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Synecological structure of the lichen synusiae within forest natural reserves from the Moldavian Plateau (Romania)

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Abstract: This study describes and assesses the influence of the particular features of microhabitats on the abundances of lichen species. The research was performed in 4 natural reserves: Seaca-Movileni, Bădeana, Hârboanca-Brăhăşoaia, and Bălteni (all within Vaslui county). The distribution of lichen species abundances was investigated in 20 cm × 20 cm sampling units at a height of 1 m above the ground. In the studied area 27 lichen species were sampled in 81 sampling units. Cluster analysis indicated both similarities and dissimilarities between the natural reserves investigated. Kruskal–Wallis tests pointed out significant differences regarding tree girths, depth of rhytidome crevices, and relative abundances of the lichen species. The results of a SIMPER test show that *Physconia enteroxantha* (Nyl.) Poelt. and *Candelaria concolor* (Dicks.) Stnr. are the species responsible for the dissimilarities between investigated sites. Mann–Whitney U tests revealed significant dissimilarities between the lichen synusiae investigated. Of all the lichen species recorded, only *Physconia enteroxantha* and *Lecidella elaeochroma* (Ach.) M. Choisy were significantly correlated with trees of the genus *Quercus*. There were fewer trees of the genus *Quercus* with large girths compared to other analyzed tree genera.

Key words: Lichen abundances, tree girths, depth of rhytidome crevices, floristic composition of the host trees, forest natural reserves, Vaslui county, Romania

1. Introduction

The forest natural reserves within the studied area are important botanically due to the presence of forest habitat types dominated by oaks, i.e., *Quercus pubescens* Willd., *Q. pedunculiflora* K. Koch, *Q. robur* L., and *Q. virgiliana* (Ten.) Ten. Among the natural reserves investigated, the Hârboanca-Brăhăşoaia Natural Reserve includes an exceptional hybridogen genetic center for oak species in Romania, some of which are endemic (Sârbu et al., 2007).

In Europe, oaks are the major constituents of mixed temperate forests (Herzog, 1996; Dumolin-Lapègue et al., 1997). At a European level, it has been estimated that only 0.2% of deciduous forests are relatively old (natural), while the remainder are more or less intensively exploited for the extraction and processing of timber (Nascimbene et al., 2013). The diversity of epiphytic lichens is related to a lower intensity of forestry management and the preservation of old trees; old forests have a more diverse structure and include diverse substrata that are important to the lichen species most characteristic of forests, especially rarer lichen species (included in the Red Lists) and those indicating late successional stages (Ranius et al., 2008a; Nascimbene et al., 2013).

In the Mediterranean forests of central Spain, the richness of lichen species was higher in old forests at high altitudes with steeper slopes, low management intensity, and high median girths of trees (Aragón et al., 2010).

The relationships between epiphytic lichen communities and the characteristics (predictors) of the host corticolous substratum (tree species and their girths) must be analyzed both in terms of trees within the same genus and by comparing trees from different genera. Such considerations are of great importance because each tree represents a zonal microhabitat that supports a community of local epiphytic elements; each microhabitat area is capable of directing the process of formation and perpetuation of other microhabitats (microhabitat survival and continuity) with a specific diversity (Thor et al., 2010).

Host tree diversity and their attributes are particularly important to epiphytic lichen species. Thus, both the number and high abundance of epiphytic lichen species are influenced by canopy cover, depth of rhytidome crevices, rhytidome pH of the host trees (Mistry and Berardi, 2005; Paltto et al., 2011), management of woodlands (mowing and selective cutting of trees), structure of the forestry vegetation, and girth of host trees (Leppik and Jüriado,

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2008). The predictors mentioned above actively contribute to the formation of diverse microhabitats, with different lichen species displaying particular preferences (Ranius et al., 2008b). Other studies have attributed great importance, on the one hand, to geographical (altitude and aspect), climatic (temperature, precipitation, and humidity), and physical (light) factors and, on the other hand, to biotic and physicochemical factors that are characteristic to the host substratum (host trees and their age, tree girths, rhytidome pH, and tree texture) and that favor and influence the growth of epiphytic lichen species (Prigodina-Lukošienė and Naujalis, 2006; Mežaca et al., 2008; Ranius et al., 2008a; Guvenc et al., 2009; Ellis and Coppins, 2010; Kumar et al., 2010; Oran and Öztürk, 2012; Nascimbene et al., 2013).

The aim of the present paper is to describe and assess the synecological structure of lichen synusiae from 4 natural reserves: Seaca-Movileni, Bădeana, Hârboanca-Brăhășoaia, and Bălteni (Vaslui county).

The approaches taken in this study are based on 2 assumptions: 1) there are differences between the natural reserves investigated regarding the quantified variables (abundance of lichen species, girths of host trees, depth of rhytidome crevices, and floristic composition of host trees), and 2) the abundances of lichen species are related to the girth of host trees, depth of rhytidome crevices, and floristic composition of host trees.

2. Materials and methods

2.1. Studied area

The natural reserves investigated are located on the Moldavian Plateau (Figure 1), which lies between 105 and 400 m in altitude. The Moldavian Plateau is formed of Sarmatian deposits represented by marls, sandstone, clays, and sands. The valleys situated within this plateau include recent alluvial deposits (Doniță et al., 1992; Bălteanu et al., 2006; Sârbu et al., 2007).

The climate is warm and dry with annual mean temperatures ranging between 7.5 and 10 °C. The Moldavian Plateau is under strong continental influences, e.g., the annual mean precipitation is low (450–600 mm). The climatic conditions have a strong influence on vegetation and soils. The presence of gray soils; mixed forests of *Quercus*, *Carpinus*, *Tilia*, and *Fraxinus*; and the sylvosteppe complex are determined by this climate (Doniță et al., 1992; Bălteanu et al., 2006).

The natural reserves investigated occur on a relatively small range of soils: chernozem, on clayey-loessoid substrate (Bădeana Forest Nature Reserve); alluvial (Bălteni Forest Nature Reserve); levigated chernozem in different degrees of evolution (Hârboanca-Brăhășoaia Forest Nature Reserve); and levigated chernozem on loess substratum in Seaca-Movileni Forest Nature Reserve (Sârbu et al., 2007).

2.2. Vegetation

The Seaca-Movileni Natural Reserve comprises mainly *Quercus pubescens* and *Quercus pedunculiflora* and covers 50 ha. The Bădeana Nature Reserve contains a picturesque forest of *Quercus pubescens* of the type most typical in Romania, and the reserve extends over 150 ha. The Bălteni Natural Reserve supports a small floodplain forest (only 22 ha) made up of *Fraxinus angustifolia* Vahl., *Ulmus minor* Mill. (*U. foliacea* Gilib., *Ulmus campestris* auct. non L., *U.*

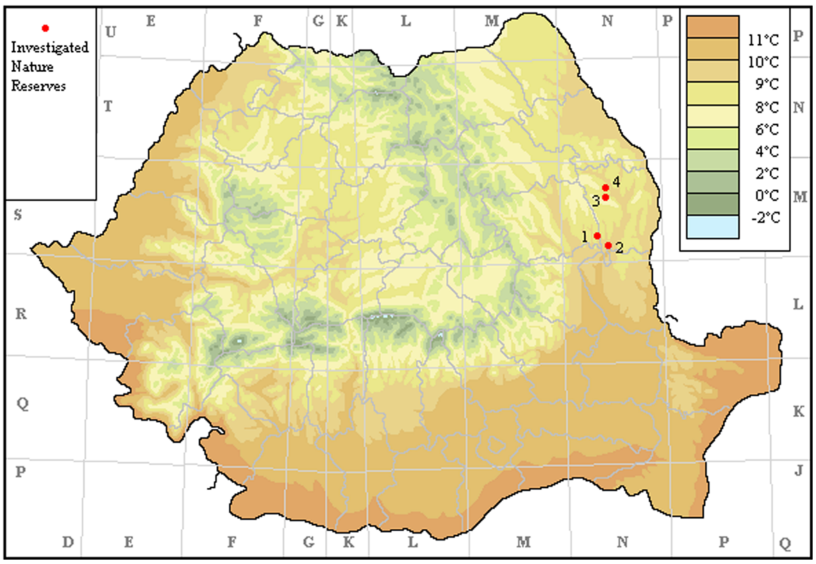

Figure 1. Forest nature reserves investigated. 1– Seaca-Movileni Forest Nature Reserve; 2– Bădeana Forest Nature Reserve; 3– Bălteni Forest Nature Reserve; 4– Hârboanca-Brăhășoaia Forest Nature Reserve.

carpinifolia Gleg.), *Quercus pedunculiflora*, and *Quercus robur*. Finally, the Hârboanca-Brăhășoaia Natural Reserve (43.1 ha) is dominated by *Fraxinus* and *Quercus* species, and on a relatively small area natural hybrids have been identified, e.g., *Quercus* × *diversifrons*, *Quercus* × *dacica*, and *Quercus* × *valachica* (Sârbu et al., 2007).

2.3. Sampling procedure

Field research activities were carried out between June and September 2012, following the methods given by Prigodina-Lukošienė and Naujalis (2006). Within the 4 natural reserves 8 sampling units of 10 m × 10 m were randomly selected at each site (a total of 32 overall). The girth of each selected tree was measured 1 m above the ground. Within each sampling unit there were trees with girths of >80 cm; thus, the 20 cm × 20 cm frame would be entirely included on sampled trunks. A total of 49 trees were sampled, with the frame set on the selected trees at 1 m above the ground. Within each sampling unit all specimens from each lichen species were counted, and the depths of the rhytidome crevices were measured (cm).

The variety of tree species providing substrata for lichen species included: *Quercus pedunculiflora* and *Q. pubescens* (Seaca-Movileni Nature Reserve); *Q. petraea* Liebl., *Cerasus avium* (L.) Moench (*Prunus avium* L.), *Q. pubescens*, and *Q. pedunculiflora* (Bădeana Nature Reserve); *Fraxinus excelsior* L., *Q. polycarpa* Schur, *Q. robur*, *F. angustifolia* Vahl. subsp. *oxycarpa* M.Bieb. ex Willd. Franco & Rocha Afonso (*F. angustifolia* subsp. *pannonica* Soó & Simon and *F. pojarkoviana* V. Vassil.), and *Q. pedunculiflora* (Hârboanca-Brăhășoaia Nature Reserve); and *Acer platanoides* L., *Tilia tomentosa* Moench (*T. argentea* DC), *Fraxinus* sp., and *Q. pedunculiflora* (Bălteni Nature Reserve).

2.4. Surveying samples

Any sampled lichen species that could not be identified in the field was transported to the laboratory for identification by handbook (Moruzi and Toma, 1971; Purvis et al., 1994; Ciurchea, 2004), stereomicroscope (Zeiss Stereo CL 1500 ECO), and optical microscope (Zeiss Scope A1). Lichen species were identified from microscope slides and by using chemical reagents, i.e. iodine-potassium iodide (IIK), chlorine (Cl_2), potassium hydroxide (KOH), and calcium chloride ($CaCl_2$).

Identification and nomenclature of the tree species followed Ciocârlan (2009), while lichen nomenclature followed Ciurchea (2004).

The identified material is preserved in Ioana Vicol's collection, within the Mycological Herbarium of the Institute of Biology of the Romanian Academy, Bucharest.

2.5. Data analysis

Within this study, the following variables were analyzed: tree girths, depth of rhytidome crevices, floristic composition of host trees, and relative abundances of lichen species.

Statistical tests [normal distribution, cluster analysis, Mantel test, similarity percentage (SIMPER) test, nonparametric correlation, nonparametric Kruskal–Wallis one-way ANOVA test, and Mann–Whitney U test] were performed using PAST software (Hammer et al., 2001).

The data collected were checked using the Shapiro–Wilk test for normal distribution, which showed that the data were nonnormally distributed (P > 0.05). All variables were therefore log-transformed to improve the normality of the dataset. The log-transformed data also showed a nonnormal distribution; therefore, nonparametric statistical methods were used such as the Mann–Whitney U test, nonparametric Kruskal–Wallis one-way ANOVA test, and nonparametric correlation (Mărușteri, 2006; Zamfirescu and Zamfirescu, 2008).

2.5.1. Assessment of the relative abundances of the lichen species

The relative abundance was calculated according to the following formula (Botnariuc and Vădineanu, 1982):

$$A = \frac{n}{N} \times 100$$

where A = relative abundance, n = the total number of specimens of a particular species, and N = the total number of specimens of all species.

2.5.2. Classification of lichen species abundances

Cluster analysis was used for determination of the similarities and dissimilarities among the Seaca-Movileni, Bădeana, Hârboanca-Brăhășoaia, and Bălteni natural reserves based on dependent variables such as relative abundances (Dytham, 2011) of the lichen species. The chord distance coefficient (Ludwig and Reynolds, 1988) was used as a similarity measure. Classification analysis was based on the selection algorithm called unweighted average pair groups, according to which groups are merged based on the average distance between members of the 2 groups (Hammer et al., 2001; Cristea et al., 2004). This statistical method was used to test whether there were grouping relationships among the relative abundances of lichen species within lichen synusiae from the 4 natural forestry reserves.

2.5.3. Assessment of the differences between investigated lichen synusiae

The Kruskal–Wallis test was used in order to evaluate the significant differences among the 4 natural reserves in terms of relative abundance of lichen species, host tree girth, depth of rhytidome crevices, and floristic composition of host trees. For this model, the data were grouped in samples according to a single factor (forest nature reserve) (Zamfirescu and Zamfirescu, 2008).

The Mann–Whitney U test allows multiple comparisons if the tested differences are significant. This test is a nonparametric alternative to the t-test (Student test) used to make pairwise comparisons for independent samples. The 4 natural reserves were compared 2 by 2 based on independent variables (host tree girth, depth of rhytidome crevices, and floristic composition of host) and dependent variables (relative abundances of the lichen species) (Zamfirescu and Zamfirescu, 2008).

The SIMPER test is a simple method for assessing which taxa are primarily responsible for an observed difference between groups of samples (Hammer et al., 2001). As a measure of similarity/dissimilarity between lichen synusiae from the natural reserves, the chord distance coefficient was used (Ludwig and Reynolds, 1988; Hammer et al., 2001). The significant differences obtained by the Mann–Whitney U test and the Kruskal–Wallis one-way nonparametric ANOVA test regarding lichen abundance are thus explored through the SIMPER test.

2.5.4. Assessment of the correlations between variables

The permutation Mantel test was used for correlation between 2 distance matrices. The distance matrices were computed based on chord distance coefficient (Ludwig and Reynolds, 1988). The first matrix consists of records of relative abundances of the lichen species, while the second matrix consists of records of the independent variables (host tree girth, depth of rhytidome crevices, and floristic composition of host trees). The distance matrices were correlated 2 by 2. The Mantel test compared the original matrices computed at 5000 random permutations (Hammer et al., 2001). The ranks of independent variables and of species responses (relative abundances of lichen species) were correlated according to Pearson's formula (Zamfirescu and Zamfirescu, 2008). Correlation significance was calculated through a permutation test based on 5000 random permutations (Hammer et al., 2001).

Nonparametric correlation analysis based on the Spearman correlation coefficient reduces precision if there is a relatively high number of equal values (i.e. more than half the ranks). It is therefore recommended that the correlation coefficient be calculated according to the Pearson correlation coefficient, in which the original value is replaced by their ranks. This approach was followed for the independent variables and the independent one (relative abundances of the lichen species), i.e. correlated according to Pearson's formula (Zamfirescu and Zamfirescu, 2008).

3. Results

Table 1 lists the 27 lichen species identified within the natural reserves investigated.

The dendrogram (Figure 2) displays the results of cluster analysis of the lichen assemblages (synusiae) and indicates similarities between Seaca-Movileni and Bădeana lichen synusiae and dissimilarities between Seaca-Movileni and Hârboanca-Brăhășoaia, Seaca-Movileni and Bălteni, Bădeana and Hârboanca-Brăhășoaia, Bădeana and Bălteni, and Hârboanca-Brăhășoaia and Bălteni.

According to the results obtained, the natural reserves were significantly dissimilar in terms of relative abundances of lichen species ($H = 12.56$; $P < 0.01$; df = 3), tree girths ($H = 23.48$; $P < 0.001$; df = 3), and depth of rhytidome crevices ($H = 56.17$; $P < 0.001$; df = 3). However, no significant differences were found among the natural reserves regarding floristic composition of host trees ($H = 1.35$; $P > 0.05$; df = 3).

Results of the Mann–Whitney U tests on data from the 4 parks are presented for abundance of lichens (Table 2), girth of host trees (Table 3), depth of the rhytidome cervices (Table 4), and floristic composition of the host trees (Table 5). Significant results for similarities ($P > 0.05$) are identified in these tables.

For the relative abundance of lichen species (Table 2), comparison of lichen synusiae between Seaca-Movileni and Bădeana, between Bădeana and Bălteni, and between Hârboanca-Brăhășoaia and Bălteni showed similarities of $P > 0.05$. In contrast, there were very significant dissimilarities ($P < 0.01$) between the lichen synusiae in Seaca-Movileni and Hârboanca-Brăhășoaia and between Bădeana and Hârboanca-Brăhășoaia. The lichen synusiae between Seaca-Movileni and Bălteni were also significantly dissimilar, but at a lower level of significance ($P < 0.05$).

Assessing the girth of the host trees (Table 3), the lichen synusiae showed similarities ($P > 0.05$) when comparing both Seaca-Movileni with Bădeana and Hârboanca-Brăhășoaia with Bălteni. Highly significant dissimilarities ($P < 0.001$) in lichen synusiae were found between Seaca-Movileni and Hârboanca-Brăhășoaia, between Seaca-Movileni and Bălteni, and between Bădeana and Bălteni. Finally, very significant dissimilarities ($P < 0.01$) in lichen synusiae were found when comparing Bădeana with Hârboanca-Brăhășoaia.

Focusing on the depth of rhytidome crevices (Table 4), the lichen synusiae from Seaca-Movileni and Hârboanca-Brăhășoaia were similar ($P > 0.05$). However, highly significant dissimilarities ($P < 0.001$) in lichen synusiae were found between Seaca-Movileni and Bălteni, between Bădeana and Bălteni, and between Hârboanca-Brăhășoaia and Bălteni. Very significant dissimilarities ($P < 0.01$) were found between the lichen synusiae in Bădeana and Hârboanca-Brăhășoaia, and less significant dissimilarities ($P < 0.05$) were found between the synusiae from Seaca-Movileni and Bădeana natural reserves.

Application of the Mann–Whitney U tests to findings on floristic composition of the host trees did not indicate any significant differences ($P > 0.05$) between the lichen synusiae (Table 5).

Table 1. Spatial distribution of lichen species within investigated natural reserves.

Species	Seaca-Movileni	Bădeana	Hârboanca-Brăhășoaia	Bălteni
Anaptychia ciliaris (L.) Körb. ex Mass.	+	+	-	-
Arthonia radiata (Pers.) Ach. em. Th. Fr.	-	-	-	+
Bacidia polychroa (Th. Fr.) Körb.	-	-	-	+
Candelaria concolor (Dicks.) Stnr.	-	-	-	+
Flavoparmelia caperata (L.) Hale	+	+	-	-
Graphis scripta (L.) Ach.	-	-	-	+
Hypotrachyna sinuosa (Sm.) Hale	+	-	-	-
Lecanora piniperda Körb.	-	-	+	-
Lecanora subintricata (Nyl.) Th. Fr.	+	-	-	-
Lecidella elaeochroma (Ach.) M. Choisy	+	+	+	-
Melanelia exasperatula (Nyl.) Essl.	-	-	-	+
Melanelia glabra (Schaer.) Essl.	+	+	-	-
Melanelia glabratula (Lamy) Essl.	-	+	-	-
Opegrapha vulgata Ach.	-	-	-	+
Parmelina tiliacea (Hoffm.) Hale	-	-	+	-
Phaeophyscia orbicularis (Něck.) Moberg.	-	+	-	-
Physcia adscendens (Fr.) Oliv.	-	+	-	-
Physcia aipolia (Ehrh. ex Humb.) Fürnr.	+	-	+	-
Physcia dubia (Hoffm.) Lett.	+	+	-	+
Physcia tribacia (Ach.) Nyl.	-	+	-	-
Physconia distorta (With.) J. R. Laudon	-	-	+	+
Physconia enteroxantha (Nyl.) Poelt.	+	+	+	-
Pleurosticta acetabulum (Necker) Elix & Lumbsch.	-	+	-	-
Ramalina calicaris (L.) Fr.	+	-	-	-
Ramalina pollinaria (Westr.) Ach.	+	+	-	+
Xanthoria fallax (Hepp.) Arn.	-	-	+	-
Xanthoria parietina (L.) Th. Fr.	+	+	+	-

Legend: + lichen species present, - no available data.

The Mantel permutation test revealed a significant positive correlation ($r = 0.80$; $P < 0.05$) between the relative abundances of lichen species and floristic composition of host trees.

The similarity matrices computed for relative abundance of lichen species were insignificantly correlated with the similarity matrices computed for tree girths ($r = 0.42$; $P > 0.05$) and depth of rhytidome crevices ($r = -0.07$; $P > 0.05$).

Statistical analysis of nonparametric correlation performed on the variables investigated indicated that the relative abundances of lichen species were significantly correlated with the floristic composition of host trees. Thus, significant and very strong positive correlations ($r = 0.95$; $P < 0.05$ and $r = 0.96$; $P < 0.05$) were recorded between *Quercus* trees and relative abundances of *Physconia enteroxantha* and *Lecidella elaeochroma*. Within lichen synusiae from the investigated natural reserves, a significant and very strong negative correlation ($r = -0.98$; $P < 0.05$) between floristic composition of trees tabulated in the genus *Quercus* and their girths was found.

The SIMPER test indicated that *Physconia enteroxantha* and *Candelaria concolor* were the main lichen species responsible for the observed differences based on abundances between lichen synusiae, with results of 0.56% and 0.36%, respectively. These 2 lichen species locally showed relatively high abundances in lichen synusiae for *Physconia enteroxantha* in Seaca-Movileni (85%)

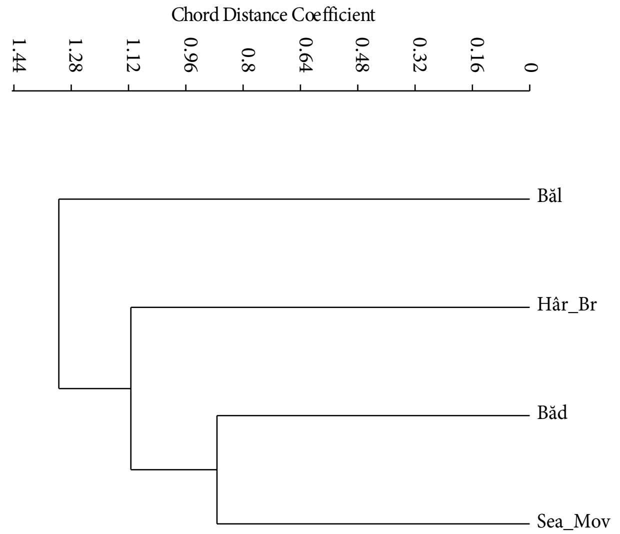

Figure 2. The results of cluster analysis showing similarities and dissimilarities among the investigated natural reserves. Abbreviations: Băl– Bălteni Forest Nature Reserve, Hâr_Br– Hârboanca-Brăhăşoaia Forest Nature Reserve, Băd– Bădeana Forest Nature Reserve, Sea_Mov– Seaca-Movileni Forest Nature Reserve.

and Bădeana (79%) natural reserves and for *Candelaria concolor* 48% in Bălteni Natural Reserve. Three lichen species [*Parmelina tiliacea* (Hoffm.) Hale, *Lecanora piniperda* Körb., and *Physcia dubia* (Hoffm.) Lett.] were represented by somewhat lower percentage values (0.20%, 0.11%, and 0.10%, respectively). The remaining 22 lichen species had percentage values lower than 0.10%.

4. Discussion

4.1. The influence of microhabitat factors on lichen synusiae from investigated forest natural reserves

In this study differences between lichen synusiae were identified, especially in terms of the relative abundance of lichen species, girths of host trees, and depth of rhytidome crevices.

Lichen synusiae in the 4 natural reserves may be grouped on the basis of a range of investigated dependent and independent variables. Thus, lichen synusiae from Seaca-Movileni and Bădeana natural reserves represent a well-marked group, distinct from the lichen synusiae in Hârboanca-Brăhăşoaia and Bălteni natural reserves. The substratum conditions (girths of host trees and host tree species) and the relative abundances of lichen species are similar in Seaca-Movileni and Bădeana natural reserves.

Significant differences recorded for the 4 natural reserves are due to lichen abundances, girths of host trees, and depths of rhytidome crevices. In the studied area there are variations at the substratum level and within the biotic elements. Generally, the floristic composition of host trees is homogeneous and is represented especially by *Quercus petraea*, *Q. pedunculiflora*, and *Q. pubescens* (Bălteanu et al., 2006).

According to Oran and Öztürk (2012), there are differences between *Quercus frainetto* Ten. and *Q. cerris* L. regarding the depth of rhytidome crevices. Thus, lichens make up ecological groups based upon their shared requirements for a particular rhytidome texture. Leppik et al. (2011) emphasized that the most probable causes of such differentiation among tree species are lichen

Table 2. The values of Mann–Whitney U test for investigated natural reserves based on relative abundance of lichen species. Legend: U = result of Mann–Whitney test; *P < 0.05, **P < 0.01, ***P < 0.001.

Natural reserves	Seaca-Movileni	Bădeana	Hârboanca-Brăhăşoaia	Bălteni
Seaca-Movileni	0	P = 0.06398	P = 0.003636	P = 0.02296
Bădeana	U = 44	0	P = 0.007145	P = 0.2755
Hârboanca-Brăhăşoaia	U = 12**	U = 16**	0	P = 0.2843
Bălteni	U = 26*	U = 47	U = 27.5	0

Table 3. The values of Mann–Whitney U test for investigated natural reserves based on the girths of host trees. Legend: see Table 2.

Natural reserves	Seaca-Movileni	Bădeana	Hârboanca-Brăhăşoaia	Bălteni
Seaca-Movileni	0	P = 0.0508	P = 0.0007492	P = 0.0008615
Bădeana	U = 76.5	0	P = 0.007065	P = 0.0002472
Hârboanca-Brăhăşoaia	U = 12.5***	U = 21**	0	P = 0.158
Bălteni	U = 9***	U = 12***	U = 21	0

Table 4. The values of Mann–Whitney U test for lichen synusiae from investigated natural reserves based on the depth of rhytidome crevices. Legend: see Table 2.

Natural reserves	Seaca-Movileni	Bădeana	Hârboanca-Brăhăşoaia	Bălteni
Seaca-Movileni	0	P = 0.0153	P = 0.3018	P = 0.0001347
Bădeana	U = 4933*	0	P = 0.0046	P = 0.0008619
Hârboanca-Brăhăşoaia	U = 3666	U = 2931**	0	P = 0.0008446
Bălteni	U = 1289***	U = 2061***	U = 904***	0

Table 5. The values of Mann–Whitney U-test for lichen synusiae from investigated natural reserves based on floristic composition of host trees. Legend: see Table 2.

Natural reserves	Seaca-Movileni	Bădeana	Hârboanca-Brăhăşoaia	Bălteni
Seaca-Movileni	0	P = 1	P = 1	P = 1
Bădeana	U = 2	0	P = 1	P = 0.80
Hârboanca-Brăhăşoaia	U = 2	U = 2	0	P = 0.4667
Bălteni	U = 4	U = 3	U = 2	0

responses to tree-species–specific bark properties. Working in southeastern Sweden, Ranius et al. (2008b) investigated forest ecosystems largely composed of old oaks and found that variations in the depth of rhytidome crevices, girths of host trees, light conditions, inclination of tree trunks, and bryophyte cover were environmental factors that had a significant influence on lichen species abundance.

In the present study, the significant differences between lichen synusiae are due to *Physconia enteroxantha* and *Candelaria concolor*, identified mainly on trees of *Quercus* and *Fraxinus* species. These 2 lichen species are nitrophilous (Hauck et al., 2012; Oran and Öztürk, 2012), and the occurrence of *Physconia enteroxantha* on the rhytidome of *Quercus* might be induced by anthropogenic activity such as animal grazing. Animal grazing close to natural reserves might be directly responsible for the shift of rhytidome chemical properties. Within lichen communities, agriculture and animal grazing synergistically contribute to an increased level of eutrophication in tree substrata and in the number of nitrophilous species (Oran and Öztürk, 2012).

4.2. Relationships between microhabitat drivers and relative abundance of lichen species

Lichen abundances increase with the specific diversity of host trees. Only *Physconia enteroxantha* and *Lecidella elaeochroma* are significantly influenced by trees belonging to the genus *Quercus*. Within Seaca-Movileni and Bădeana natural reserves, *Quercus pubescens* and *Q. pedunculiflora* are well represented, and the highest values of abundance of *Physconia enteroxantha* (85% and 79%, respectively) were recorded in these 2 natural reserves. In forests from Gotland (Sweden) and Saaremaa (Estonia) islands, lichen species such as *Calicium viride* Pers., *Chaenotheca chlorella* (Ach.) Müll. Arg., *Cyphelium inquinans* (Sm.) Trevis., and *Physconia enteroxantha* are influenced by both species and tree girths of the genus *Quercus* (Thor et al., 2010). The microhabitat conditions vary depending on tree species; therefore, lichen diversity increases with tree species diversity (Hauck, 2011).

The rhytidome of *Quercus* species is acidic (Laundon, 1963; Oran and Öztürk, 2012), but this situation is contrary to the preferences of *Physconia enteroxantha* for eutrophic substrata (Zedda and Sipman, 2001; Matwiejuk, 2008; Riddell et al., 2012). Grazing is the main source of eutrophication of lichen substrata in the Bădeana Forest Reserve (Sârbu et al., 2007). Agricultural practices and livestock induce organic nutrient enrichment of substrata, providing opportunities for communities of the *Xanthorion* alliance (Aragón et al., 2010; Hauck et al., 2012).

Great importance is attributed to *Hypotrachyna sinuosa* (Sm.) Hale, one of the species included in the Red List of Macrolichens for Romania (Sârbu et al., 2007). This lichen was found in the Seaca-Movileni Natural Reserve on *Quercus pedunculiflora* with a large girth (0.91 m). In a similar study, red-listed lichen species from Sweden were found on oak trunks with large girths (Thor et al., 2010). "In Europe, a large proportion of the oldest trees are *Quercus robur* L., partly because this species is naturally very long-lived and partly because it has tended to be retained during management. Therefore this is a keystone species for biodiversity associated with ancient trees, including lichens" (Ranius et al., 2008b).

In the studied area there are a low number of old *Quercus*, possibly due to illegal removal of trees (Sârbu et al., 2007). The present study confirmed that diversity in age of the trees and all their physical and chemical attributes is associated with a great diversity of lichen species (Ranius et al., 2008b; Leppik et al., 2011).

In this study it was found that lichen abundances are not related to the girth of trees and depth of rhytidome crevices. In contrast with the present work, Paltto et al. (2011), working in oak forests in Östergötland Province (Sweden), stated that the recorded abundance of *Calicium adspersum* Pers. was positively correlated to the depth of rhytidome crevices and to the pH of host trees. In a wooded area in Estonia, Leppik et al. (2011) found that lichen abundances were influenced by both tree girth and rhytidome texture, and Mistry and Berardi (2005) also showed a positive relationship between lichen abundance and depth of rhytidome crevices. In old-growth deciduous forests in Latvia, there were no significant relationships between the richness of lichen species and depth of rhytidome crevices (Mežaca et al., 2008). Ranius et al. (2008a) found no significant correlations between the girth of host trees and richness of lichen species. However, lower tree girth might provide an available substratum for epiphytic cryptogams (Mežaca et al., 2008).

Few other expected relationships between the variables taken into account were found due to the weakness of the nonparametric correlation tests. These tests are generally less powerful, although they are safer. They are also somewhat restrictive and cannot be used to for more complicated issues (Dytham, 2011).

The main findings of this study relate to the heterogeneity of microhabitat conditions that are responsible for significant differences of lichen abundances and the importance of oak species diversity, especially ancient oaks, to lichen abundance.

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