2006). Relatively few studies deal with shrub communities and shrub layer dynamics after oak death and the relationship between the trees and shrubs (Légaré *et al.* 2002).

In Hungary, the interdisciplinary, long-term biosphere research program "Síkfőkút Project" was established within the framework of the IBP (International Biological Program) organized by the ICSU (International Council of Scientific Unions) and the MAB (Man and Biosphere Program) launched by UNESCO. In our country, the LTER projects carrying out long-term ecological research were partly created from these. The Síkfőkút Project is also such a scientific research program, 50 years ago this year. The entire research concept was presented in detail by Pál Jakucs in his paper (Jakucs 1973). In the predecessor institution of Eszterházy Károly Catholic University, Imre Kárász former department head and institute director directed the extensive investigation of production and structural condition in the shrub layer from the beginning. These studies included research on the species richness and number of individuals (density), biomass and root structure studies, and measurements of the size and foliage cover of the shrub's species (Kárász 1991).

Misik *et al.* (2013) described the possible responses of parameters of understory shrub layer to the remarkable changes in stand density on the study site. Misik *et al.* (2014) reported the dynamics behind the increase in the sizes of woody species and the structure of the new subcanopy layer below the canopy. The aim of the study was to investigate the composition, size condition, foliage cover and diversity of low understory in the mixed oak forest and analysed how low shrub layer changed after five decades of the structural measurements in the monitoring plot.

MATERIAL AND METHODS

Study site

The research site (Síkfőkút Project) was established in 1972 by Jakucs (1985) and is located in the Bükk Mountains (47°552 N, 20°462 E) in the north-eastern part of Hungary at an altitude of 320-340 m a.s.l. and 6 km from the city of Eger (*Figure 1A*). The continuity of long-term research the forest section in order to ensure it, in 1976 the forest stand was declared a nature reserve with a nationally important (Jakucs 1985). Management and maintenance of the 27 hectares protected area is the responsibility of the Bükki National Park Directorate. The study area belong to the ILTER (International Long-Term Ecological Research) sites and has been used for the long-term study of forest ecosystems. Mean annual temperature is 9.9 °C and mean annual precipitation ranges typically from 500 to 600 mm. Descriptions of the geographic, climatic, soil conditions, and herbaceous layer were reported in detail by research papers (Kiss and Berki 1996, Koncz *et al.* 2010, Switoniak *et al.* 2014). The mixed oak forest community with a dominant canopy of *Q. petraea* and *Q. cerris* deciduous tree species structure is presented in the works of Mázsa *et al.* (2005), Kotroczó *et al.* (2007) and Fekete *et al.* (2017). Both oak species are important dominant native species of the Hungarian natural woodlands. The long-term dynamics of understory shrub layer are described among others in works of Misik *et al.* (2013, 2017) and Misik and Kárász (2022). The plots under study were made up of evenly aged temperate, deciduous forest that was at least 110 years old and had not been harvested for more than 55 years.

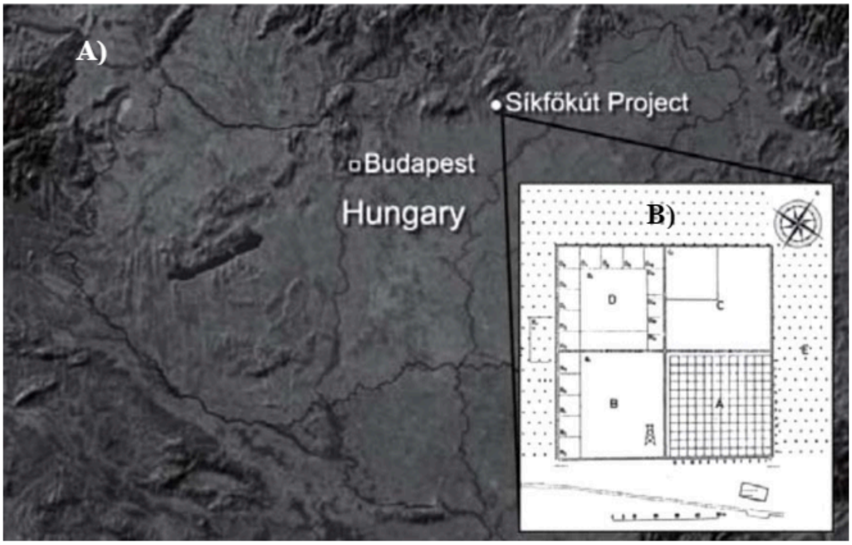

Figure 1. A) Location of the study area in Hungary. **B)** Study site location with plots (Misik and Kárász 2022)

Sampling and data analysis
The structural condition of the low shrubs was monitored on "A" plot at the research site, 48 m × 48 m in size; the plot was subdivided into 144 pieces 4 m × 4 m permanent subplots (*Figure 1B*). The subplots were established in 1972; the understory data collected at subplots measured during the 1972 and 2022 vegetation periods (in June or in July) on site. The dominant and co-dominant shrub specimens of the vegetation were lower than 1.0 m of height were categorized as low understory. Oak stems < 50.0 cm and between 50.0 and 100.0 cm of height were inventoried and categorized as oak seedlings and oak saplings.

The following measurements were carried out for low shrub species in each subplot: species composition, species density, height and diameter, mean foliage cover of species and finally diversity indices. The shrub specimen's density was extrapolated for one hectare. It was recorded the specimen height with a tape measure with an accuracy of 1.0 cm and the diameter at a height of 5.0 cm above the soil surface with a digital calliper. In the low shrub layer, a number of specimens were randomly selected in proportion to the species density to determine the size parameters. The foliage cover of specimens was determined with the tape measure, with two perpendicular measurements laid on the foliage. The mean foliage area was given in square cm. Following diversity indices were used: Shannon-index (H) (*Eq. 1*) and Evenness (E) (*Eq. 2*).

$$H' = -\Sigma (p_i \times \ln p_i) \qquad (1)$$

$$E = H'/H_{max} = H'/\ln S \qquad (2)$$

Where: p_i – proportion of specimens found in the i^{th} species, S – total number of species in the shrub layer. Evenness was calculated as the ratio of observed diversity (*H*) to maximum diversity (H_{max}) (Magurran 1988).

RESULTS

Composition and density

Sixteen and seventeen native low shrub species were identified across the entire study area in 1972 and five decades later; fifteen species were present continuously in the monitoring plot. Species composition of low understorey was essentially constant. In 2022 two new species were identified in the plot compared to 1972: *Tilia cordata* Mill. (small-leaved linden) and *Quercus pubescens* Willd. (downy oak) occurred with a few specimens; *Sorbus torminalis* L. (checker tree) disappeared from the site after 50 years (*Table 1*).

The density of shrub layer per hectare was 87.401 specimens at the first survey. The most common low shrub species was *Ligustrum vulgare* L. (wild privet) with a 24.1% ratio of all low specimens; *Euonymus verrucosus* Scop. (spindle tree) and *Cornus sanguinea* L. (common dogwood) followed them in 1972. 50 years later the most common low shrubs were *Q. petraea* with 37.8% and *E. verrucosus*. The total density decreased remarkably to 2022, from 87401 to 17317 individuals' ha^{-1} below 1.0 meter in height. In the low shrub community, *Q. petraea* was the most common oak species with a 25.2% average ratio of all low shrubs based on data from the 1972 and 2022 surveys. In the last 50 years, we observed the largest decrease in the number of individuals, two orders of magnitude, in the species *L. vulgare* and *C. sanguinea* (*Table 1*).

Table 1. Species composition and density condition of the low shrub layer on the Síkfőkút mixed oak forest in 1972 and in 2022.

species	1972			2022		
	density ind.	density ind. ha^{-1}	rate %	density ind.	density ind. ha^{-1}	rate %
A. campestre	1313	5699	6.52	355	1541	8.90
A. tataricum	1690	7335	8.39	69	299	1.73
C. mas	221	959	1.10	8	35	0.20
C. sanguinea	3150	13673	15.64	67	291	1.68
Cr. monogyna	381	1654	1.89	49	213	1.23
E. europaeus	1793	7782	8.90	69	299	1.73
E. verrucosus	3387	14700	16.82	1429	6202	35.81
J. regia	11	48	0.55^{-3}	6	26	0.15
L. vulgare	4852	21059	24.09	211	916	5.29
Lo. xylosteum	179	777	0.89	16	70	0.40
P. avium	1	4	0.50^{-4}	12	52	0.30
Q. cerris	334	1450	1.66	88	382	2.21
Q. petraea	2526	10963	12.54	1510	6553	37.84
Q. pubescens	0	0	0	91	395	2.28
Rh. cathartica	181	786	0.90	3	13	0.75^{-3}
R. canina	117	508	0.58	4	17	0.98^{-3}
S. domestica	1	4	0.50^{-4}	0	0	0
T. cordata	0	0	0	3	13	0.75^{-3}
total	20137	87401	100	3990	17317	100

Size condition

The mean shoot height of the detected shrub species changed between 10.31 cm and 66.96 cm in the low shrub layer based on the two survey years. It was measured the lowest mean height by *Rosa canina* L. (dog rose) and the biggest mean height by *Lonicera xylosteum* L. (European fly honeysuckle) individuals in the low shrub community. 5 decades later, we recorded the minimum mean height by *Q. petraea* seedlings and the maximum value by *Cornus mas* L. (European cornel). It was recorded between 1.46 mm and 7.51 mm mean diameter values of the low shrubs in 1972 and in 2022. *E. europaeus* had got the thinnest shoot diameter from 1972; in this year *Cr. monogyna* had got the thickest shoot. 5 decades later, we recorded the minimum diameter value by *Q. petraea* and the maximum value by *C. mas.* Based on the above data in 2022 the largest low species was identified as *C. mas* with 56.30 cm mean height and 6.90 mm mean diameter (*Table 2*).

Table 2. Height and diameter condition (means ± standard deviation) of the low shrub layer on the Síkfőkút mixed oak forest in 1972 (N = 423) and in 2022 (N = 549).

species	1972		2022	
	mean height (cm±S.D.)	mean diameter (mm±S.D.)	mean height (cm±S.D.)	mean diameter (mm±S.D.)
A. campestre	32.93±7.12	4.42±1.03	17.51±5.67	3.37±1.04
A. tataricum	29.13±14.26	3.54±1.46	13.64±9.31	2.04±1.12
C. mas	42.24±23.55	5.12±2.64	56.30±28.55	6.90±4.09
C. sanguinea	43.41±28.48	3.19±1.75	29.65±19.35	2.93±1.15
Cr. monogyna	43.70±19.89	7.51±3.48	36.56±23.90	6.27±2.98
E. europaeus	17.55±6.71	2.01±0.89	11.13±4.54	2.37±1.51
E. verrucosus	29.12±16.67	3.53±2.08	20.49±14.27	3.29±1.37
*J. regia**	23.22±12.04	3.20±2.96	47.90±21.64	4.50±2.33
L. vulgare	40.90±24.46	3.14±1.61	31.44±19.19	3.55±1.44
*Lo. xylosteum**	23.22±12.04	3.20±2.96	42.10±24.18	4.46±2.46
*Q. cerris**	23.22±12.04	3.20±2.96	11.74±4.72	1.86±1.04
Q. petraea	22.69±7.36	3.83±2.34	10.31±6.20	1.46±0.99
Q. pubescens	-	-	12.54±3.74	1.61±0.32
*P. avium**	23.22±12.04	3.20±2.96	11.88±5.36	2.70±1.90
*Rh. cathartica**	23.22±12.04	3.20±2.96	12.63±1.89	1.67±0.50
R. canina	66.96±33.91	3.88±0.93	14.40±6.37	2.00±0.31
*S. domestica**	23.22±12.04	3.20±2.96	-	-
T. cordata	-	-	16.73±7.77	5.83±2.13
mean	**35.60**	**3.87**	**21.72**	**3.34**

*The mean size values of these species were measured in total in 1972.

The highest species based on the data of the two surveys is *C. mas* with 49.27 cm; the thickest diameter measured by *Cr. monogyna* with 6.89 mm. The mean height and diameter of low shrub species decreased from 35.60 cm to 21.72 cm and from 3.87 mm to 3.34 mm (*Table 2*).

Foliage cover

The mean cover of the shrub species changed between 68 cm^2 and 432 cm^2 in the low shrub layer in1972. It was measured 35-2026 cm^2 mean foliage cover by the low species of the shrub community five decades later. The maximum cover values were detected for *C. sanguine* and *A. tataricum* species with 432 cm^2 and 403 cm^2 under the first investigation. By far the biggest mean foliage cover was detected for *L. xylosteum* with 2026 cm^2. It was recorded the lowest cover by *E. europaeus* and *P. avium* with 68 and 35 cm^2 in the years under review. The mean cover of all low shrubs decreased considerably, from 455 to 280 cm^2 for this year (*Table 3*).

Table 3. Foliage cover condition (means ± standard deviation) of the low shrub layer on the Síkfőkút mixed oak forest in 1972 (N = 858) and in 2022 (N = 674).

species	1972		2022	
	mean cover (cm²±S.D.)	**measured shoots number**	**mean cover (cm²±S.D.)**	**measured shoots number**
A. campestre	341±382	43	217±281	113
A. tataricum	403±130	73	94±104	30
C. mas	189±246	15	571±661	4
C. sanguinea	432±205	62	66±181	52
Cr. monogyna	354±243	87	331±295	16
E. europaeus	68±39	47	39±35	41
E. verrucosus	359±317	148	78±75	153
*J. regia**	339±278	88	534±339	4
L. vulgare	308±296	106	434±453	65
*Lo. xylosteum**	339±278	88	2026±1268	10
*Q. cerris**	339±278	88	43±20	20
Q. petraea	334±175	124	57±131	125
Q. pubescens	-	-	60±44	25
*P. avium**	339±278	1	35±25	7
*Rh. cathartica**	339±278	88	50±4	3
R. canina	113±64	63	64±50	3
*S. domestica**	339±278	1	-	-
T. cordata	-	-	66±46	3
mean	**455**	**-**	**280**	**-**

*The mean cover values of these species were measured in total in 1972.

Diversity indices

Diversity indices varied between 0.41 and 2.16 in the understory shrub layer under 50 years. Shannon-Wiener index was between 1.08 and 2.16 in two years. The highest index was recorded in 1972 the total low shrub layer; by 2022, we measured a significant decrease in the diversity index values. In the low shrub layer was measured only 1.08 Shannon index value without oak seedlings and saplings in 2022. Evenness index varied between 0.41 and 0.75 in the low understory. It was detected a low difference between the low shrub layer with or without oak seedlings in 1972. 5 decades later, it was measured only 0.57 and 0.41 Evenness value with and without low oak specimens (*Table 4*).

Table 4. Shannon and Evenness indices of the understory shrub layer on the Síkfőkút mixed oak forest in 1972 and in 2022.

year	1972		2022	
index	low shrub layer	low shrubs without oaks	low shrub layer	low shrubs without oaks
Shannon	2.1571	1.9892	1.6191	1.0810
Evenness	0.7463	0.6922	0.5715	0.4096

DISCUSSION

The consequences of tree decline cause notable changes in the light and stand thermal conditions which led to structural changes of the understory (Chapman *et al.* 2006). Our results suggest and confirm that the decreasing canopy oak density led to the significantly structural changes of the shrub community. Fifteen native woody species as constant low shrubs were identified across the long-term study area since the first survey. In the past 5 decades despite the important oak decline; there is only two new low shrub species established in the study site. *T. cordata* and *Q. pubescens* was established in the forest as new woody species (*Table 1*). Similarly to our site, in the Vár-hegy forest reserve of Hungary the species composition of understorey (herb and shrub layer) did not change after oak decay in the 1970s and 1980s (Horváth 2012). The total shoot density of low understory decreased considerably, essentially reduced by a fifth from 1972 to 2022 on Síkfőkút site (*Table 1*).

Results of Grime (1966) suggested that shade tolerance rate depends largely on the capacity for germination and seedling establishment in the understory environment. The shade-intolerant species can survive and grow in the understory, among others in the low shrub layer, producing multi-layered and multi-aged forest stands (e.g. Muir 1993, Paré and Bergeron 1995, Volney 1998). The mean height of the low shrub species changed between 10.3 cm and 67.0 cm in the shrub community for two years. It was recorded between 1.5 mm and 7.5 mm mean diameter values of these shrubs. Based on size condition in the study site tolerant and dominant low shrub species with higher individuals density are *L. vulgare* and *Cr. monogyna* (*Table 2*).

Results from Kerns and Ohmann (2004) suggest that in the Oregon forest structure, stand development, site disturbance history and other environment conditions all interact to influence the understory foliage cover. Total foliage cover of the understory shrub layer increased slightly, but non-significantly in a mature oak forest stand of the USA, from 45.0% in 1950 to 51.0% in 1969 and 1979. Contrary, the Shannon diversity index increased considerably, from 0.06 to 0.71 in 1979 (Davison and Forman 1982). On Síkfőkút site the mean cover of shrub species decreased notably. The mean cover values changed between 35 cm^2 and 2026 cm^2 in the low shrub layer (*Table 3*).

Shannon index and Evenness of the low understory varied among 1.08–2.16 and 0.41-0.75 in 1972 and in 2022. Shannon-Wiener and Evenness diversity indices of the low shrub layer decreased considerably from 1972 to 2022 parallel to the decreased in the individual density of low shrubs. The highest negative difference was detected for Evenness index without oaks in the low shrub layer (*Table 4*). De Grandpré *et al.* (2011) results suggested that the Shannon index increased significantly ($P < 0.001$) with time since treatment application in Canada; along a foliage gap of canopy severity gradient in old-growth and mature forest stands. According the paper of Onaindia *et al.* (2004) to use Shannon diversity and Evenness indices to evaluate the effects of disturbances in temperate forest stands.

CONCLUSIONS

Our most important results from 1972 and 2022 suggest that the low shrub layer responded negatively to the biotic and abiotic factors under 5 decades; this is especially true to the density, cover and diversity indices of species. Important decreasing also observed in the density, mean height, foliage cover and diversity indices by 2022. Forest compensated for the dead oak trees by forming a subcanopy layer between 8.0-13.0 m in height with *Acer campestre* L. (field maple), *Acer tataricum* L. (Tatar maple) and *C. mas* from the starting of oak decline. Especially field maples can influence on the density and mean size condition of low understory species by through it controlling ecosystem processes such as light transmittance and nutrient cycling. All information of our study will allow us to better understand the long-term shrub community development and to develop use and management after the serious oak decline. More research is needed to gain a better understanding of the relationship between oak canopy density and low shrub layer development, especially the long-term tendencies in density, size, cover and diversity condition.

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Research article

SUPPLEMENT TO IDENTIFICATION KEYS FOR HUNGARIAN BRYOPHYTES

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Abstract: 'Keys for the Identification of bryophytes occurring in Hungary', published in 2021, are here supplemented (addition of six taxa newly found in Hungary, one species and one subspecies of liverworts, four species of mosses). Some keys have been improved, and some errata amended. The list of references has also been updated.

Keywords: liverworts, mosses, additional taxa, Hungary

Since the publication of 'Keys for the Identification of bryophytes occurring in Hungary' (Erzberger 2021, simply called 'Keys' below), five taxa of bryophytes have been newly reported from Hungary, four species and one subspecies: *Encalypta spathulata* Müll.Hal. (Ellis *et al.* 2021c), *Hymenoloma crispulum* (Hedw.) Ochyra (Ellis *et al*. 2022; Németh and Erzberger 2023), *Marchantia polymorpha* L. subsp. *montivagans* Bischl. & Boissel.-Dub. (Aszalósné Balogh *et al.* 2021), *Pohlia bulbifera* (Warnst.) Warnst. (Ellis *et al.* 2021c) and *Sphaerocarpos michelii* Bellardi (Ellis *et al*. 2022; Wolf *et al.* 2023). Another new species, *Lewinskya fastigiata* (Bruch ex Brid.) Vigalondo, F.Lara & Garilleti, which has been mentioned in 'Keys' in a note, has been confirmed to occur in Hungary in the meantime (Németh and Erzberger, unpublished). In order to keep the identification keys for Hungarian bryophytes up to date, it is necessary to supplement the published keys in several points. Since the publication of a completely revised version of the original paper is not feasible momentarily, as a pragmatic compromise the necessary amendments are here published in the same format as the original keys, so that they can be printed out and incorporated into the printed version or used with the online version.

Taxonomy and nomenclature follow the latest Hungarian and European checklists (Erzberger and Papp 2020; Hodgetts *et al.* 2020). Four species missing in the Hungarian checklist (Erzberger and Papp 2020) were already included in 'Keys', but without proper references, which are given here: *Rhytidiadelphus loreus* (Hedw.) Warnst. (Ellis *et al.* 2021a), *Calypogeia arguta* Nees & Mont., *Hydrogonium croceum* (Brid.) Jan Kučera and *Orthothecium rufescens* (Dicks. ex Brid.) Schimp. (Ellis *et al.* 2021b).

A few errata in 'Keys' concerning the year of a reference (p. 14, 32), numbering (p. 139) and the use of certain terms (dextrorse and sinistrorse, p. 175, 176) have also been amended.

Amendments to 'Keys'

Page 3

Abstract: At present, 698 bryophyte taxa are known to occur in Hungary, 2 hornworts, 151 liverworts and 545 mosses.

Page 14

SMITH, A.J.E. (1990). *The Liverworts of Britain and Ireland*. Cambridge University press, Cambridge, 362 pp.

Page 17

Key to species of *Sphaerocarpos*	121
Key to species of Rhabdoweisiaceae (incl. *Hymenoloma*)	142

Page 24

Family	46a. Hymenolomataceae
	78a. *Hymenoloma*

Page 32

SMITH, A.J.E. (1990). *The Liverworts of Britain and Ireland*. Cambridge University press, Cambridge, 362 pp. – Second choice after the publication of PATON (1999) as concerns the illustrations as well as the descriptions. Missing taxa are the same as in PATON (1999).

Page 37
Thalloid liverworts

1	Thallus circular, completely covered by clavate involucres on dorsal side.......... ***Sphaerocarpos*** (p. 121)
–	Thallus not as above, not covered completely by clavate involucres.......... 2

Page 56
Group 19 Acrocarps with exserted erect capsule, peristome teeth 16, entire or slightly and irregularly divided

3	Alar cells differentiated, sometimes orange or brownish.... 3 a
–	Alar cells not differentiated.......... 4
3a	Leaves strongly crisped when dry, cuticle longitudinally striate, alar cells not conspicuously orange.......... ***Hymenoloma crispulum*** (rr)
–	Leaves ± straight, not crisped when dry, cuticle smooth, alar and basal cells conspicuously orange.......... ***Blindia acuta*** (n.s.)

Page 70
Group 30 Acrocarps with isodiametric cells, apex acute, subacute or acuminate, margins recurved at least on one side, costa not excurrent or lacking

4	Leaves acute or acuminate; capsule ± cylindrical, sulcate, strumose.......... ***Ceratodon*** (p. 143)
–	Leaves longly acuminate; capsule ellipsoidal, smooth, not strumose.......... 4a
4a	Alar cells differentiated, enlarged at least in some leaves; cuticle longitudinally striate.......... ***Hymenoloma crispulum*** (rr)
–	Alar cells not differentiated; cuticle smooth, not striate.......... ***Dicranoweisia cirrata*** (w)

Page 112

Key to Marchantiales pp. (incl. *Asterella, Clevea, Conocephalum, Lunularia, Mannia, Marchantia, Reboulia*)

2 Gemmae cups semi-lunate; air-pores volcano-shaped, simple; female receptacles cruciate, 4-rayed..***Lunularia cruciata*** (r)

– Gemmae cups goblet-shaped, circular; air-pores barrel-shaped, each composed of 4 (6) rings of superimposed cells; female receptacles at apex of thallus, stellate, deeply divided with usually (5) 8–9 (11) terete lobes
Marchantia polymorpha..3

3 Thallus usually prostrate, without or with a discontinuous dark median band on dorsal side; margins usually crenulate by protruding marginal cells; margins of appendages of median scales sharply toothed..3a

– Thallus usually growing erect, with a conspicuous, dark median band on dorsal side; margins usually entire; margins of appendages of median scales entire or nearly so..***Marchantia polymorpha*** subsp. ***polymorpha*** (r)

3a Thallus dark green (young parts), 6–9 (15) mm wide, with a discontinuous darker median band on dorsal side; growing often in man-made habitats..***Marchantia polymorpha*** subsp. ***ruderalis*** (w)

– Thallus yellowish-green (young parts), 7.5–11 (20) mm wide, lacking distinct median band on dorsal side; in natural, wet habitats, in Central Europe usually at high elevations..***Marchantia polymorpha*** subsp. ***montivagans*** (rr)

Page 121

Key to species of *Sphaerocarpos*

References: Smith (1990), Paton (1999), Nebel and Philippi (2005), Schill *et al.* (2009), Xiang and Zhu (2019), Hugonnot and Chavoutier (2021), Wolf *et al.* (2022)

– Spore tetrads yellowish to dark brown, (70) 90–130 (150) µm diameter, individual spores ± distinct at maturity, their distal face with (6) 8–12 irregular to ± hexagonal areolae, (8) 10–14 (20) µm wide, across diameter, areolae delimited by smooth lamellae, 2.5–5 µm high, at junctions of areolae protruding as spines 7–10 (12) µm long, rendering spore tetrads spinulose in silhouette, each areola with a single central tubercle difficult to see in light microscope, best seen in SEM..***Sphaerocarpos michelii*** (rr)

– Spore tetrads light brown to red-brown, (120) 135–170 µm diameter, individual spores indistinctly delimited at maturity, their distal face with 4–6 irregularly hexagonal areolae, (15) 20–32 (36) µm wide, across diameter, areolae delimited by papillose lamellae, 10–12.8 µm high, hardly protruding at junctions of areolae, tetrads in silhouette winged, not spinulose, central tubercle of areola lacking.......... .....***Sphaerocarpos europaeus*** (*Sphaerocarpos texanus*) (n.s.)

Page 130, 131 **Key to species of *Encalypta***

References: Nyholm (1998), Smith (2004), Guerra *et al.* (2006), Magill (2007), Meinunger and Schröder (2007)

1 Plants with clusters of brownish filamentous gemmae in leaf axils; plants dioicous, rarely with sporophytes; urn spirally striate, spirally furrowed when dry; uppermost leaves obtuse or subacute; costa not excurrent.. ....***Encalypta streptocarpa*** (w)

– Plants without gemmae in leaf axils; urn smooth or with longitudinal, not spiral stripes or furrows; costa excurrent or not..2

2 Seta yellow; base of loosened calyptra lobed (“ciliate”), calyptra shiny, smooth; capsule smooth; vaginula ± elongate, in upper part with cup-shaped remnant of base of calyptra; peristome present, single; leaves with sharp, short or slightly elongate point; spores not papillose, with numerous radial plicae on the proximal surface, distal surface with a central depression surrounded by a stout circular ridge from which 5 short radial ridges run towards equator..***Encalypta ciliata*** (r)

– Seta red; base of loosened calyptra ± strongly erose; vaginula short, in upper part with umbrella-like remnant of base of calyptra; peristome present or absent; leaves with or without hair point; spores with large hemispherical papillae on distal face..3

3 Peristome present, well-developed, red-brown; capsule with prominent longitudinal red-brown striae, deeply furrowed when dry; calyptra smooth or erose at base, papillose throughout.......................................***Encalypta rhaptocarpa*** (n.s.)

– Peristome absent; capsule smooth or with faint golden striae, weakly furrowed when dry..4

4 Leaves without hair point, bluntly pointed, costa ceasing below leaf apex (rarely shortly excurrent); margin usually incurved towards leaf apex; capsule smooth or almost so; calyptra smooth or erose at base...***Encalypta vulgaris*** (w)

Note: In ***Encalypta vulgaris*** var. ***apiculata*** (rr) the costa is shortly excurrent or ending in a more or less long hairpoint.

– Upper leaves with ± elongate hair point; margin usually plane; capsule finely yellow striate; calyptra erose to unevenly frayed at base.....................***Encalypta spathulata*** (rr)

Page 139

Key to species of Dicranaceae

In the first couplet, the second line should lead to 5, not 4.

Page 142

Key to species of Rhabdoweisiaceae incl. *Hymenoloma*

1 Lamina cells smooth, sometimes with longitudinal striae, not mamillose...2

– Lamina cells mamillose; upper leaf margin ± bistratose, mamillae of marginal cells forming double teeth........................5

2 Capsules striate when dry and empty, less than 3 times as long as wide; leaf margin denticulate in upper part of leaf, sometimes only very slightly so..3

– Capsules smooth; leaf margin ± entire 2a

2a Alar cells differentiated, enlarged, at least in some leaves; cuticle longitudinally striate; leaf margin plane, bistratose above; mid-leaf cells 6–8 (10) µm wide; capsules ovoid-ellipsoid; plants saxicolous .... ***Hymenoloma crispulum*** (rr)

– Alar cells not differentiated; cuticle smooth; leaves with recurved unistratose margins; mid-leaf cells 12–14 µm wide; capsules narrowly ellipsoid to subcylindrical; plants corticolous or saxicolous .... ***Dicranoweisia cirrata*** (w)

Page 175

Key to species of Grimmiaceae

In this key as printed in 'Keys', the use of the terms dextrorse and sinistrorse should be interchanged. Their definition as given in the Glossary (p. 231–252) is correct. In the literature, the use of terms denoting the torsion of the seta is often ambiguous and contradictory. The correct use of dextrorse and sinistrorse is in accordance with Malcolm and Malcolm (2000), Larraín *et al.* (2013), Muñoz *et al.* in Brugués & Guerra (2015), Chavoutier (2016), but contrary to the use in the papers of Bednarek-Ochyra, e.g. Bednarek-Ochyra (2006). In Erzberger *et al.* (2016), the definition of the terms is correct, but not their use.

To sum up: in *Racomitrium*, the seta is dextrorse in *R. lanuginosum* and *R. canescens*, whereas it is sinistrorse in the other species occurring in Hungary (*R. aciculare, R. affine, R. aquaticum, R. heterostichum, R. microcarpum*).

The correct couplets are as follows:

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1 Basal leaf cells elongate, with incrassate nodulose-sinuose walls; seta elongate (capsules exserted), mostly sinistrorse (forming a left-handed helix unlike a normal screw) when dry (dextrorse in *R. lanuginosum, R. canescens*); stem without central strand. ***Racomitrium*** 4

– Basal cells never at the same time elongate and incrassate nodulose-sinuose; seta often short, untwisted or dextrorse; stem with or without central strand 2

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4(1) Hair point present, papillose; seta dextrorse when dry 5

– Hair point absent or present, not papillose, but often denticulate; seta sinistrorse when dry 6

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Key to species of *Pohlia*

References: Smith (2004), Erzberger (2005), Köckinger *et al.* (2005), Guerra *et al.* (2010)

2 All bulbils ± globose, hardly longer than wide........................2a

– Bulbils oblong, obconic or elongate and vermicular..................3

2a Primordia of all bulbils broadly triangular-laminate, obtuse, reaching about 1/3 of total bulbil length, conspicuously concave, forming a dome over the apex that often traps an air bubble; bulbils 230–400 µm × 100–230 µm, (green) yellow-orange (red), according to age; plants glossy when dry...***Pohlia bulbifera*** (rr)

– Leaf primordia poorly formed, peg-like, incurved, consisting of only 1(–2) cell(s), never laminate; bulbils mostly (70) 80–130 (175) µm × 60–110 (150) µm, usually stalked, yellow-translucent, occasionally brown; plants dull when dry...***Pohlia camptotrachela*** (n.s.)

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Key to species of Orthotrichaceae

References: Schäfer-Verwimp in Nebel and Philippi (2001), Guerra *et al.* (2014), Caparrós et al. (2016), Blockeel (2017), Vigalondo *et al.* (2020)

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16 Capsules yellowish, thin-walled, smooth or almost so when dry, immersed in the leaves or clearly exserted above the leaves; calyptra with scattered or abundant hairs; outer peristome teeth united in pairs or not, recurved but arcuate when dry, only the tips touching the surface of capsule ('tea cup handle'); inner peristome segments whitish, sometimes with irregular outlines; leaves mostly with a narrow, acute apex...17

– Capsules pale, elongate-cylindrical, strongly sulcate when dry, hemi-emergent to shortly exserted; calyptra naked or with few short hairs; outer peristome teeth united in 8 pairs (or partly separating when old), regularly recurved when dry, touching surface of capsule throughout their length; inner peristome segments ± transparent, coarsely or finely papillose (rarely nearly smooth); leaves mostly with a broad, short apex...16a

16a Exothecial bands broad, 4 rows of cells near capsule mouth (often 6–8 below); exostome teeth cancellate (lattice-like) and frequently fenestrate (pierced by broad openings resembling windows) at apex; spores verrucose and usually with scattered coarse lines; capsule usually hemi-emergent, urceolate, deeply furrowed when dry and empty; apex of perichaetial leaves acute to acuminate, frequently asymmetric; leaves shorter and more broadly lanceolate than in the next species................................***Lewinskya fastigiata***
(in Hungary at present known from few sites only, but probably widespread)

– Exothecial bands narrow, 2–3 rows of cells near capsule mouth (sometimes 4–6 below); exostome teeth sometimes weakly fenestrate at apex; spores with thin and irregular papillae; capsule usually shortly emergent, cylindrical to ovoid-cylindrical, moderately furrowed when dry and empty; apex of perichaetial leaves shortly apiculate; leaves lanceolate...***Lewinskya affinis*** (cc)

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