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LICHEN DIVERSITY PATTERNS IN ALTITUDINAL GRADIENT: THEIR INDICATOR VALUE FOR THE HABITATS CONSERVATION IN PIETROSUL RODNEI

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Summary of the PhD thesis

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CONTENTS

Key words: Lichen diversity, Rodnei Mountain National Park, Conserved, Managed, functional groups, species richness.

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Introduction

Biodiversity is a major concern for researchers in their nature conservation efforts. The changes in the way ecosystems are running may have major long term effects. Therefore, it is very important to understand the patterns and processes taking place under changing environmental conditions, especially during habitat management.

Lichens are a species-rich and widespread group, reaching approx. 13,500 species globally (Hawksworth & Hill, 1984) and occurring in various habitats. They act as natural sensors of changing environments. Approximately 8% of terrestrial ecosystems are climatically extreme or represent oligotrophic environments and are dominated by lichens. Furthermore, in temperate forest ecosystems lichens play numerous functional roles including significant N-fixation and nutrient cycling. They also serve as forage for mammals and arthropods (Nash, 2008).

The protected areas are refugees of biodiversity, especially for rare and endangered species. Rodnei Mts. National Park is an important protected area due to its geology and geomorphology and the presence of many plant and animal species that are either endemic and/or glacial relicts (APNMR, 2013). Pietrosul Mare region was declared a UNESCO Biosphere Reserve in 1980, this status being extended later to the current limits of the national park.

The conclusions resulted from analysis of the lichen species diversity patterns extend our knowledge on the existing habitat types and have the potential of improving the management plan, which implies certain conservation strategies.

Chapter 1

LICHEN FLORA OF RODNEI MOUNTAINS NATIONAL PARK (EASTERN CARPATHIANS, ROMANIA) INCLUDING NEW RECORDS FOR THE ROMANIAN MYCOFLORA

Introduction

260 lichen species from 11 locations were previously reported in Rodnei Mountains (Ciurchea, 2004), and reflected the high species richness of the national park. However, the knowledge of lichen species distribution is still scattered in Romania and some of the species records have not been rechecked since more than a century (Bartok & Crișan, personal communication).

Conserved areas are well known sanctuaries for threatened species (Goward, 1995; Zoller et al., 2000; Nascimbene et al., 2013; Ignatov et al., 2004; Lackovičová & Guttová, 2006) and important lichen habitats such as old-growth forest stands and veteran trees are lost due to management of habitats (Wolseley, 1995; Thor, 1995; Scheidegger & Werth, 2009).

The aims of this study are:

1) Assess the lichen flora of characteristic habitats of the Rodnei Mountains in a replicated design with a standardized lichen diversity assessment.
2) Reveal the importance of conserved areas for the maintenance of lichen diversity in the Rodnei Mts.
3) Contribute to decisions about future conservation strategies within this biosphere reserve.

Materials and methods

Study area

The Rodnei Mountains are located in the northern part of the Eastern Carpathians reaching their highest elevation at Pietrosul Mare Peak (2303 m). Most of the study area is part of the Rodnei Mountains National Park, established in 1932 and declared a UNESCO Biosphere Reserve in 1979.

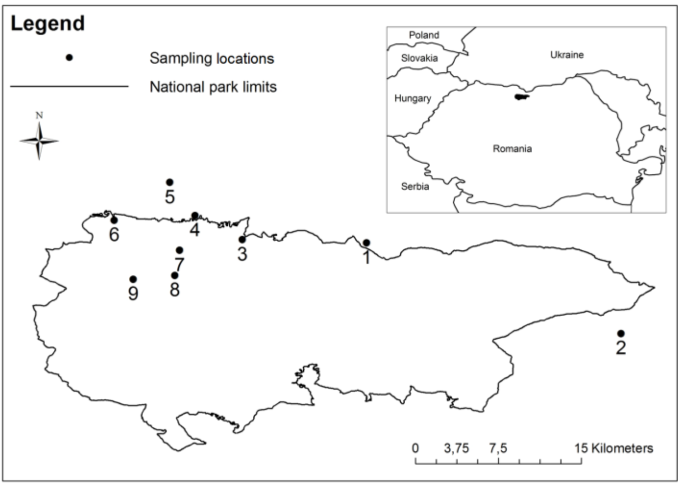

Figure 1. Location of the Rodnei Mts National Park in Romania, and study area with sampling localities. 1 – Cascada Cailor, 2 – Rotunda Pass, 3 – Repedea Valley, 4 – Borșa 1, 5 – Borșa 2, 6 – Izvorul Dragoș Valley, 7 – Pietrosul Mare, 8 – Gropile, 9 – Bătrâna.

Climate is characterised by the Baltic and the Oceanic influences with mean annual temperature decreasing with altitude, from 6℃ at the base of the mountains to –1.5℃ at the highest altitudes. Mean annual precipitations range from 1300 to 1400 mm (Gorduza, 1983).

Sampling (according to Scheidegger *et al.*, 2002):

- ✓ sampling unit of one hectare circular plot.
- ✓ four main substrates: trees, wood, soil and rock - 6 relevés for each (if the substrate was not available, it was substitued with other available substrates), thus achieving 24 relevés in each plot.
- ✓ all lichen species within a relevé surface of 0.2 m^2 were collected (except the crustose lichens from rocks).
- ✓ the investigated habitats follow an altitudinal gradient: wooded meadows to mixed and coniferous forests, to *Pinus mugo* shrubs and alpine vegetation.
- ✓ two levels of conservations: conserved and managed (except *Pinus mugo* shrubs and wooded meadows).
- ✓ seven replicated plots of 1 ha for each habitat with its corresponding levels of conservation (i.e., 56 total).

Data assessment

The importance of lichen flora was determined by the total number of species, the number of new species for the region and the new species for Romanian lichen flora. We also took into account the number of species in the proposed Red List of macrolichens from Romania (Bartok & Crișan, personal communication) and the Red Lists of the surrounding countries which harbour the Carpathian mountain ridge: Hungary (Lőkös &

Tóth, 1996), Ukraine (Didukh, 2009), Slovakia (Pisút et al., 2001), and Poland (Cieslinski et al., 2003).

Results and discussions

- ✓ we found 283 lichens species and one subspecific taxon;
- ✓ we confirmed 102 species that were reported previously;
- ✓ 182 taxa that were new records for the region;
- ✓ 67 species are reported as new in Romania;
- ✓ considering previous reports and our results, 442 lichen taxa are reported in Rodnei Mountains region, accounting for approx. 35% of the total lichen flora of Romania.

Out of 284 taxa:

- ✓ 13 are listed in the proposed Red List of macrolichens of Romania (Bartok & Crișan, personal communication),
- ✓ 8 species in the Red List of Ukraine (Didukh, 2009),
- ✓ 65 in the Red List of Hungary (Lőkös & Tóth, 1996),
- ✓ 96 in the Red List of Slovakia (Pisút et al., 2001),
- ✓ 125 in the Red List of Poland (Cieslinski et al., 2003).

The high number of new species is due to fact that, using this sampling method, we collected inconspicuous taxa (*Micarea* sp., *Placynthiella* sp., *Scoliciosporum* sp., *Lichenomphalia* sp.) and taxa that only recently have received a thorough taxonomic treatment, thus making identification possible in routine lichen diversity assessments (*Lepraria* sp.).

We found a relatively high number of species that are restricted to conserved habitats in Rodnei Mountains and which are known as indicators of ancient woodland and ecological continuity in forest landscapes (Rose, 1976; Goward, 1995; Wolseley, 1995; Thor, 1995; Gauslaa & Solhaug, 1996): *Arthonia caesia*, *Bryoria lanestris*, *Cetrelia olivetorum*, *Chaenotheca brachypoda*, *Ch. brunneola*, *Heterodermia* *speciosa, Lecanora cinereofusca, Lobaria pulmonaria, Loxospora cismonica, Megalospora tuberculosa, Menegazzia terebrata, Pertusaria coccodes, Thelotrema lepadinum, Usnea florida* and *U. subfloridana*.

Also, species from Red Lists, which depend on rare and often threatened habitats (Thor, 1995), such as *Anisomeridium biforme* and *Usnea fulvoreagens*, are extinct in some regions of the Carpathians (Pisút et al., 2001) but were recorded (once each) in conserved mixed forests in the present study of the Rodnei Mountains. Other examples of species limited to conserved areas, having Critically Endangered status in the Red Lists and being recorded once or twice in our study include: *Arthonia vinosa, Bellemerea cinereorufescens, Bryoria capillaris, B. chalibeiformis, Cetraria aculeata, Cladonia magyarica, Hypogymnia vittata, Icmadophila ericetorum, Lecanactis abietina, Lecanora albella, Mycoblastus sanguinarius, Nephroma parile, Phaeophyscia endophoenicea* and *Pyrenula nitidella*.

All these species stress the importance of maintaining their suitable habitats, which are currently restricted to protected areas.

The present study, with its large number of new species for Romanian lichen flora and for the Rodnei Mountains region suggests the need of more detailed inventories. To this day, there is no official Red List of lichens for Romania, except a manuscript dealing with macrolichens only (Bartok & Crișan, personal communication). Lichen diversity and richness inventories are important for estimating the degree of threat for each species and for building a comprehensive Red List of Lichens from Romania.

The existing National Park here has the potential of conserving a considerable part of the lichen diversity and the lichen's characteristic habitats. Their presence is also important for other groups of organisms, which depend on lichens or their habitats, thus emphasizing the biocomplexity of microbial and invertebrate communities.

It is important that at least these „islands" such as Rodnei Mountains to be conserved if otherwise natural resources are still exploited in a non–sustainable manner that is leading to a substantial loss of biodiversity.

Chapter 2

EFFECTS OF HABITAT MANAGEMENT ON LICHEN BIODIVERSITY, USING RODNEI MOUNTAINS NATIONAL PARK AS MODEL AREA

Introduction

Lichen diversity studies provide important information related to patterns and processes within ecosystems. Lichens act as natural sensors of changing environments. Particular lichen species and communities are described in the literature as having a high sensitivity to a wide range of environmental conditions.

Along with altitudinal gradients, numerous studies that are focused on lichen biodiversity, describe the variables responsible for changes in species richness and communities in different habitat types (Pinokiyo et al., 2008; Banya et al. 2010; Bruun et al., 2006).

Lichen communities are a strong discriminating factor when comparing the natural and secondary forests using their richness and composition (Bergamini et al., 2005).

Rodnei Mountains National Park is an important protected area in Romania, and we deem important to assess the patterns of lichen diversity in the main habitats along the altitudinal gradient: mixed forests, spruce forests and alpine vegetation. Drawing the difference between the influence of vegetation type, macroclimate, and management, upon the lichen species diversity improves the knowledge of lichen ecology.

The aim of this study is to answer to the following questions:

1) What is the distribution of lichen species richness and composition and what are the factors influencing it?

2) How are the lichen functional groups (created based on reproduction, vegetative, and ecological traits) distributed in terms of their richness and abundance?

3) Do communities from different substrates show particular answers regarding the measured environmental variables?

Materials and methods

Three habitats are included in the present analysis: mixed forests, spruce forests, and alpine vegetation.

Each category has two conservation levels: conserved (C) and managed (M). The management varies for each habitat type, as follows:

- Mixed forests – logging, resulting in uneven aged forests,
- Spruce forests - clear-cut forestry, resulting in evenly aged forests,
- Alpine vegetation – grazing with sheep and sometime with horses and cattle.

The other two habitat types investigated in Rodnei Mountains, wooded meadows and *Pinus mugo* shrubs, could not be considered in this study brcause they had only a level of conservation. The wooded meadows are managed habitats, while the *Pinus mugo* shrubs can be found only in conserved state.

Environmental variables measured:

✓ exposure of slopes,

- ✓ altitude,
- ✓ slope of the versant.

The data sets tested for these analyses comprised the lichens from all substrates and subsets of lichens from each substrate type separately: living trees, wood, soil, and rocks.

We also analysed a subset of lichens from soil, wood and rocks covered by mosses, which is abridged as *swr.m.*

We analysed the richness of species, and particularly the red-listed species threatened (including the sozological categories of threat from VU – vulnerable, to RE – regionally extinct) in the Carpathians.

The functional traits were assessed using groups of species delimited on the reproductive, vegetative and ecological traits of lichen species (according to Stofer *et al.* 2006).

Data analysis

The species richness analysis was carried out using Generalized Linear Models (GLMs) with JMP 8.0.2 (SAS Institute Inc.).

The species composition and the groups of species (based on reproductive, morphological and ecological traits) were analysed with Non Metric Multidimensional Scaling (NMDS) ordination, with R version 2.15.2 (The R Foundation for Statistical Computing, 2012), using *metaMDS* R function from vegan package (Oksanen *et al.*, 2013). Bray-Curtis distance was used. Environmental variables were fitted afterword, using the *envfit* R function with 9999 permutations.

The distribution of abundances for the reproductive strategy, growth form and photobiont type, and the afterword fitting with environmental variables were carried out also with NMDS, using the same computational options as for the species and group ordination.

The beta diversity was measured in order to compare community homogeneity among the groups (each habitat type with its corresponding levels of conservation). The values were counted in multivariate space using the *betadisper* R function, vegan package. The dispersion of pairwise beta diversity values to the group centroid (represented by each habitat type whith it's level of conservation) were computed (Anderson et al., 2006). Pairwise similarity matrixes were obtained with the Sørensen similarity coefficient in each of the different data sets.

Results

Species richness at habitat level:

The highest number of species is found in the mixed forest – followed by the spruce forests and then alpine vegetation (Figure 2).

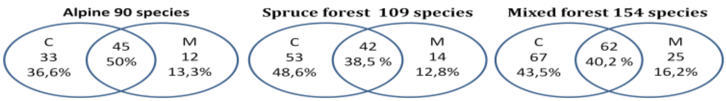

Figure 2. Venn diagrams of lichen species richness from all substrates at habitat level, restricted to one conservation level or shared between the two conservation levels: C – conserved and M – managed.

A higher number of species was present in the conserved sites for all the three habitats.

The substrate types have different importance among the three habitat types.

The substrate with higher species richness in each of the three habitat types:

- mixed forests – trees (117 species)
- spruce forests – wood (63species)
- alpine vegetation – soil (81species)

Patterns of lichen species richness

The species richness is influenced at different intensities by the environmental factors considered for each dataset analysed with GLMs.

- ❖ The conservation status is important for: lichens from all substrates, on trees and on *swr.m*, in all cases the conserved habitats having higher number of species.
- ❖ The habitat type is influencing the lichen richness in all the datasets used, but the number of species varies from one substrate to another:
- \- The alpine vegetation has the higher species richness on all substrates, soil, *swr.m* and rock.
- \- The mixed forest has the highest number of species on trees and on wood (compared o spruce forest) and the lowest number of species on soil (among all the three habitat types).
- ❖ The altitude has a weak positive influence on species richness shown only for the wood and rock substrates.
- ❖ The slope (higher slope lower species richness) and the easting exposition (more species in easting exposition) significantly influence only the species on wood.

The red-listed species have similar responses to the tested environmental variables, with several exceptions.

- ❖ The conservation status show stronger relation with red-listed species from all substrates and trees, and it is significant also for species on wood. However, for the species on *swr.m* substrate the conservation status is not influencing the number of red-listed lichens.

- ❖ The altitude is not significant anymore for the lichens on wood.
- ❖ The habitat type is not significant anymore for the lichens on wood and rock.

The variation of species composition and it's influencing factors.

Unlike for the richness of species, the altitude is an important factor in the changing of species composition for all data sets analysed.

The communities are well delimited among the vegetation types for the lichens on all substrates, on trees, on soil, and on *swr.m* (Figure 3). A big difference is especially reported among the alpine vegetation and the two forest types.

The conservation status (Figure 4) is important in delimiting the lichen communities when analysing the lichens on trees.

The northing exposition is important for differentiating the communities of species on all substrates, soil and *swr.m*.

Groups of species show similar patterns with the species, but the relations with the environmental factors are stronger.

In some cases the groups reveal new relations with environmental factors, not shown by species alone. One example is for the lichens on wood, where slope is correlated with changes in lichen communities. Or for species on rock where except altitude, the vegetation type is also significant for the delimitation of lichen communities.

Groups for species on trees (for fig. 4)

GR1: Foliose – Rarity 3 and 2 - narrow distribution and high or low abundance

GR2: Foliose – Rarity 1 - wide distribution and high abundance in most areas

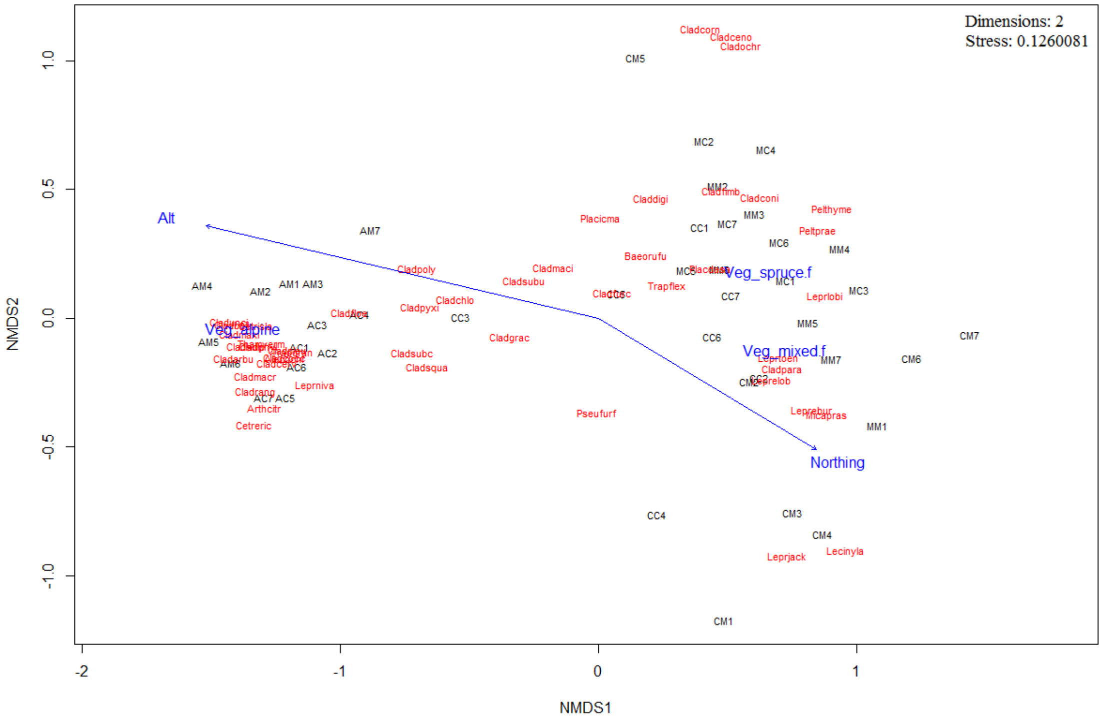

Fig. 3. NMDS ordination with lichen species composition from *swr.m*. Bray-Curtis dissimilarity index was used. Species short name - in red colour. Site codes - in black: AC1-7 – alpine conserved; AM1-7 - apine managed; CC1-7 – spruce conserved; CM1-7 – spruce managed; MC1-7 – mixed conserved; MM1-7 – mixed managed. Correlations with environmental variables and responses – in blue (only p> 0.05 are shown):Veg_alpine – alpine vegetation, Veg_spruce.f – spruce forests, Veg_mixed.f – mixed forests.

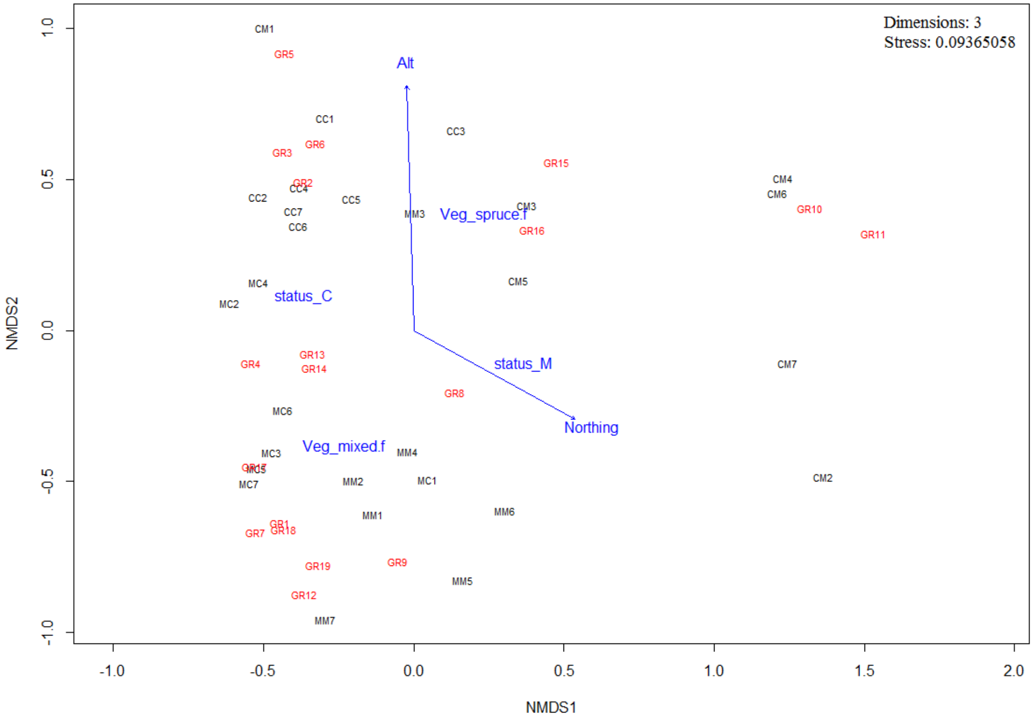

Fig. 4. NMDS ordination with groups with lichen species from trees. Bray-Curtis dissimilarity index was used. Groups (See Appendix 1) - in red colour. Site codes - in black: CC1-7 – spruce conserved; CM1-7 – spruce managed; MC1-7 – mixed conserved; MM1-7 – mixed managed. Correlations with environmental variables and responses – in blue (only p> 0.05) are shown: Status_C – conserved sites; Status_M – managed sites; Veg_spruce.f – spruce forests, Veg_mixed.f – mixed forests.

GR3: Fruticose pendulose
GR4: Fruticose erect, in Red List
GR5: Fruticose erect not in Red List
GR6: Crustose with stalked apothecia
GR7: *Pertusaria* sp.
GR8: *Lepraria* sp.
GR9: *Scoliciosporum* sp.
GR10: *Micarea prasina* s.l.
GR11: *Dimerella pineti*
GR12: *Arthonia* sp.
GR13: Crustose sterile in Red List
GR14: Crustose sterile not in Red List
GR15: Crustose fertile green algae with soredia
GR16: Crustose fertile green algae (excl. *Trentepohlia* sp.) without soredia, not in Red List
GR17: Crustose fertile green algae (excl. *Trentepohlia* sp.) without soredia, in Red List
GR18: Crustose fertile, with *Trentepohlia* sp. algae
GR19: Crustose fertile *Trentepohlia* sp. algae with perithecia.

Functional traits of lichen species

R*eproductive traits*. The management type has a significant influence on richness and abundance of species when considering the lichens from all substrates and the lichens from trees. Generally, all the groups based on reproductive traits had higher richness in the conserved sites, compared to the managed ones. The species with all types of strategies together (spores, symbiotic and fungal propagules) are more abundant in the managed habitats, indicating that the species which invest in reproductive strategies are more successful here (Figure 5).

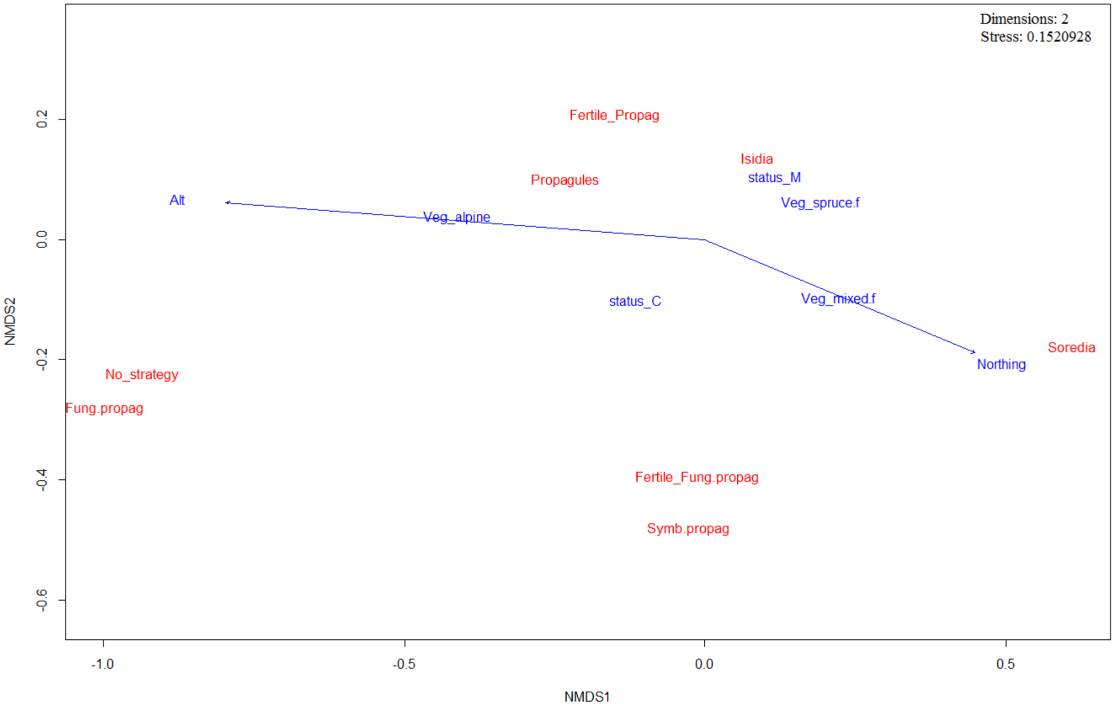

Fig. 5. NMDS ordination with reproductive traits considering lichen species from all substrates. Bray-Curtis dissimilarity index was used. Short for reproductive traits – in red colour: Fertile_Propag – Fertile with symbiotic and fungal propagules, Fertile_Fung.propag – Fertile with fungal propagules, Propagules – symbiotic and fungal propagules, Fung.propag - fungal propagules, Symb.propag – both soredia and isidia symbiotic propagules. Correlations with environmental variables and responses – in blue (only p> 0.05) are shown: Veg_alpine – alpine vegetation, Veg_spruce.f – spruce forests, Veg_mixed.f – mixed forests.

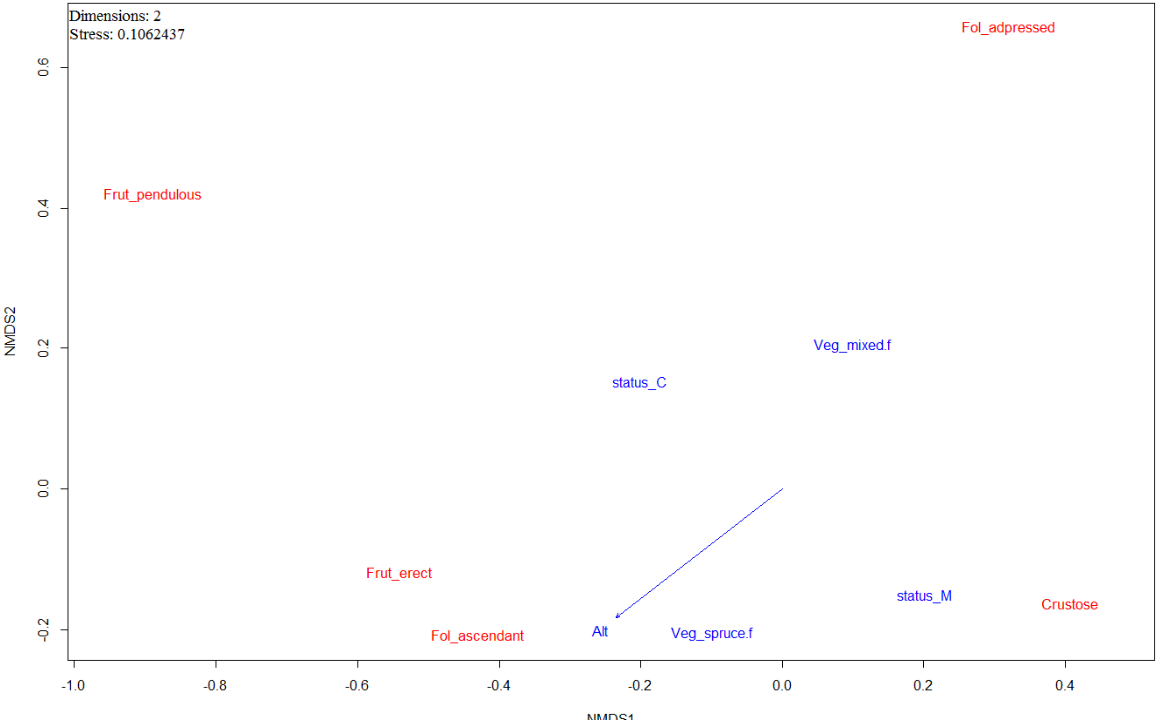

Fig. 6. NMDS ordination with lichen growth forms considering species from trees. Bray-Curtis dissimilarity index was used. Short for growth forms - in red colour: Fol_adpressed - foliose-adpressed, Fol_ascendant - foliose ascendant, Frut_erect - fruticose-erect, Frut_pendulous - fruticose-pendulous. Correlations with environmental variables and responses – in blue (only $p > 0.05$) are shown: Status_C – conserved sites; Status_M – managed sites; Veg_spruce.f – spruce forests, Veg_mixed.f – mixed forests.

The habitat type is also important when analysing the distribution of lichens according to reproductive traits, in terms of richness and abundance. For the lichens from all substrates the following habitat types have higher richness of groups with distinct reproductive traits:

- Spruce forests – mostly sterile species.
- Alpine vegetation – isidia, fungal propagules.
- The mixed forests have high richness for most of the groups created based on reproductive traits.

The abundance and richness of species considering the dispersion strategy also differs among the substrates.

V*egetative traits.*

The growth forms show significant correlation with the tested variables. From the simple crustose to more complex growth forms there are suggestive relations with the habitat management. There is a higher richness of species among the growth form groups in the conserved habitats. Moreover the complex, foliose and fruticose, forms are more abundant in the conserved sites whereas the crustose are mostly abundant in the managed ones, as shown by species on trees (Figure 6), wood and *swr.m* substrates.

Photobiont type. The mixed forests are more complex from this point of view, the *Trentepohlia* sp. and *Nostoc* sp. being more abundant in this habitat type. The alpine vegetation has a very high abundance of lichens with green algae (excl. *Trentepohlia* sp.) instead.

The *ecological traits* expressed in substrate specificity show a decrease of specialist species in the managed habitats and an increase of generalist species. According to the rarity

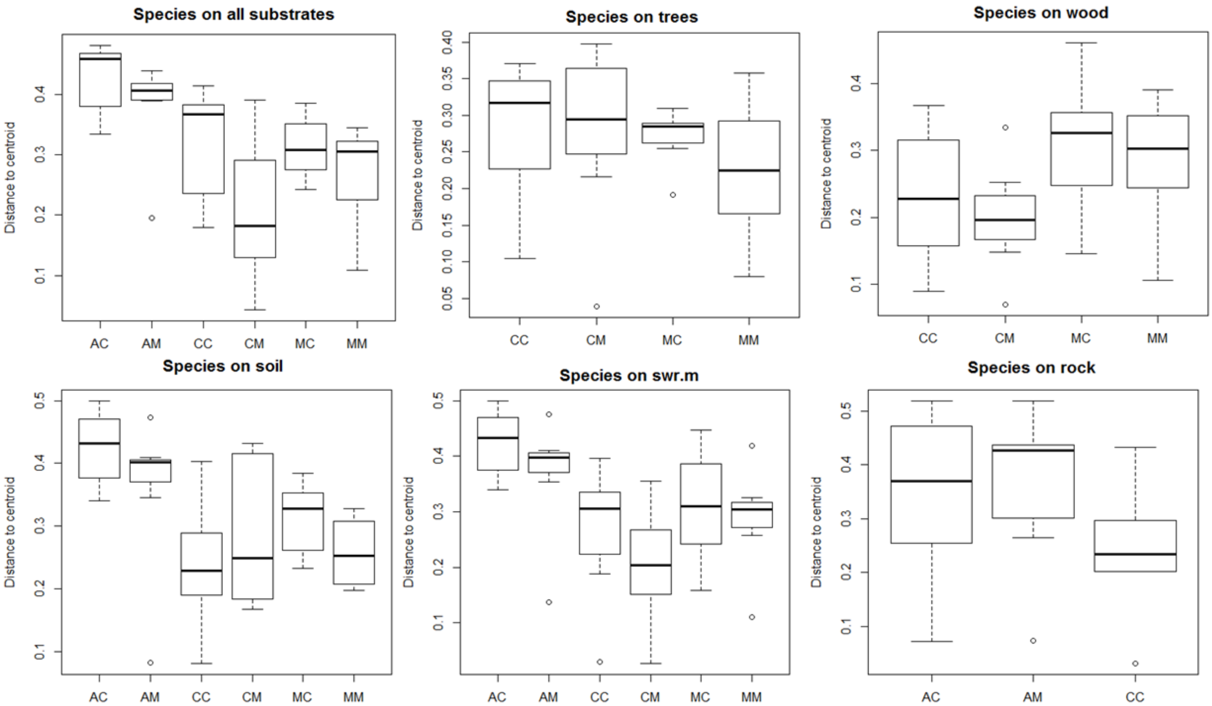

Fig. 7. Boxplots with homogeneity of multivariate dispersions as a measure of Beta diversity for lichen composition on all substrates and for each substrate separately. Codes of the groups: AC – alpine conserved; AM – alpine managed; CC – spruce conserved; CM – spruce managed; MC – mixed conserved; MM – mixed managed.

of species, the species with wide distribution and high abundance in some areas, but rare in others have lower richness, and species with wide distribution and high abundance in most areas have higher richness in the managed habitats.

The importance of altitude and slope exposition differs among the data sets tested for each functional group regarding the richness and abundance.

Beta diversity

For the species on all substrates the conserved alpine vegetation has the highest values of beta diversity and the managed spruce forests have the lowest. The individual analysis for each substrate type underlines different effects of management and habitat type on composition diversity (Figure 7)

Discussions

The environmental factors play different roles in driving the lichen diversity. In our results, the habitat type and conservation level are the most important factors that influence the patterns of lichen diversity. The altitude has a weak or absent influence on species richness, but for the changes in species composition it plays an important role. The changes in lichen communities can be observed along the altitudinal gradient (Figure 3).

The protected areas are very important for the conservation of rare and vulnerable lichen species. All the three investigated habitats are important for the lichens in Rodnei Mountains.

The scale of observation in the biodiversity assessment is very important as long as the mixed forests have the higher species richness at the habitat level and the alpine vegetation is with highest species richness at the one hectare plot level. This result could suggest that among alpine vegetation and mixed forests, a higher protected area is needed for the mixed forests to conserve a higher number of species.

Analysing the lichen communities on the different substrates allowed us to understand particular responses to environmental variables, compared to the dataset of lichens from all substrates.

The habitat type and the management of habitats influence the lichen species and composition in a high degree, especially when analysing the lichens from all substrates and those from trees.

The groups based on functional traits also showed a higher diversity in the conserved habitats, suggesting that management diminishes the habitat functionality. This result could be extrapolated to other groups of organisms, and thus underlie the importance of protected habitats due to their high functionality compared to the managed ones.

As a measure of lichen biodiversity, both species and functional traits composition and richness were proved to be very suggestive in the characterisation of the habitats, and can contribute to the decisions implemented for habitat conservation.

Chapter 3

LICHEN SPECIES DIVERSITY OF *PINUS MUGO* SHRUBS COMPARED TO ADJACENT HABITAT TYPES IN THE RODNEI MTS. NATIONAL PARK (ROMANIA)

Introduction

The habitats dominated by *Pinus mugo* (a.k.a., 4070* "Bushes with *Pinus mugo* and *Rhododendron myrtifolium*") have a high conservation value. It is also a habitat of interest in the European Community. *P. mugo* is protected in Romania because of the anthropogenic pressure (Doniță et al., 2005). It occupies the most ecologically extreme habitats, such as glacial *cirques*, tall and steep slopes in Rodnei Mts.

Coldea *et al.*, (1981) identified *Cetraria islandica* as a "companion" species with relatively high frequency in the *Rhododendro myrtifolii – Pinetum mugi* Borza 1959 em. Coldea 1995 plant association, described in their plant diversity inventory of Pietrosul Mare protected area. In habitats with such harsh conditions lichens can have major importance, contributing to the complexity of the food chains, influencing water retention, and soil formation.

We explored:

1) lichen species richness and composition of *Pinus mugo* shrubs and adjacent habitat types, alpine vegetation and spruce forests and

2) the distribution of lichen species in the *P. mugo* shrubs in relation to environmental factors.

Materials and methods

The study area is situated in Pietrosul Mare Scientific reserve. The alpine vegetation, *Pinus mugo* shrubs and spruce forests habitat types are only in conserved state, thus eliminating the anthropogenic influence.

The comparisons among the three habitats were based on alpha and gamma diversity, and also additive, multiplicative and multivariate measurements of beta diversity.

Except the lichens from all substrates, epiphytic, terricolous and saxicolous lichens were considered.

The species composition and it's correlation with the environmental factors was assessed with the NMDS ordination and afterwards fitting with the R function *envfit* from vegan package (Oksanen et al., 2013).

Results

Table 1. Gamma diversity - ϒ (the species richness of the habitat type) and alpha diversity – α (as the mean species richness/plot) values for the *AV*, *PM* and *SF* habitat types, counted for species on all substrates, and species on soil, trees and rock separately.

	All substrates		Soil		Trees		Rocks	
	ϒ	α	ϒ	α	ϒ	α	ϒ	α
AV	78	33	69	28	-	-	16	6
PM	69	23,7	29	11	41	13	16	4
SF	95	31,5	37	10	44	13	15	3,1

The total number of species and the mean species density in one hectare plots are both lower in the *Pinus mugo* shrubs than in the other two habitat types.

However, *P. mugo* shrubs harbour 15 species that are not present in the other habitat types.

The measured beta diversity revealed that lichen communities from *P. mugo* shrubs are heterogeneously distributed.

- ❖ The regional to local diversity ratio, shows that the species richness of *P. mugo* shrubs is three times higher than that of a one hectare sampling plot of, which is true for the spruce forest, too. This ratio is also higher than in the alpine vegetation.
- ❖ The total species turnover, which shows the number of species that are present in the entire habitat type in addition to the average number of species for one hectare plot, is also high, about 45 species, as in the alpine vegetation, and lower than in the spruce forests.
- ❖ The beta diversity measured with a multivariate approach had higher values in *P. mugo* shrubs than in spruce forest, when considering the lichens from all substrates. The alpine vegetation had higher species richness of terricolous and saxicolous lichens.

Altitude and northing of the slope significantly influence the distribution pattern of lichen species of the *P. mugo* habitat type.

Discussions

Habitat type influences lichen diversity and the substrate types have different importance for the species richness as well as for the variation in species composition. Trees have the higher number of species in the *P. mugo* habitat, followed by soil, and rock. The wood substrate was so sparce that we haven't assessed it in our analysis. The *P. mugo* habitat has a high diversity of lichen species even though, at habitat level, the species richness is higher in the other two habitats considered: alpine vegetation and spruce forest. This is confirmed by the three measurements of beta divesity, which indicate a relatively high habitat heterogenity for the lichen species.

Moreover, even if it has a high degree of compositional overlap with the adjacent habitats, it still has a 10% unique species, restricted to this habitat, among the three considered.

This study underlines the importance of *Pinus mugo* habitat type for the lichen divesity, and brings another reason for its conservation.

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CONTENTS OF THE PHD THESIS

PUBLICATIONS FROM THE PHD THESIS

Per reviewed articles

Ardelean, I.V., Keller, C. & Scheidegger, C. 2013. Lichen flora of Rodnei Mts. National Park (Eastern Carpathians, Romania) including new records for the Romanian mycoflora. *Folia Cryptogamica Estonica* 50: 101-115.

Ardelean, I.V., Keller, C, Cristea,V. & Scheidegger, C. 2013. Lichen species diversity from P*inus mugo* habitat type in relation to adjacent habitats from Rodnei Mts. National Park. *Contribuţii Botanice* 48: *In press*

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Ardelean, I. V. & Crișan, F. 2012. Lichen Flora Diversity from Rodnei Mountains National Park, *Kitaibelia*, 17 (1): 70.

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