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Bryophyte flora of the Košice Zoo (E Slovakia)

Pavel Širka[1], Margaréta Marcinčinová[2], Matej Dudáš[2] & Svatava Kubešová[3]

[1] Department of Phytology, Faculty of Forestry, Technical University in Zvolen, T.G. Masaryka 24, SK-960 01 Zvolen, Slovakia, pavel.sirka@tuzvo.sk
[2] Department of Botany, Institute of Biology and Ecology, Faculty of Science, Pavol Jozef Šafárik University, Mánesova 23, 041 54 Košice, Slovakia, margareta.marcincin@gmail.com, dudas.mato@gmail.com
[3] Department of Botany, Moravian Museum, Hviezdoslavova 29a, CZ-627 00, Brno, Czech Republic; skubesova@mzm.cz

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Abstract: In this paper we studied bryophyte flora of the Košice Zoo and analyzed morphological, life history and ecological traits of the recorded taxa. A total of 129 bryophyte taxa (10 liverworts and 119 mosses) were identified on nine substrate types. One species (*Physcomitrium eurystomum*) potentially belongs to vulnerable species in Slovakia and all of Europe (its identification needs confirmation) and one species (*Schistidium dupretii*) is new to Slovakia. Out of 14 different life forms, the recorded species most frequently form turfs and rough mats, while colonists and perennials predominate among seven displayed life strategies. On average, species found indicate rather well-lit, drier but at the same time colder situations. Most taxa prefer acidic soils but a significant portion are also found on basic substrate. Roughly half of the identified species are bound to forests and roughly half to open land. Almost half of the species found show stronger affinity towards natural ecosystems but a smaller portion are also indicative of ecosystems with a very strong human impact. Substrate frequency indices show that most taxa usually grow on natural rock, soil and gravel or sand but a significant portion are also bound to man-made rock, and both living and dead wood. Such noticeable functional and ecological bryophyte diversity is attributed to a complex geology and diverse landscape of the zoo area which has the prerequisite of being a local hotspot of diversity of other organism groups as well. The Košice Zoo has a major potential in educating visitors about the connection between animals, plants and their habitat and in their active conservation.

Keywords: bryophytes, mosses, liverworts, diversity, conservation.

Introduction

Urban areas represent a more inhospitable environment for plants than natural biotopes and are often impoverished of less tolerant species. However, they offer various ecological situations and microhabitats, which make good preconditions for a rich flora, especially of cryptogams (e.g. Zechmeister et al. 2002; Smith et al. 2010). In urban landscape, bryophytes have often been used as indicators in assessment of environmental contamination (e.g. Burton 1990; Giordano et al. 2004; Dymytrova 2009). Other studies examined mainly bryophyte flora of city parks, gardens and cemeteries (e.g. Fudali 2006; Pokorny et al. 2006; Sabovljević & Grdović 2009; Sabovljević & Sabovljević 2009), or they focused only on a certain group such as epiphytes (e.g. Durwael & Lock 2000; Fudali 2019). Similarly, in Slovakia mostly parks, gardens and cemeteries of the capital Bratislava (Mišíková & Kubinská 2010; Godovičová 2017; Godovičová & Mišíková 2017; Godovičová et al. 2020) and other selected villages in its vicinity (Mišíková et al. 2015; Mišíková et al. 2018; Godovičová et al. 2020) have been studied. In European cities, however, zoological gardens were rarely examined (Baur 2011; Segarra-Moragues et al. 2019), even though their landscape is often diverse and substantial in size (Frediani 2009). Moreover, besides providing leisure and recreation, zoological gardens play an important role as scientific and educational centres (Urban et al. 2015; Adamska 2017). Botanical studies in cities, especially in zoos and those of non-vascular plants, are therefore important not only from a scientific point of view but also in conservation of biodiversity. The zoological garden in the city of Košice (eastern Slovakia) belongs to one of the largest zoos in Europe and offers a variety of different microhabitats, which make it a prerequisite for being rich in bryophytes.

The city of Košice and its wider area has been bryologically poorly investigated. More comprehensive data on the bryophyte flora within the Čierna hora Mts, the Košická kotlina basin and the Volovské vrchy Mts can be found mainly in the studies of Šmarda (1940a, b, 1948), Boros (1961), Peciar (1974, 1976) and Duda (1997). No bryological studies in any of the Slovak zoos have been carried out to this day. The aim of this work is to present the results of an extensive survey of bryophyte flora of the Košice Zoo, to analyze morphological, life history and ecological traits of the identified taxa and to discuss the potential of zoological gardens in biodiversity conservation. This paper is a part of a series of extensive studies on the diversity of the Košice Zoo (Marcinčinová et al. 2020; Dudáš et al. in prep.).

Material and Methods

Study area

The Košice Zoo, located in the city of Košice in the local city part of Kavečany in the Čierna Hora Mts, is the largest zoo in Slovakia and the third largest in Europe. Its construction began in 1979 and in 1986 it was opened to public. Presently, it has a total area of 288 ha but only about 75 ha are accessible to visitors including a 5 ha large DinoPark (https://www.zookosice.sk/about.html). The area of the zoo has a slightly warm and slightly humid climate with a maximum long-term average annual temperature of 16°C (Tometz et al. 2019). The average yearly air temperature values of the city of Košice are between 8.4 and 8.7 °C with an average of -3°C in January and 19 °C in July (Poórová & Vranayová 2020; Slovak Hydrometeorological Institute 2021). The long-term average annual rainfall in Košice is 630 mm (Tometz et al. 2019) and it increases with altitude (600–700 mm in the planar areas and 700–800 mm in the mountains) (Poórová & Vranayová 2020; Slovak Hydrometeorological Institute 2021). The territory of the city of Košice has a rather complex geology. While a larger part of the city is located in the Košická kotlina basin and built by Neogene and Quaternary deposits (i.e. clays, silts, sands, gravels, loams), in the north-western part of the city (the Volovské vrchy Mts and the Čierna hora Mts, where the zoo is located) these deposits are rare and the area of the zoo is build mostly by Paleozoic and Mesozoic rocks of Gemericum and Veporicum (i.e. Triassic dolomites, clayey shales, sandstones, Jurassic limestones, as well as biotitic granodiorites). The whole territory of the city of Košice belongs to the watershed area of the Hornád river (Tometz et al. 2019). According to the phytogeographical classification of Slovakia (Futák 1984), the Košice Zoo belongs to the area of the West Carpathian flora (*Carpaticum occidentale*), district of the pre-Carpathian flora (*Praecarpaticum*). Once part of the agricultural landscape, the zoo now consists, besides animal enclosures and various man-made substrates and small water bodies, also of habitats such as brooks, meadows and pastures, surrounded by *Fagus sylvatica*-*Carpinus betulus*-dominated forests (Marcinčinová et al. 2020).

<u>List of visited localities (see Fig. 1)</u>

1 – the entrance to the zoo, an old apple-tree orchard along the stream and the pavement from the entrance to the DinoPark, ca 48°47'0.67"N, 21°12'15.40"E-48°47'20.23"N, 21°12'24.90"E; ca 382-407 m a.s.l.;

2 – limestone rocky outcrops behind the toilets, across the Humboldt penguins, 48°47'16.31"N, 21°12'22.36"E; 389 m a.s.l.;

3 – DinoPark, including biotitic granodiorite rocky outcrops in the backside, roughly a 100 m diameter from 48°47'20.45"N, 21°12'28.34"E; 391 m a.s.l.;

4 – alder (*Alnus glutinosa*) stand from the pond with water birds along the pavement to the Eurasian wolf, including wet lawn, ca 48°47'19.45"N, 21°12'22.58"E-48°47'21.96"N, 21°12'5.84"E; 379-399 m a.s.l.;

5 – pavement, lawns and trees around the enclosures of the red deer, ostriches and Sheetland ponies, ca 100-200 m diameter of the center roughly at the crossroads at 48°47'16.94"N, 21°12'6.65"E; 410 m a.s.l.;

6 – from the overbridge near the Eurasian lynx by the brown emu, bird aviaries and racoons to the pond with water birds and swamp capybaras, including alder (*Alnus glutinosa*) stand and playground, area roughly between the points 48°47'13.67"N, 21°11'57.80"E; 48°47'13.11"N, 21°11'44.84"E and 48°47'7.64"N, 21°12'10.78"E; ca 400-442 m a.s.l.;

7 – the apiarian trail from the crossroads near the llamas and the racoon dogs, continuing further along the hornbeam (*Carpinus betulus*) forest, area roughly between points 48°47'12.01"N, 21°11'45.25"E; 48°47'6.50"N, 21°11'51.31"E; 48°47'7.31"N, 21°11'43.93"E and 48°47'12.61"N, 21°11'34.81"E; ca 435-475 m a.s.l.;

8 – pavement and dry lawn from Bactrian camels to Chapman's zebras, including slope with limestone rocks above the meerkats, ca between 48°47'21.30"N, 21°12'17.40"E and 48°47'9.77"N, 21°12'12.62"E, ca 383-395 m a.s.l.;

9 – from the pond with water birds and swamp capybaras by the large aviary to the zoo entrance, ca between 48°47'9.77"N, 21°12'12.62"E and 48°47'1.64"N, 21°12'15.19"E, ca 395-407 m a.s.l.;

10 – road along the beech forest from the pond with water birds to the zoo warehouse, ca between 48°47'21.60"N, 21°12'22.61"E and 48°47'33.09"N, 21°12'12.11"E, ca 382-423 m a.s.l.;

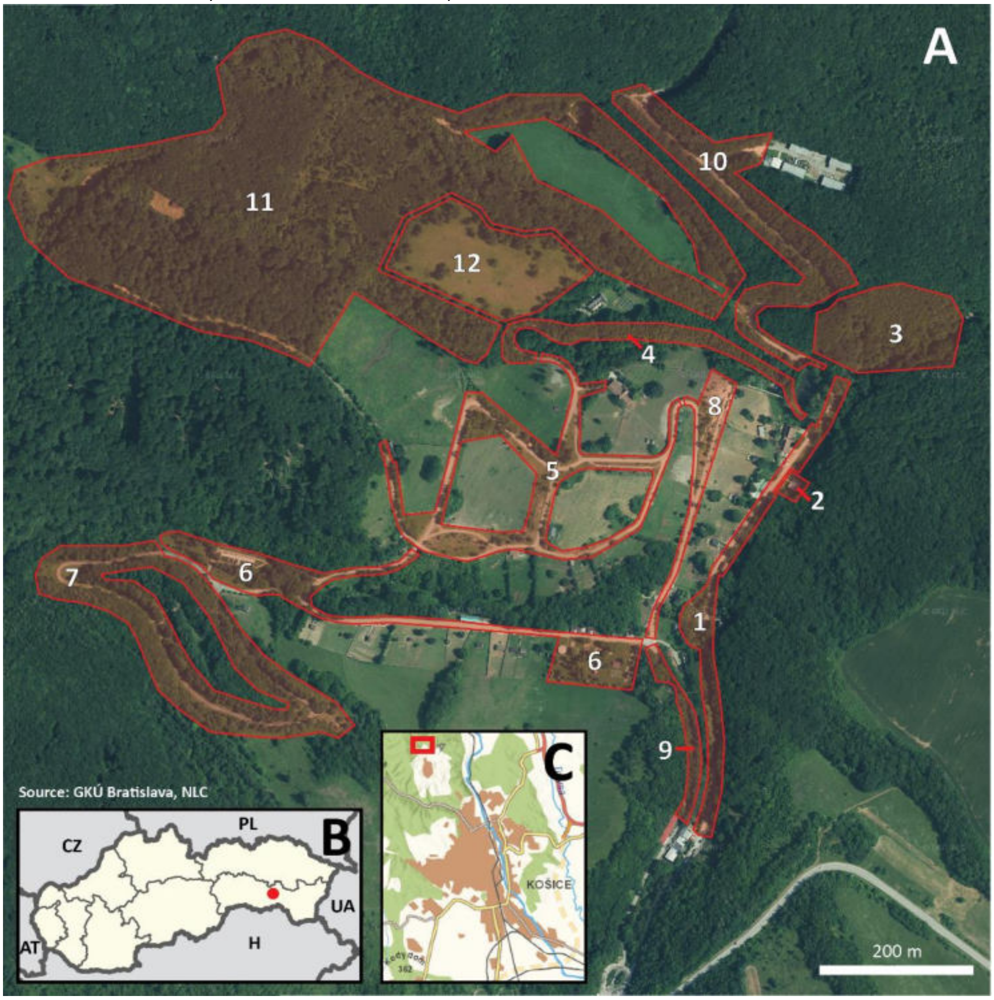

Fig. 1 Location of the Košice Zoo within Slovakia (B), city cadastral area (C) and a map of the examined area within the zoo (A), referred to as localities (numbers correspond to descriptions above).

11 – beech (*Fagus sylvatica*) forest with admixture of maple (*Acer pseudoplatanus*) with sporadic limestone rocks, including alder (*Alnus glutinosa*) stands along the stream and small heaps of building material, area roughly between points 48°47'24.42"N, 21°12'14.90"E; 48°47'32.78"N, 21°12'8.86"E; 48°47'28.50"N, 21°11'34.41"E and 48°47'22.23"N, 21°11'51.06"E, ca 380-470 m a.s.l., excluding a fenced grassland with horses and dry grassland (locality n. 12);

12 – dry grassland surrounded by beech (Fagus sylvatica) forest, including a few trees within the grassland, ca 50-100 m diameter from 48°47'25.45"N, 21°12'2.92"E, ca 395-425 m a.s.l.

Field work

The field survey of the Košice Zoo was conducted during the vegetation seasons of 2019 and 2020 and it included also the DinoPark and some parts not accessible to visitors. Map of the visited localities within the study area (Fig. 1) was designed in Adobe Illustrator using map layers from the Geodetic and Cartographic Institute Bratislava (©Geodetický a kartografický ústav Bratislava 2022) and the National Forest Centre (©Národné lesnícke centrum 2021). At each locality, substrate type (modified according to Hill et al. 2007) on which a given taxon grew was noted. Life forms and substrate classes are according to the BRYOATT database (Hill et al. 2007), life strategies follow Dierßen (2001) and forest affinity and hemeroby indices are given according to Bernhardt-Römermann et al. (2018). Indicator values for light, temperature, moisture and reaction are given according to Ellenberg et al. (1992), missing values were supplemented from the BryForTrait database (Bernhardt-Römermann et al. 2018). Taxonomy and nomenclature follows Hodgetts et al. (2020). Endangerement was assessed according to the Red list of mosses (Mišíková et al. 2020), hornworts and liverworts (Mišíková et al. 2021) of Slovakia, as well as European Red list (Hodgetts et al. 2019).

Results

A total of 129 bryophyte taxa (10 liverworts and 119 mosses) were identified (Tab. 1), belonging to 42 different families. *Amblystegium serpens* and *Hypnum cupressiforme* (s.l.) were recorded in all localities, while a total of 38 taxa were found only in one locality. Taxa grew on as many as nine different substrate types (amongst other bryophytes, decaying vegetation, decorticated wood, living wood, natural rock, worked rock, soil, soil on rock and gravel or sand). One species (*Physcomitrium eurystomum*) potentially belongs to vulnerable species in Slovakia and on a whole-European level and one species (*Schistidium dupretii*) is new to Slovakia.

The recorded taxa represent 14 different life forms with turfs (27.6 %) and rough mats (21.9 %) being the most numerous (Fig. 2A) and they display seven life strategies (Fig. 2B) with colonists (41.1 %) and perennials (39.9 %) predominating.

Concerning the occurrence of the recorded taxa in relation to the relative irradiance intensity, almost half of them (46.8 %) indicate generally well-lit places or are plants growing in full light, as much as 45.2 % have intermediate values (4-6), while only a very small number (3.2 %) are shade-loving (Fig. 3A). Identified species show rather cold situations where as much as 43.1 % have low indicator values for temperature (2-3), one third (32.5 %) have intermediate values and indicate fairly warm conditions, almost one forth (23.6 %) are indifferent towards temperature, while only an insignificant percentage (0.8 %) are warmth indicators (Fig. 3B). Based on indices for moisture, two thirds (66.1 %) of taxa have intermediate values (4-6) and grow in slighly dry to slightly moist situations, 21.8 % tolerate drought or grow in very dry sites, while 11.3 % prefer moist to wet soils (Fig. 3C). The species found on average indicate more acidic reaction, where more than half (56.4 %) have values for slightly acidic to very strongly acidic soils, 21.8 % are indicators of neutral soils, while a significant portion (17.8 %) are also found on basic to calcareous or other high-pH soils (Fig. 3D).

More than half (52.7 %) of the recorded species in the Košice Zoo are bound to both forests and open land, roughly one quarter (24.1 %) may occur in forests, but prefer open land and almost one quarter (22.3 %) are restricted to closed forest (Fig. 4).

Almost half (43.5 %) of the species found show stronger affinity towards natural ecosystems with weak to absent human impact, more than half (51.3 %) indicate moderately disturbed situations, while a small portion (5.2 %) are also indicative of ecosystems with a (very) strong human impact (Fig. 5).

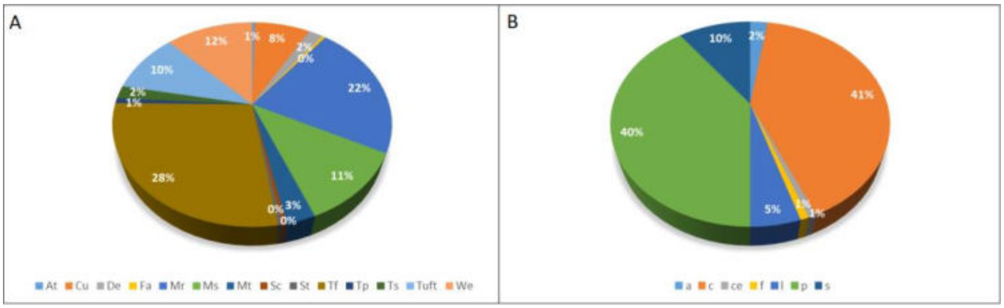

Fig. 2 Life forms (A) and life strategies (B) of the recorded bryophyte taxa. (A): At – aquatic attached to substrate and trailing in the water; Cu – cushion, dome-shaped colonies formed by variously-oriented shoots with a central origin; De – dendroid, sympodially branching shoots with stolons from which spring erect main shoots bearing branches above; Fa – fan, shoots arising from vertical bark or rock, branching repeatedly in horizontal plane; Mr – mat, rough, shoots creeping substratum, having numerous erect lateral branches; Ms – mat, soft, shoots that creep over substratum, having leafy branches that generally lie flat; Mt – mat, thalloid, shoots that creep over substratum, composed of a layer of thalli; Sc – solitary creeping, solitary or scattered, crawling over or through substrate, if more crowded would generally be a mat; St – solitary thalloid rosette, forming a small patch rather than the more extensive growth of a thalloid mat; Tf – turf, many loosely or closely packet vertical stems with limited branching; Tp – turf, protonemal, scattered vertical shoots from persistent protonema, can approach turf form if dense; Ts – turf, scaterred, scattered vertical shoots, normally lacking protonema, can approach turf form if dense; Tuft – tufts, forming loose cushions not necessarily of central origin; We – weft, loosely intertwining, usually richly branched layers. (B): a – annual shuttle species; c – colonists; ce – ephemeral colonists; f – fugitives; l – long-lived shuttle species; p – perennials; s – short-lived shuttle species.

Based on indices of frequency with which species occur in a specific substrate class, most taxa (75 %) are typically found on rock (both hard and soft), two thirds (65 %) on soil and 45 % on gravel or sand but a significant portion are also bound to worked rock and living wood (36.7% for both substrate types) or are epixylic (21.7 %) (Fig. 6).

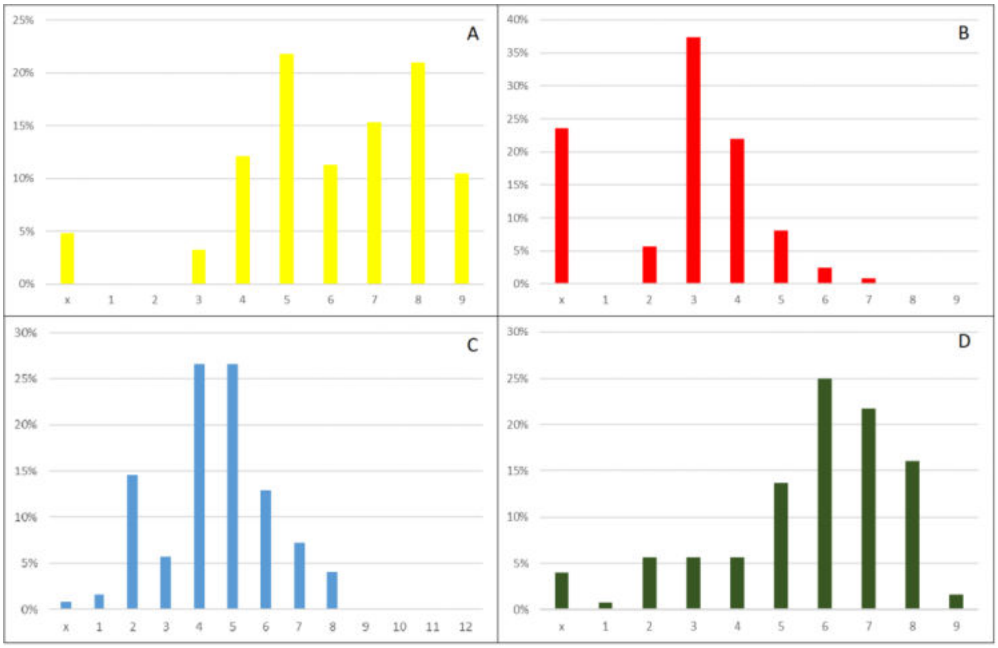

Fig. 3 Identified species Ellenberg's indicator values for light (A), temperature (B), moisture (C) and reaction (D). The indicator values reflect the occurrence of a taxon in the gradient of a given environmental factor expressed by a number from 1 to 9 (in case of moisture to 12), where 1 is the lowest value and 9 (12) is the highest value, x means the taxon is indifferent (see Ellenberg et al. 1992).

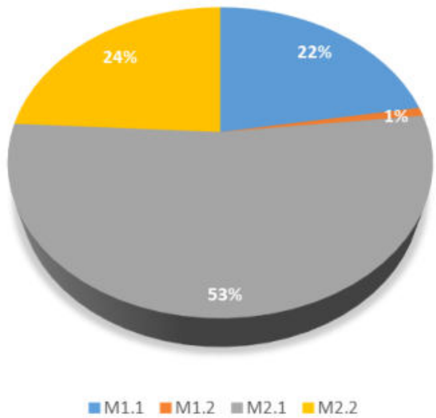

Fig. 4 Affinity of the identified taxa to forest habitats. M1.1 – largely restricted to closed forest; M1.2 – prefers forest edges and in clearings; M2.1 – occurrs in forests as well as in open land; M2.2 – may occur in forests, but prefers open land.

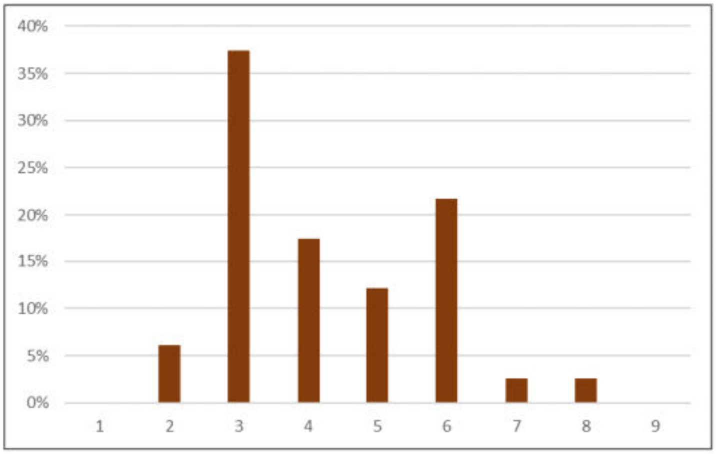

Fig. 5. Occurrence of the recorded species in the gradient of background human impact on the ecosystem – hemeroby. 1 – absent; 2 – absent to weak; 3 – weak; 4 – weak to moderate; 5 – moderate; 6 – moderate to strong; 7 – strong; 8 – strong to very strong; 9 – very strong.

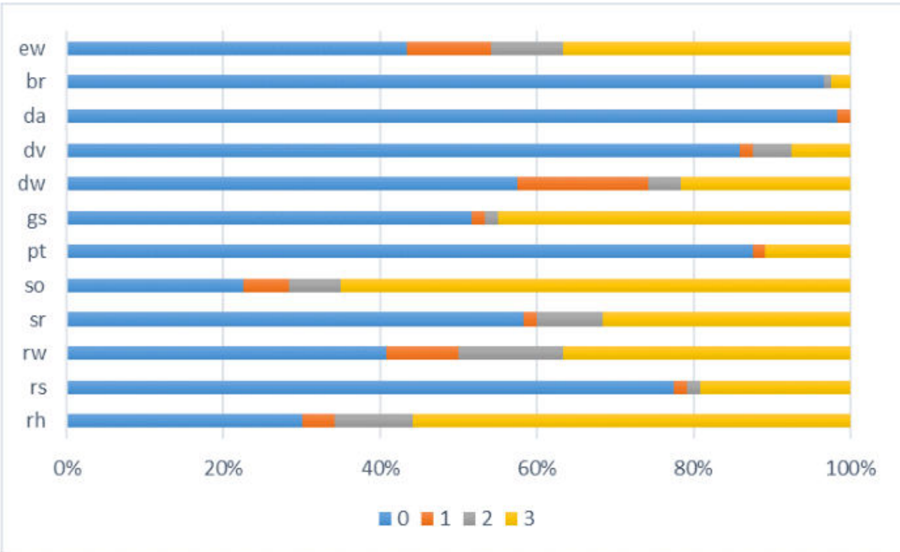

Fig. 6. Frequency of occurrence of identified bryophytes on different substrate types. Substrate abbreviations are in accordance with those in Tab. 1 (rh and rs = r; da – decaying animal; pt – peat); 0 – species does not occur on such substrate; 1 – a rare substrate for the species; 2 – an occasional substrate for the species; 3 – a normal substrate for the species.

Discussion

Within the examined complex of the Košice Zoo, we recorded 129 taxa of bryophytes which make up almost one seventh of the total currently known bryophyte flora of Slovakia. Owing to the complex geology of the area, species typical for silicate (e.g. *Grimmia hartmannii, Hedwigia ciliata, Paraleucobryum longifolium*) as well as calcareous rocks (e.g. *Anomodon viticulosus, Ctenidium molluscum*, *Encalypta streptocarpa, Fissidens dubius, Tortella tortuosa*) can be found indicating both acidic and basic situations. Similarly, due to a considerable diversity of natural as well as man-made substrate types within the zoo, the identified taxa typically occur (according to their indicative frequency values) on eleven different substrate classes (all except peat were confirmed in our study, although hard and soft unworked rock was considered as one category) in dry as well as wet conditions, both in forest and non-forest ecosystems. As a result, species found display as many as 14 different life forms (from cushions, tufts, wefts, fans, various mats and turfs to dendroid and aquatic forms) and seven life strategies (with a prevalence and well-balanced composition of both short-lived colonists as well as long-lived perennial stayers). In addition, potentially, some species of conservation concern (*Physcomitrium eurystomum*, treated as vulnerable in Slovakia and within the European continent, although its identification was based only on one fertile plant and needs to be confirmed) or even proven as new for Slovakia (*Schistidium dupretii*, its occurrence confirmed and treated as a Least Concern taxon in most neighbouring countries accoring to Hodgetts & Lockhart 2020) were also recorded. Alike some other European zoos such as the one in Basel (Baur 2011), the Košice Zoo can thus rightfully be considered as a local hotspot of (not only) bryophyte diversity.

Interestingly, a high percentage of the recorded taxa occur in sun-exposed sites but at the same time a significant portion of them on average also indicate colder situations. This can be partially explained by the presence of wet or at least damp habitats with cooler microclimate within the zoo (streams, lawns near water bodies) and species that grow in open and/or colder places (e.g. *Brachythecium rivulare*, *Calliergonella cuspidata, Climacium dendroides, Cratoneuron filicinum, Rhytidiadelphus squarrosus*) also have higher indices for moisture. However, some species (e.g. *Brachythecium albicans, Campyliadelphus chrysophyllus, Entodon concinnus, Orthotrichum anomalum, O. diaphanum, Pseudoleskeella catenulata, Racomitrium canescens, Tortella inclinata*) growing in exposed xerothermic habitats, especially in calcareous regions (thus having high indicative values for light and low indicative values for moisture), possess rather contradictory (low) indicative values for temperature. The classification of bryophytes based on their life-histories has its limitations due to a general lack of trait information (During 1992; Bernhardt-Römermann et al. 2018), so it is probable that the ecological indicator values of bryophyte species are less firmly established than those of vascular plants, as suggested already by Tinya et al. (2009). More trait studies on bryophytes are needed for better understanding and for making comparisons of the ecology of species in different geographical regions.

Although the primary role of zoological parks is to provide recreation and to display and protect animal species, modern zoos also have a tremendous potential in promoting education and awareness about plant and habitat diversity as part of the animal environment (WAZA 2005; Frediani 2009; Adamska 2017). Zoos should encourage a holistic view of nature that emphasizes the ecological relationships between flora and fauna (including man) and their habitat (e.g. Glądalski et al. 2021) but these vital connections are often not made or are overlooked (Frediani 2009).

This so called plant blindness or the lack of awareness about plants (Wandersee & Schussler 2001; Conley 2009), especially of non-vascular plants, is an important challenge zoos should overcome (Balding & Williams 2016; Jose et al. 2019). Through education programmes zoos can link zoology and botany and explain the importance of conservation through plants and landscapes (Conley 2009; Frediani 2009; El-Tork 2017).

In light of the current conservation crisis, zoos should develop efforts to conserve not only individual non-native animal species in human care but also native species of various other taxonomic groups, including bryophytes, as well as both intact and man-made habitats and ecosystems (Miller et al. 2004; Baur 2011). Our results as well as research on lichens (Marcinčinová et al. 2020) and vascular plants (Dudáš et al. *in prep*.) contribute significantly to the understanding and documenting of diversity of the Košice Zoo. The survey presented can aim towards the all-taxa-biodiversity inventory approach following the example of the Basel Zoo (Baur 2011), where scientists have recorded over 3100 free-living species of plants, fungi and animals. By engaging in such comprehensive conservation, zoos like the one in Košice can develop the capacity to become fully integrated conservation organizations as suggested by Frediani (2009).

Conclusion

Extensive survey of the Košice Zoo, one of the largest zoos in Europe, has shown a noticeable functional and ecological diversity of bryophytes. Trait analyses revealed occurrence of species of various substrates and ecological situations both in natural and man-made habitats, which can be attributed to a complex geology and diverse landscape of the zoo area. Moreover, some endangered species or species reported for the first time from Slovakia were also found. It is also concluded that some bryophyte species do not have well defined ecological indicator values and more trait studies using bryophytes are needed to better understand this intraspecific variation in trait attributes in different geographical regions. Given the considerable diversity of habitat and substrate types of the Košice Zoo, it is likely that further research might also reveal substantial diversity of other organism groups. This can aim towards fulfilling the potential of such local diversity hotspot in conservation efforts. Zoos as not only showcases for exotic animals but also as educational centres can effectively allow visitors to understand wider environmental issues, i.e. to inform about the connectivity between animals, plants and their habitat and to actively engage in their conservation.

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Tab. 1 List of recorded species at each locality within the Košice Zoo. Numbers of localities correspond to those listed in Material and Methods.

Taxon/Locality	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Liverworts												
Aneura pinguis		so, sr										
Cephalozia bicuspidata	br, dv*, so						so*			so*		
Frullania dilatata	ew		ew*, r								ew*	
Lophocolea heterophylla											dw*	
Marchantia polymorpha subsp. *ruderalis*	so, sr		so	rw, so*, sr					sr*			
Metzgeria furcata			ew*, sr, r				ew*				ew	
Pellia endiviifolia			so								dw, ew, so, sr*	
Plagiochila porelloides											r, sr*	
Porella platyphylla	ew		ew, r*								ew*	
Radula complanata	ew		ew*				ew*		ew		ew*	ew*
Mosses												
Abietinella abietina	sr				so, sr	so, sr	sr	r, rw, so, sr*		so		so, sr
Alleniella besseri			r*									
Amblystegium serpens	dw, ew, rw, sr	so, r, sr	dw, ew, so, sr*	rw, so	rw	ew, rw	dw, ew*, r, so, sr	dw, r, so	dw, r, rw, so, sr	dw, ew*, rw	dw, ew*, r	dw, ew
Anomodon viticulosus			r									
Atrichum undulatum	so*	so, r, sr	r, so, sr	so, sr			so		so, sr	so	so*	
Barbula unguiculata	so		so	so			so	so*		so*	gs, so	
Brachytheciastrum velutinum	ew	so, r, sr*	dw, ew, so, sr			ew	dw, so		so*	dw, rw, so	dw, ew*, r, so, sr	dw, ew

Tab. 1 - cont.

Brachythecium albicans				so	so		so*	so, sr*		rw, sr*	sr	so
Brachythecium campestre									so*		gs, sr	so*
Brachythecium glareosum								sr*				
Brachythecium rivulare	ew, rw, so, dv			r, rw, so*		so	so, sr		so	sr	dw, so*	
Brachythecium rutabulum	ew		ew*, r, sr	ew, rw		ew	ew, so		so, sr	so*	dw, ew*, r, so, sr	
Brachythecium salebrosum		so, r, sr	dw, so	dw, ew*, so	rw	ew, sr	dw	dw*		dw, rw, so*	ew, so, sr	
Bryum argenteum	rw, so, sr			rw, sr	so, sr		so, sr	sr		rw	r, so*	
Bryum sp.	so	so, sr		so	so, sr	gs, so	so	so		rw	gs, sr	so
Calliergonella cuspidata	so, dv					so	so			sr	so, sr	
Campyliadelphus chrysophyllus					so*, sr	so*		so, sr*				
Ceratodon purpureus	so	so, r, sr		r, so, sr	r, rw, so*, sr	gs, sr	sr*	r, so*, sr	so	dw, so*	gs, so*, sr	so*
Chionoloma tenuirostre			r*									
Ciriphyllum piliferum	dv, so, sr		so	so			so		so	So*		
Climacium dendroides						so	sr*					
Cratoneuron filicinum				rw, so*					so*		dw, ew, sr*	
Ctenidium molluscum											r, sr*	
Dicranella heteromalla			so				so			so*	so*	
Dicranella staphylina											so*	
Dicranoweisia cirrata			ew*									
Dicranum montanum			dw, ew							dw, ew	dw*	
Dicranum scoparium			so	ew	so		so				dw	

Tab. 1 - cont.

Didymodon fallax				r	sr*		sr*				
Didymodon ferrugineus	so, sr	so	so*	r, sr*	so, sr*		sr*				
Didymodon rigidulus										sr*, r	
Encalypta streptocarpa										r, sr*	
Encalypta vulgaris			rw, sr				s, sr*				
Entodon concinnus							so*				
Eurhynchium angustirete		so							so*		
Fissidens bryoides		so*								so, sr*	
Fissidens dubius										r, so*, sr*	so
Fissidens pusillus										r*	
Fissidens taxifolius			so*								
Flexitrichum flexicaule							so, sr*				so*
Funaria hygrometrica						so				so	
Grimmia hartmanii		r*									
Grimmia pulvinata	rw			rw*, so, sr			rw*			rw	
Hedwigia ciliata		r*									
Herzogiella seligeri			ew								
Homalothecium lutescens	rw*			so			r, so, sr*				
Homomallium incurvatum	rw	r		rw	r*		r	r		r*	
Hygroamblystegium tenax		r*			rw*	r*				r*	
Hylocomiadelphus triquetrus						so				so	
Hylocomium splendens			ew			so*					
Hypnum andoi			ew*							ew*	

Tab. 1 - cont.

Hypnum cupressiforme	dw, ew, rw, sr	so, r, sr	dw, ew, so	dw, ew, rw, sr	rw, so, sr	ew, rw, so	dw, e, so		dw, ew, r, so, sr	dw, ew, r, rw, so	dw, ew*, r, so, sr	dw, ew
Hypnum cupressiforme var. *lacunosum*								so				so*
Isothecium alopecuroides			ew, r*, sr							ew	ew	
Jochenia pallescens	ew		dw*				dw			dw, ew	dw, ew	dw
Leskea polycarpa	ew		dw, ew*, r	ew*		ew*	ew*, r		ew*			
Lewinskya affinis var. *affinis*			ew			ew*	ew*		ew*		ew*	
Lewinskya speciosa	ew*											
Mnium hornum	so						so					
Mnium marginatum						so*						
Orthotrichum anomalum			r		rw*							
Orthotrichum cupulatum			ew									
Orthotrichum diaphanum					rw*							
Orthotrichum pallens			dw, ew*									
Orthotrichum pumilum			dw, ew*		rw*							
Orthotrichum sp.									ew	rw	rw, sr, ew	ew
Oxyrrhynchium hians	rw, so		so*	so*		so	so	r, so, sr	so	so, sr	so*	
Palustriella commutata											r*	
Paraleucobryum longifolium			dw, ew, r*									
Physcomitrium cf. *eurystomum* **VU**			so*									
Plagiomnium affine	r, so		sr	rw, so*, sr	r, sr	so	so*		so		r, so*	so
Plagiomnium cuspidatum	ew, so		dw	ew, so	so		so, sr	so	r, so*, sr	sr	ew, r*	

Tab. 1 - cont.

Plagiomnium undulatum	so			so			so			sr	so	
Plagiothecium cavifolium		r, sr*	so*, sr				so*		so*, sr	so*	so*	
Plagiothecium denticulatum			r, so*, sr	ew*					so	so*		
Platygyrium repens	ew		dw, ew*	ew		ew	ew	dw*	ew	ew	dw, ew*	ew
Pleuridium subulatum							so					
Pleurozium schreberi							so*		so		so*	
Pogonatum aloides							so*					
Pohlia nutans										so*		
Polytrichum formosum			r, so, sr	ew			so*		so	so		
Polytrichum juniperinum							so*					
Pseudanomodon attenuatus			ew*								ew*, r, sr*	
Pseudocrossidium hornschuchianum								so*				
Pseudoleskeella catenulata			r									
Pseudoleskeella nervosa			ew	ew		r					ew*	
Pseudoscleropodium purum							so*					
Pterigynandrum filiforme	ew		ew*, r									
Ptychostomum imbricatulum					so, sr			so, sr				
Ptychostomum moravicum	ew		dw, ew, so*, sr	ew, sr						so	ew*, so	
Ptychostomum rubens			so*									
Pylaisia polyantha	ew		dw, ew*			ew*	ew				ew*	ew
Racomitrium canescens								sr*				
Rhizomnium punctatum						rw			sr		ew*	
Rhynchostegium murale	r, sr			rw, sr	so, sr	rw, so, sr	sr			sr	r, rw, so*, sr	

Tab. 1 - cont.

Rhynchostegium riparioides	r		r*	r		r*					r	
Rhytidiadelphus squarrosus	so			so	so		so*			so		
Sanionia uncinata			dw	ew								
Schistidium cf. *apocarpum*							r*					
Schistidium crassipilum	rw*				rw*	rw*			rw*	rw	rw*	
Schistidium dupretii **NE**								r*, sr				
Sciuro-hypnum plumosum				r*								
Sciuro-hypnum populeum	rw		r*			r*	ew, r, rw		r, rw	rw	ew, r*	
Streblotrichum convolutum	rw, so			rw	so*, sr	sr	sr	so, sr*		rw, sr	rw	
Syntrichia ruralis					rw, so*, sr	rw*	so	so, sr*				
Syntrichia virescens											ew*	
Taxiphyllum wissgrillii			r*				so					
Thuidium assimile	sr			so	so	so, sr	so*	so*		rw, so*, sr	so, sr	so
Thuidium delicatulum					so, sr			so*	so			
Tortella inclinata					so*							so*
Tortella tortuosa						so		sr*			r, sr*	
Tortula acaulon								so	so*			
Tortula muralis					rw		rw			rw		
Tortula sp.								so			so	
Tortula subulata		r, so*, sr				so				so, sr	so	
Tortula truncata			so									
Trichodon cylindricus			so				so*					
Weissia brachycarpa	so		so		so, sr	so	r, so, sr			so*		

Tab. 1 - cont.

Weissia sp.	so	so		so, sr	so

br – growing amongst or through other bryophytes; dv – decaying vegetation (includes leaf litter, thatch, decaying vascular plant tussocks etc.); dw – decorticated wood (decorticated logs, rotting wood and worked wood - fence posts etc.); ew – epiphytic on living wood (on bark on the trunks, branches, stems and exposed roots of vascular plants); r – rock (soft or hard unworked rock); gs – gravel or sand; rw - rock, worked (building stone, roofing slates, brick, mortar, concrete, asphalt etc.); so – soil (includes mineral, sandy, gravelly, humus-rich and peaty soils; pure peats, sands and gravels are treated separately); sr – soil on rock (thin layer of soil over rock; includes soil over natural, worked or artificial rock); NE – not evaluated; VU – vulnerable.