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Theses of doctoral (PhD) dissertation

CONSERVATION ASSESSMENT OF PROTECTED LICHEN SPECIES IN BAKONY REGION

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Introduction

Lichens are pioneer organisms that play an important role in the ecosystem. Recently, lichens have been in a global decline in certain areas, mainly due to habitat degradation and destruction, deforestation, agriculture, urbanisation, and air, water and soil pollution. Like in other groups of organisms, there are rare and endangered also among lichens, therefore we should pay more attention to their conservation and prevention of there the destruction of their habitats. However, this requires more information of distribution and ecology. At the national level, lichen surveys for conservation purposes are incomplete. The conservation of protected species and lichen biodiversity is the key to good conservation practice and management. Lichenological research can be traced back to the 1800s, but the distribution of lichens is still under-studied in Hungary. The lichen species of the Bakony Region are relatively better known. The botanical collection of the Bakony Museum of the Hungarian Natural History Museum contains about 2000 specimens, provides an excellent starting point for learning about the region's lichenology. Both the experience gained in lichen identification and the lichen species collected also serve as a useful basis for updating the Hungarian Red List, that was compiled in 1997. Regular updates of the red list are necessary to protect the habitat of lichen species. Lichen conservation would also be a significant and important addition to conservation surveys. Studies to assess the distribution of protected lichen species are missing. Conservation through habitat management is overshadowed by the lack of knowledge of species identification and ecological tolerance. Lichenology could also be integrated into conservation. The lichenological conservation of our country is a priority, especially because three of our lichen species (*Cladonia magyarica*, *Xanthoparmelia pokornyi*, *Xanthoparmelia pulvinaris*) were describe originally from Hungary, and the largest populations are found in our country.

Aims

This study presents the results of research on protected lichen species and conservation issues in the Bakony Region. The research aimed to estimate the distribution range and population size of the 9 protected lichen species known to occur in the Bakony Mts, to assess their habitat status and to describe their habitat preferences. *Lobaria pulmonaria* is presumed to be extinct in the Bakony Mts, and has not been known to be present for about 80 years, so

it is not the subject of this study. *Cladonia magyarica* was also not included in the studied species due to difficulties in field identification. A survey of 9 species of lichens under legal protection was carried out (*Cetraria aculeata, C. islandica, Cladonia arbuscula, C. mitis, C. rangiferina, Peltigera leucophlebia, Solorina saccata, Xanthoparmelia pokornyi, X. pulvinaris*). This paper includes overall conclusions on the distribution and habitat preference of the 9 protected lichen species. With the results of this thesis, my future goal is to support habitat conservation by the presence of protected lichen species. Furthermore, lichens should be included in conservation surveys and measures. The developed field sampling method provides an opportunity to learn about the distribution and habitat environment of protected lichen species.

The research aims were going to answer the following questions:

1. How many sites of protected lichen species have been confirmed based on previous occurrences in the Bakony Region?
2. Are there new, previously unknown potential sites of protected lichen species in the Bakony Region? Where are these new potential sites?
3. What lichen dispersal characteristics can be observed in the Bakony Region?
4. Which are the main environmental factors affecting the distribution of protected lichen species? Which biotic-abiotic factors are responsible for the distribution of a protected lichen species in the Bakony Region? What is the primary influencing factor?
5. Which environmental factors distinguish the appearance of the various *Cladonia* species in the Bakony Region?
6. How are the environmental needs of protected lichen species similar and different?
7. How does the cover and composition of the vascular vegetation affect the species richness of lichens and the cover of lichen populations?
8. How does disturbance affect the production of the fruiting bodies of protected lichen species?
9. How does disturbance affect the lichen and moss vegetation in the biological soil crust?

Material and methods

Field studies were carried out to explore and confirme the old herbarium and literature drecords, as well as to find new occurrences of 11 protected lichen species in the Bakony Mts

between 2015 and 2019. For habitat preference investigations altogether 149 quadrats of 2 m × 2 m were sampled, which was further divided into 10 m × 10 cm microquadrats. This sampling method provides the opportunity to identify the three groups of organisms (lichens, mosses, vascular plants) at species and cover level. The microquadrats also show the pattern of the lichen thalli. Detection of animal trampling and chewing and small-scale human-induced disturbance was estimated on a four-point scale: 0 = no disturbance; or 0-5% maximum; 1 = weak disturbance, 5-25%; 2 = moderate disturbance, 25-50%; 3 = strong disturbance, trampling and chewing above 50%. The results were statistically evaluated using Statistica 13.0, R version 3.6.1 and Past 4.12.

New scientific results – theses

1. **Based on previous herbarium and literature data, the sites of the nine protected lichen species (*Cetraria aculeata, C. islandica, Cladonia arbuscula, C. mitis, C. rangiferina, Peltigera leucophlebia, Solorina saccata, Xanthoparmelia pokornyi, X. pulvinaris*) in the Bakony Region have been confirmed in 40 cases.**

The nine protected lichen species were previously known from 75 sites in the Bakony Mts, of these, 40 sites were confirmed during field researches. The total cover of the 9 protected lichen species in the Bakony Region is 146,104.3 cm^2. There are currently 268 herbarium and 6 literature records of the occurrence of protected lichen species in the Bakony. At these sites, I recorded habitat characteristics and information on the colonisation of protected lichen species using the field methodology I had developed.

For *Cetraria aculeata,* 21 herbarium specimens from the Bakony Mts and 2 literature records are available. Three (Litér: Mogyorós-hegy, Veszprém: Tekeres-völgy, Veszprém: Csatár-hegy) of the 4 previous sites (Öskü: Bér-hegy, Litér: Mogyorós-hegy, Veszprém: Tekeres-völgy, Veszprém: Csatár-hegy) were confirmed the species.

Cetraria islandica previously had only one occurrence in the Bakony Region (Várpalota), which could not be confirmed. Despite a thorough search of the military range in Várpalota, the species has not been found.

16 herbarium records of *Cladonia arbuscula* are available from the Bakony Mts. Two (Káptalanfüred: Köcsi-tó, Révfülöp: Fülöp-hegy) of the previous four sites have been confirmed.

There are 44 herbarium records of *Cladonia mitis* from the Bakony Mts. Before this present study, it was known to occur at 6 sites (Fenyőfő: ősfenyves, Zánka: Virius-telep, Uzsa: Úrbéri-erdő, Szentbékkálla: Szentimrepuszta, Káptalanfüred: Köcsi-tó, Ábrahámhegy: Kisörsi-hegy), four (Uzsa: Úrbéri-erdő, Szentbékkálla: Szentimrepuszta, Káptalanfüred: Köcsi-tó, Ábrahámhegy: Kisörsi-hegy) of which were confirmed.

Before this study, *Cladonia rangiferina* was known from 4 sites (Fenyőfő, Uzsa: Úrbéri-erdő, Káptalanfüred: Köcsi-tó, Ábrahámhegy: Kisörsi-hegy, Révfülöp: Gödepont-hegy), 2 of these have been confirmed (Uzsa: Úrbéri-erdő, Ábrahámhegy: Kisörsi-hegy).

Peltigera leucophlebia has been confirmed from 2 (Veszprém: Mohos-kő, Bakonyszentlászló: Ördög-rét) of the 9 sites previously found. The population size recorded in the three field sampling units is 2,613 cm^2.

In the case of *Solorina saccata*, 55 previous herbarium specimens were collected from 34 sites. Nine sites occur in the area of the Keszthely Hills, where investigations are expected in the future, they are not included in this paper. From the remaining 25 sites, 20 sites (Sáska: Rosta-völgy, Veszprém: Betekints-völgy, Hárskút: Slézinger-völgy, Bakonyoszlop: Ördög-árok, Felsőörs: Malom-völgy, Lovas: Királykúti-völgy, Veszprém: Csatár-hegy, Balatonfüred: Koloska-völgy, Isztimér: Burok-völgy, Hajmáskér: Tobán-hegy, Várpalota: Vár-völgy, Márkó: Malom-hegy, Bakonykúti: Kis-Burok-völgy, Bakonyszentlászló: Alsó-Cuha-szurdok, Veszprém: Mohos-kő, Bakonybél: Kerteskői-szurdok, Farkasgyepű: Bittva-patak felett, Hárskút: Fehér-kő, Tés: Szúnyog-völgy, Bakonyszentlászló: Ördög-rét) have been confirmed.

Two (Litér: Mogyorós-hegy, Királyszentistván: Ugri-hegy) of the four previous sites (Csór: Baglyas-hegy, Isztimér, Királyszentistván: Ugri-hegy, Litér: Mogyorós-hegy) of the *Xanthoparmelia pokornyi* were found recently.

Xanthoparmelia pulvinaris was found from 5 (Litér: Mogyorós-hegy, Veszprém: Tekeres-völgy, Várpalota: Kopasz-Hallgató, Csörget-völgy, Várpalota: Vár-völgy Veszprém: Csatár-hegy) of the 9 previous sites.

2. 45 new, previously unknown sites of the nine protected lichen species in the Bakony Region were explored.

45 new occurrences have been added to the previous ones of protected lichen species in the Bakony.

Cetraria aculeata is new from 6 sites (Balatonalmádi: Megye-hegy, Királyszentistván: Ugri-hegy, Olaszfalu: Eperjes-hegy, Sóly: Győri-úti-irtás, Zalahaláp: Cseket-hegy,

Ódörögdpuszta). Three of its 4 previous occurrences have been confirmed and with the 6 new occurrences it is now known from 9 sites in the Bakony Mts. The total cover at occurrences of the species at the 9 sites and the 20 field relevés is 14,678.75 cm^2.

Cetraria islandica previously had only one occurrence in the Bakony Mts (Várpalota), that could not be found, but the species was found in a new location (Taliándörögd: Baksa-top) and so it is still a member of the Bakony lichen community. Recorded population size is 90 cm^2 in the three quadrats.

The species *Cladonia arbuscula* was found in two (Balatonalmádi: Köcsi-tó, Révfülöp: Fülöp-hegy) of the four previous sites. 7 new sites (Balatonrendes: Rendesi-hegy, Balatonszepezd: Bödi-hegy, Kővágóörs: Falu-erdő, Tepécs-hegy, Vörös-domb, Uzsa: Úrbéri-erdő, Salföld: Kütyüi-domb, Köveskál: Fekete-hegy) have been found. Based on the 15 field quadrats, the population size is 2,200.3 cm^2.

13 new sites have been added to the *Cladonia mitis* in the Bakony Region (Kővágóörs: Falu-erdő, Révfülöp: Fülöp-hegy, Kővágóörs: Vörös-domb, Balatonhenye: Fekete-hegy, Köveskál: Fekete-hegy, Kővágóörs: Tepécs-hegy, Balatonrendes: Rendesi-hegy, Salföld: Csigó-tag, Káptalantóti: Mohos-tető, Salföld: Csönge-hegy, Salföld: Kütyüi-domb, Kővágóörs: Ecséri-erdő, Balatonszepezd: Bödi-hegy). The popuation size is 64,567.2 cm^2 in the 36 sample units.

For *Cladonia rangiferina*, 6 new sites were discovered (Kővágóörs: Vörös-domb, Kővágóörs: Falu-erdő, Kővágóörs: Tepécs-hegy, Balatonrendes: Felső-erdő, Kővágóörs: Ecséri-erdő, Balatonszepezd: Bödi-hegy). Total population size is 11,251.2 cm^2 in the 13 sample units.

The *Peltigera leucophlebia* was confirmed from 2 of the 9 sites previously found. I have not found a new occurrence.

In the case of *Solorina saccata*, 4 sites were newly recorded in the Bakony Mts (Csór: Baglyas-hegy, Pécsely: Zádor-vár, Tés: Mórocz-tető, Vászoly: Nagy-vár-tető). Registered thallus size is 21,975.6 cm^2 in 57 field sample units. Currently 79 herbarium records and 4 literature records are available for the species.

Of the previous 4 sites of the *Xanthoparmelia pokornyi*, 2 have been successfully found and 3 sites have been discovered as new (Balatonalmádi: Megye-hegy, Csór: Gomba-hegy, Hajmáskér: Rác-Halála). The registered popualtion size is 21,323.25 cm^2.

Of the previous 9 sites of *Xanthoparmelia pulvinaris*, the species was confirmed in 5 and 5 sites were recorded as new (Balatonalmádi: Megye-hegy, Csór: Gomba-hegy,

Királyszentistván: Ugri-hegy, Sóly: Győri-úti-irtás, Hajmáskér: Rác-Halála). Total population size 7,405 cm^2 based on 26 field sampling units.

3. **I have established the characteristic frequency and specific distribution characteristics of the protected lichen species in the Bakony Region based on the bedrock and vegetation type, the geographical distribution characteristics and conservation status of their habitat.**

The habitats show that *Cetraria aculeata, Xanthoparmelia pokornyi* and *X. pulvinaris* occur in the same calcareous bedrock habitat type, *Cetraria aculeata*, with some exceptions, in calcareous slope and scree grasslands, while *Xanthoparmelia pokornyi* and *X. pulvinaris* occur in good numbers in calcareous open rocky grasslands in addition to slope grasslands. However, populations of *Cetraria aculeata* also occur in the southern Bakony Mts, around Zalahaláp, while thalli of *Xanthoparmelia pokornyi* and *X. pulvinaris* were only observed in the dry grasslands around Veszprém, the westernmost occurrence of the Bakony Mts. Both species of *Xanthoparmelia* are the most frequent in the eastern Bakony Mts and the eastern part of the Balaton Uplands. The *Cladonia* species are most abundant in acidophilic open acidofrequent oak forests with acidic bedrock (basalt, red sandstone, Pannonian sandstone). They occur in reduced numbers in closed acidofrequent oak forests as the forest stand closes. They are also found in the dry *Calluna* heaths of Kál Basin. *Cladonia mitis* also occurs in fully open grasslands in limited numbers. *Cladonia* species are also sporadic because of the sporadic and often patchy extent of the acidic bedrock. Populations are separated by up to 100 km, and sometimes they are just fragments of a thalli without larger, developed thallus. In addition to dolomite, *Solorina saccata* thalli also develop in significant numbers in limestone habitats, mainly in the High Bakony Mts.. *Solorina saccata* occurs mainly in north-facing, closed rocky grassland and oak forests on rocky soils near hilltops. *Peltigera leucophlebia* occurs on limestone bedrock with high moss abundance in the Bakony.

More than half of the 149 field records (82) is a part of a Natura 2000 site. 28 quadrats are neither protected nor a Natura 2000 site. A significant proportion (17) of the quadrats studied are at strictly protected natural areas (Nagy-vár-tető, Kerteskői-szurdok, Fekete-hegy, Kütyüi-domb, Szentimrepusztai kőtenger). 14 quadrats were registered in protected natural areas, that belong to the Balaton Uplands National Park (Balaton-felvidéki Nemzeti Park, Balatonfüredi-erdő Természetvédelmi Terület, Magas-Bakonyi Tájvédelmi Körzet, Uzsai csarabos Természetvédelmi Terület) (Fig. 1).

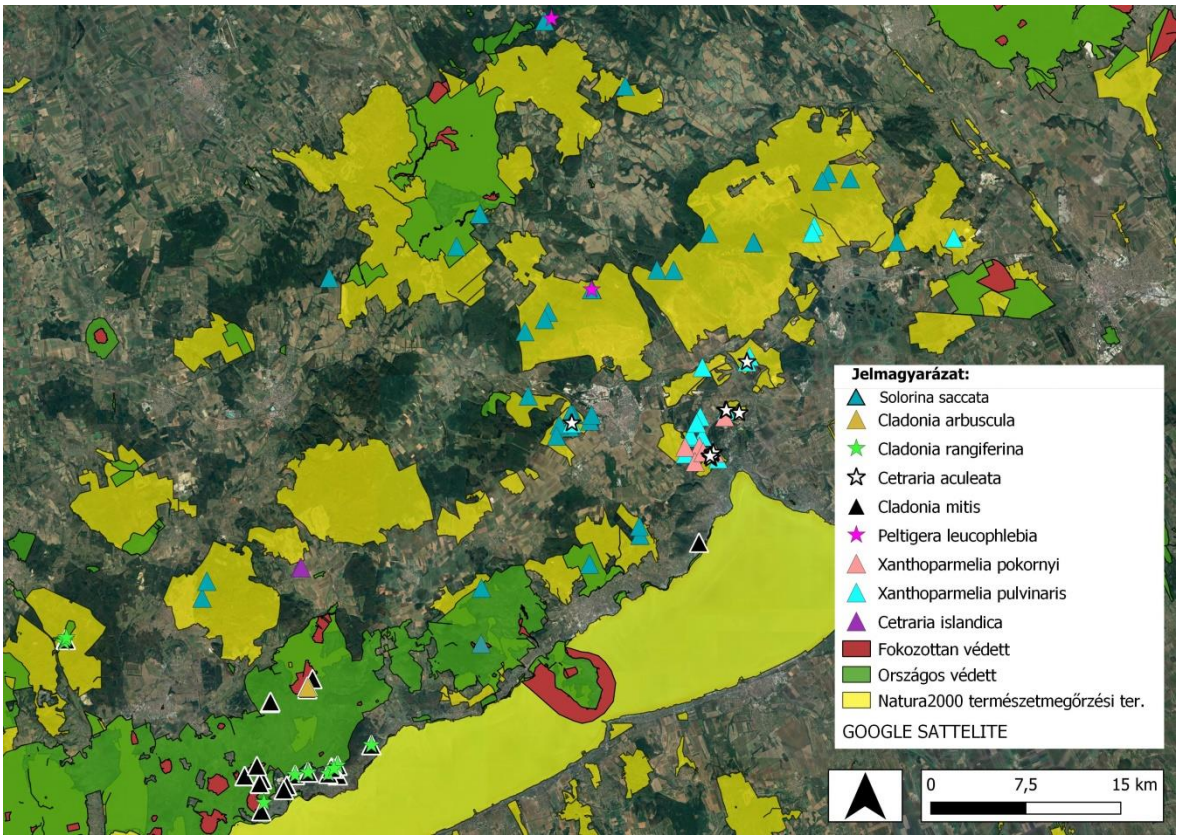

Fig. 1: Map of the protected lichen species based on the protected area, and Natura 2000 site.

4. I found, that the primarily influencing environmental factors on the distribution of the protected lichen species in the Bakony Region are the cover of vascular plants, mosses and rocks, furthermore the canopy closure.

Seven (*Cetraria aculeata, Cladonia arbuscula, C. mitis, C. rangiferina, Solorina saccata, Xanthoparmelia pokornyi, X. pulvinaris*) of the nine protected lichen species were sampled for multivariate statistical evaluations in the Bakony Region. In this chapter, the results of multivariate analyses based on the species composition and environmental variables of *Cetraria aculeata*, *Solorina saccata*, *Xanthoparmelia pokornyi* and *X. pulvinaris* are presented.

The habitats of the *Cetraria aculeata* are quite similar in the Bakony Mts according to the Principal Component Analysis (PCA) of its quadrats. Most of the quadrats are of the same habitat type (H2). A few quadrats are isolated, explained by the higher cover values of species typical of grasslands that are more open. Among the environmental variables, the quadrats (PCA) show weak separation based on moss and rock cover.

The quadrats of *Solorina saccata* are separated by woodland and grassland habitats. The separation of these two groups is striking both in the plot of the principal component analysis

based on the species cover values and in the one based on the environmental variables (PCA). The first axis determined by canopy closure explains the separation of the two groups.

Evaluation of the quadrats of *Xanthoparmelia pokornyi* and *X. pulvinaris* suggests that the poor separation of closed and open habitats is due to changes in rock cover and vascular plant cover.

5. I have determined the environmental factors (bedrock type, soil pH, ecological tolerance – especially tolerance of disturbance -, and canopy closure) that distinguish the species of reindeer lichen (*Cladonia arbuscula, C. mitis, C. rangiferina*) in the Bakony Region.

The habitats of the three reindeer lichen species are quite similar and their ranges overlap considerably. The three reindeer lichen species cannot be separated by the species composition of their habitats. However, there are some differences in the abiotic factors. *Cladonia arbuscula and C. mitis* prefer similar habitat and abiotic factors. They are mostly found on basalt, Pannonian sandstone and red sandstone at soil pH 3.6-5.7. *C. arbuscula* tolerates soil disturbance better than *C. mitis*. In general, *C. mitis* has the broadest ecological tolerance, occurring in almost all types of habitats where the other two species occur. Nevertheless, it is the only one of the three species to be found in the more closed areas dominated by deeper soil and higher vascular plant cover. *C. rangiferina* has the narrowest ecological tolerance of the three species (Fig. 3.). It tolerates only up to 25% trampling and chewing. Based on our studies, *C. rangiferina* is found in acidofrequent oak forests with a significant canopy closure of up to 95%, mainly in undisturbed or less disturbed habitats. Although *C. rangiferina* is not very different from the other two species, it is mostly found where the canopy is more closed, the moss cover is higher (75% on average), and the vascular plant and lichen cover are lower, the soil is shallower and more acidic (pH 3.6 and 4.6). When comparing habitat characteristics, no significant differences are obtained, although there are minor differences in habitat requirements, no sharp distinction is apparent (Fig. 2). The canopy cover was the most significant difference between the three species. *C. mitis* occurs in habitats with lower canopy closure, *C. rangiferina* is found in the most closed habitats, while *C. arbuscula* prefers medium canopy closure. In the occurrences, developed and fragmented thalli of *C. arbuscula* are significantly smaller in number than thalli of the other two species. The low ecological tolerance of the species allows the indication of natural habitats in Hungary. Reindeer lichens are endangered in most of the sites in the Balaton Uplands due to

their limited occurrence, small number of thalli and exposure to humans, game trampling. Artificial propagation of thallus fragments is proposed for their future survival.

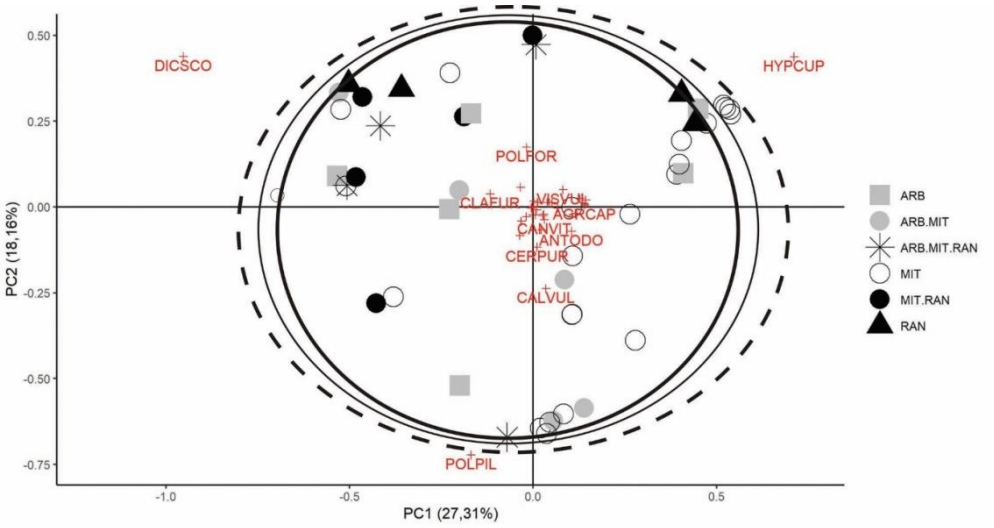

Fig. 2: Principal component analysis (PCA) based on species cover data. For analysis, the data were subjected to Hellinger transformation and only species that occurred in at least five records were included. The grey square, grey circle and star symbols refer to *C. arbuscula*, the grey, white and black circles and star refer to *C. mitis*, the black circle, black triangle and star indicate records of *C. rangiferina*. The thin outline indicates *C. arbuscula*, the dashed outline *C. mitis* and the thick outline *C. rangiferina.* POLFOR = *Polytrichum formosum*, CLAFUR = *Cladonia furcata*, VISVUL = *Viscaria vulgaris*, AGRCAP = *Agrostis capillaris*, CANVIT = *Candelariella vitellina*, ANTODO = *Anthoxanthum odoratum*, CERPUR = *Ceratodon purpureus*, CALVUL = *Calluna vulgaris*, POLPIL = *Polytrichum piliferum*, DICSCO = *Dicranum scoparium*, HYPCUP = *Hypnum cupressiforme*.

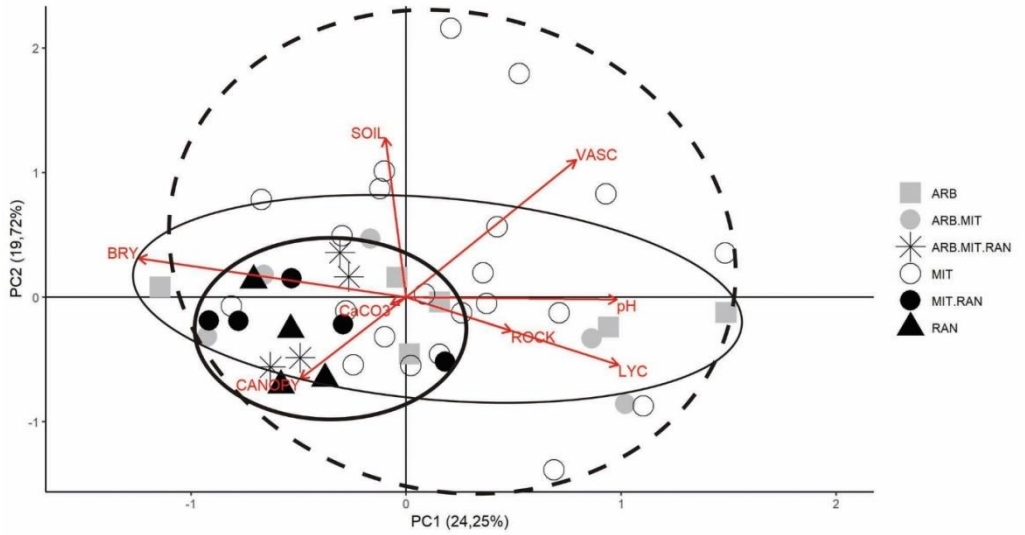

Fig. 3: PCA analysis based on numerical environmental variables. Grey square, grey circles and star symbols refer to *C. arbuscula*, grey, white and black circles and star refer to *C. mitis*, black circles, black triangle and star indicate *C. rangiferina* records. The thin outline indicates *C. arbuscula*, the dashed outline *C. mitis* and the thick outline *C. rangiferina*. SOIL – soil depth, VASC – vascular plant cover, LYC –lichen cover, pH – soil pH, CANOPY – canopy closure, BRY – bryophyte cover, $CaCO_3$ – soil $CaCO_3$-content.

6. I have demonstrated that three groups of protected lichen species can be distinguished on the basis of environmental variables – canopy closure, rock deposition and soil chemistry –, and species composition. Segregation is primarily influenced by canopy closure, rock deposition and soil chemistry.

As a result of the comparison of sites of protected lichen species, three major groups can be distinguished on the basis of the cover (%) of vascular plant, lichen and moss species (501 species). The groups are separated partly on the basis of protected lichen species and partly on the basis of habitat type (ÁNÉR). Significant differences along species composition ($p = 0.0001$) were detected by permutational multivariate analysis of variance (one-way perMANOVA, Bray–Curtis index, 9999 repetitions).

One group includes the main protected lichen species *Cetraria aculeata, C. islandica, Xanthoparmelia pokornyi* and *X. pulvinaris*, a separate group includes records of *Solorina saccata* and *Peltigera leucophlebia* and a third group includes records from the habitats of *Cladonia arbuscula, C. mitis and C. rangiferina*. One calcareous and two acidic species communities have been outlined. The difference between the two calcareous groups is caused by differences in soil pH and $CaCO_3$ content, vascular plant species, moss cover and soil depth, based on an RDA analysis of environmental variables (Fig. 5). Principal component analysis (PCoA, Bray–Curtis test - 4. Fig. 4) shows that the calcareous habitat types (E5, L4b, L4a, G1, G3) form a separate group from the reindeer lichen species quadrats, the dry grassland group (G2, H2, H3a, H4) are the habitats of *Cetraria* and *Xanthoparmelia* species, and the rocky habitats (H1, LY3, LY4, M1) are the habitats *of Solorina saccata* and *Peltigera leucophlebia*. The two calcareous groups differ in canopy closure, rock cover and disturbance (Fig. 5). The separation of *Solorina saccata* and *Peltigera leucophlebia* from the other species is largely explained by canopy closure and rock cover (Fig. 5).

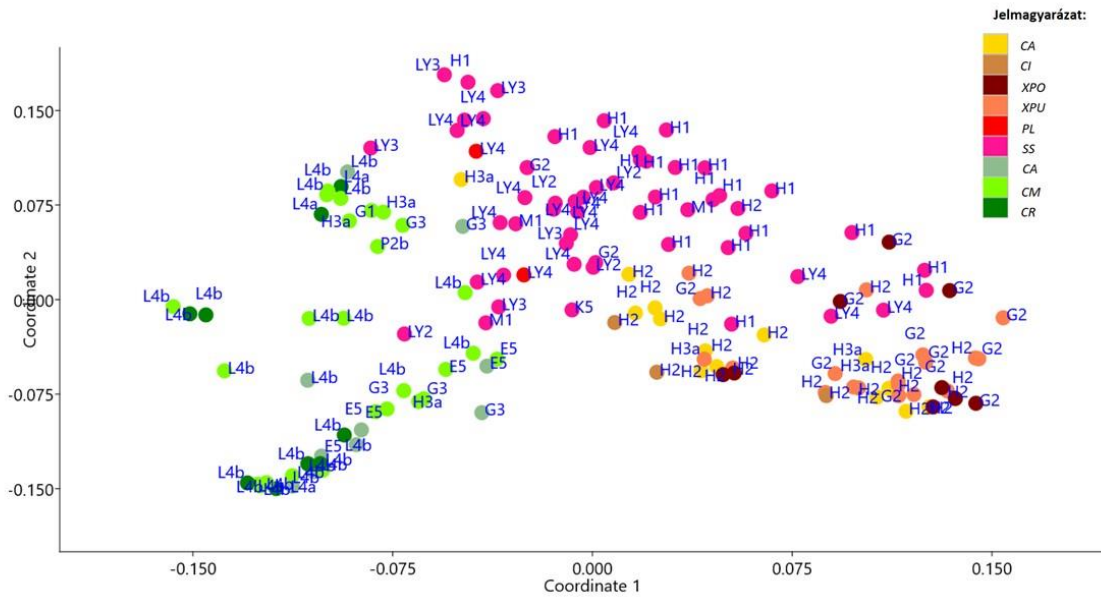

Fig. 4: Habitat type ordination (PCoA, Bray–Curtis index) of the sampled records (149) based on the percentage of vascular plant, lichen and moss cover (CA – *Cetraria aculeata*, CI – *Cetraria islandica*, XPO – *Xanthoparmelia pokornyi*, XPU – *Xanthoparmelia pulvinaris*, PL – *Peltigera leucophlebia*, SS – *Solorina saccata*, CAR – *Cladonia arbuscula*, CM – *Cladonia mitis*, CR – *Cladonia rangiferina*) (axis 1: 11.21%, axis 2: 8.15%).

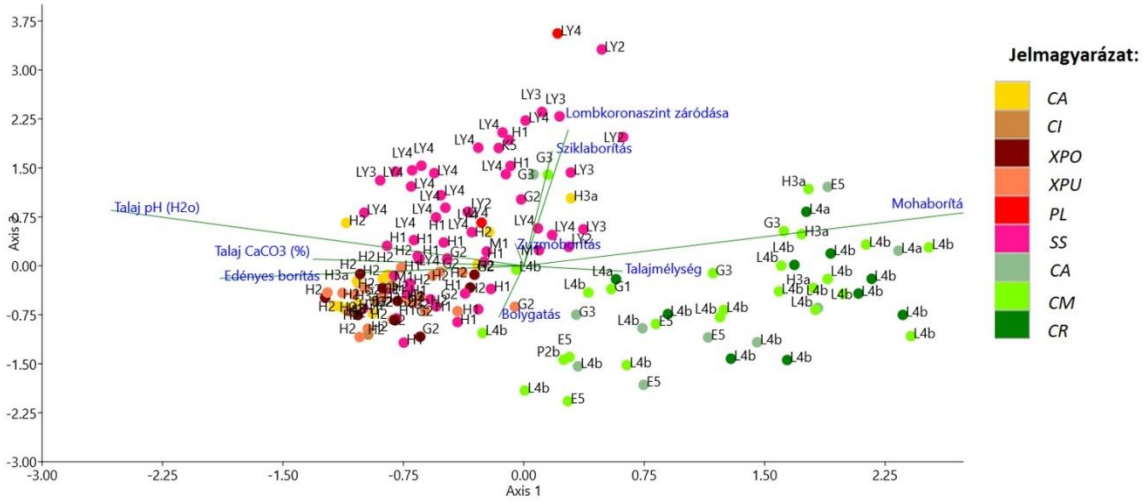

Fig. 5: RDA analysis (501 species) based on environmental variables (CA – *Cetraria aculeata*, CI – *Cetraria islandica*, XPO – *Xanthoparmelia pokornyi*, XPU – *Xanthoparmelia pulvinaris*, PL – *Peltigera leucophlebia*, SS – *Solorina saccata*, CAR – *Cladonia arbuscula*, CM – *Cladonia mitis*, CR – *Cladonia rangiferina*) (axis 1: 11.06%, axis 2: 13.79%)

7. I found that there is a positive correlation between the number of vascular plant species and the number of lichen species in the investigated 149 sampling units of the Bakony Region.

Based on the 149 quadrats, there is a weak relationship between the number of lichen species and the number of lichen species as a result of Kendall's tau correlation analysis, as the obtained p values are below 0.05 (p = 0.043951), i.e. there is a weakly significant positive relationship between the two variables. The number of vascular plant species is positively correlated with the number of lichen species. According to the correlation calculations carried out, there is a relationship between the composition of the vascular plant vegetation and the number of lichen species. The number of lichen species is higher in areas with a high number of vascular plant species. However, the cover values indicate that there is no relationship between vascular plants and lichens, with values above 0.05 (vascular plant species number and lichen cover: p = 0.7533; vascular plant cover and lichen cover: p = 0.69501; moss cover and lichen cover: p = 0.36788).

8. **The number of protected lichen species depends on the degree of disturbance, thus the fruiting body formation of lichen thalli increases with descreasing disturbance in the investigated 149 sampling units of the Bakony Region.**

Among the vitality indicators, I investigated the growth rate of lichen fruiting body. Field experience has shown that as the rate of disturbance increases, the number of fruiting bodies decreases and lichen thalli die out partially or completely. *Solorina saccata* forms a spectacular, countable number of fruiting bodies. In the case of *S. saccata* thalli, it was observed that most of the fruiting bodies develop at 0 disturbance value, there were quadrats where the vitality was represented by even 600 and 300 fruiting bodies, but the value around 100 fruiting bodies meant already a significant number. At a value of 1, numbers below 100 are more likely to be observed, mostly between 0 and 50.

9. **I found that disturbance affects the investigated lichen and moss vegetation (biological soil crust) in different ways in the investigated 149 sampling units of the Bakony Region.**

The main disturbance factor is trampling and chewing of animals in the study area. *Cetraria aculeata, C. islandica, Cladonia magyarica, Xanthoparmelia pokornyi* and *X. pulvinaris* are exposed to sheep grazing which live in rocky and sloping grasslands. It can be observed in places that the thallus sizes of these species are decreasing due to intensive sheep grazing. In 149 quadrats, moss cover reaches 100% at 0 value of disturbance. In all but one

quadrat, the maximum moss cover is 45% at a value of 2, and at a value of 3 the highest cover is close to 40%. The lichen cover also shows the highest values at 0 disturbance. Developed thalli of protected lichen species show the highest numbers at disturbance values 0 and 1. According to SOUSA 1984 and HUSTON 1994, minimal disturbance can facilitate the production of new thalli by thallus fragments, since the highest number of quadrats with a large number of thallus fragments are observed at disturbance value 1.

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Publications related to the topic of the thesis

Publications in peer-reviewed journals:

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