Acta Biol. Univ. Daugavp. 19 (2) 2019
ISSN 1407 - 8953

EPIPHYTIC BRYOPHYTES AND LICHENS AND THEIR FUNCTIONAL TRAIT RELATIONSHIPS WITH HOST CHARACTERISTICS IN THE LŪZNAVA MANOR PARK

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Mežaka A., Kirillova J. 2019. Epiphytic bryophytes and lichens and their functional trait relationships with host characteristics in the Lūznava Manor Park. *Acta Biol. Univ. Daugavp., 19 (2): 241 – 251.*

Manor parks are urban areas that offer favorable environmental conditions for epiphytic bryophyte and lichen conservation. We investigated epiphytic bryophyte and lichen species richness and functional trait associations with tree diameter and documented data about tree bark pH in Lūznava manor park in southeastern Latvia. In total, 76 epiphytic (44 lichen, 32 bryophyte) species, including rare species, were found on 91 host trees. We found that epiphytic bryophytes with a perennial stayer life strategy were significantly positively associated with tree diameter, but negatively with high tree bark pH. Lichen functional traits, however, were not associated with tree diameter. Lichens with leprose growth form, similar to lichens with asexual reproductive strategy, were associated positively with low bark pH trees. The study shows the importance of bryophytes and lichens in ecological studies exploring functional trait and environment relationships. Future studies are needed to involve larger spectrum of bryophyte and lichen functional traits across larger spatial scales.

Key words: Epiphytic bryophytes and lichens, conservation, manor park, functional traits.

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INTRODUCTION

Urban forest biodiversity represents a critical ecosystem services for sustaining human health and environmental quality (Alvey 2006). Latvia is particularly rich in manor parks due to historical reasons (Anonīms 2000) and the presence of large and old trees. These parks are generally conclusive to the study of epiphytes and may even present rare species.

In the process of establishing the urban park areas, both native and also newly introduced tree species are planted, and after a certain time-span, epiphytic species colonize these trees depending on light, humidity, tree bark pH, pollution and other factors (Āboliņa & Bambe 2010). In the past, epiphytic bryophytes and lichens have been used as urban area bioindicators (Larsen et al. 2007, Motiejūnaitė 2009, Sujetuviene & Sliumpaite 2013).

Most Latvian lichenoflora consists of epiphytic lichens, but there is also a large amount of epiphytic bryophytes in Latvian bryoflora (Āboliņa et al. 2015). Epiphytes compose a significant part of the manor park biodiversity and participate in the function of other organisms in urban areas. To date, we are lacking studies on bryophyte and lichen biodiversity and ecology in manor parks.

Functional traits can help us understand specific organism variability in relation to environmental conditions. Vascular plant functional traits have been used in ecological studies for decades (Diaz et al. 1998, Cornelissen et al. 2003, Purschke et al. 2013). Only in recent years has the number of ecological studies using bryophyte and lichen functional traits begun to increase (Giordani et al. 2012, Löbel et al. 2009, Sierra et al. 2018, Mazziotta et al. 2019, Nelson et al. 2015). There is little knowledge about the relationships between epiphytic bryophyte and lichen functional traits and environmental variables. A study in Italian forests revealed that epiphytic lichen traits were not significantly associated to tree age in different forest types (Giordani et al. 2012). Another study in Great Britain showed that epiphytic lichen functional traits were associated with *Populus tremula* stand age (Ellis & Coppins 2006).

The present study aims to evaluate epiphytic bryophyte and lichen species richness in conservation perspective and functional trait relationships with host characteristics in Lūznava manor park. We asked the following questions:
1) Does Lūznava manor park contribute to bryophyte and lichen species conservation?
2) Are epiphytic bryophyte and lichen species functional traits shaped by tree diameter and tree bark pH?

We hypothesize that: 1) epiphytic bryophytes with longer shoots and larger spores will be associated with greater diameter at breast height (DBH) and higher tree bark pH; 2) bryophytes with colonist and short-lived shuttle life strategies will be associated with trees with smaller DBH, while bryophytes with perennial stayer and perennial shuttle life strategy will be associated with greater DBH; 3) bryophyte life strategies will not show significant associations with tree bark pH; and that 4) lichens with crustose growth form will be associated with trees with smaller DBH; foliose and squamulose lichens will be indifferent to DBH; but leprose and fruticose lichens will be associated with trees with greater DBH; 5) lichen growth form and photobiont will be indifferent to both tree DBH and pH; 6) lichens with asexual reproduction will be associated with greater tree DBH and high pH, while lichens with sexual and sexual and asexual reproduction will not show any preference to DBH and pH.

MATERIALS AND METHODS

Study area

Lūznava manor park is located in southeastern part of Latvia in the Lūznava parish of Rēzekne district and is included in Rāzna National Park (Fig. 1). The study territory is characterized by mean temperatures of –6.7 °C to –6.2°C in February and +17.4 0°C, in July, with an annual precipitation of 667 mm (LVGMC 2016).

Fig. 1. Studied area (noted with black dot).

Table 1. Characteristics of studied sample plots

Sample plot	Coordinates		Studied tree species
	E	N	
1	56° 21'30.81"	27° 15'36.89"	*Fraxinus excelsior, Acer platanoides, Ulmus glabra*
2	56° 21'25.44"	27° 15'31.77"	*Fraxinus excelsior, Acer platanoides, Ulmus glabra, Larix decidua*
3	56° 21'22.86"	27° 15'29.10"	*Picea abies, Pinus sylvestris*
4	56° 21'22.53"	27° 15'29.48"	*Picea abies, Pinus sylvestris, Populus tremula*
5	56° 21'20.65"	27° 15'39.35"	*Larix decidua*
6	56° 21'26.00"	27° 15'45.11"	*Larix decidua*
7	56° 21'28.77"	27° 15'49.19"	*Quercus robur, Fraxinus excelsior, Acer platanoides, Tilia cordata*
8	56° 21'31.64"	27° 15'46.17"	*Ulmus glabra, Quercus robur, Acer platanoides*
9	56° 21'34.15"	27° 15'44.23"	*Fraxinus excelsior, Tilia cordata, Quercus robur*
10	56° 21'28.79"	27° 15'42.43"	*Ulmus glabra, Fraxinus excelsior*
11	56° 21'25.15"	27° 15'40.55"	*Fraxinus excelsior, Ulmus glabra*
12	56° 21'23.67"	27° 15'41.30"	*Ulmus glabra, Tilia cordata, Fraxinus excelsior, Acer platanoides, Betula pendula*
13	56° 21'22.06"	27° 15'42.38"	*Fraxinus excelsior, Betula pendula*
14	56° 21'20.74"	27° 15'43.20"	*Pinus sylvestris, Picea abies*
15	56° 21'18.97"	27° 15'44.28"	*Pinus sylvestris, Picea abies*
16	56° 21'17.42"	27° 15'40.47"	*Larix decidua, Picea abies*
17	56° 21'18.90"	27° 15'39.55"	*Quercus robur*
18	56° 21'26.23"	27° 15'38.89"	*Fraxinus excelsior, Acer platanoides*

The establishment of Lūznava manor park dates to the end of the 19th century. Ninety three tree, shrub, and half-shrub taxa have been identified in Lūznava Manor Park, 29 of which are native taxa and 64 introduced taxa (DUSBI 2013). One of the introduced taxa, *Larix decidua,* is included in the present study.

Field work

The data were collected from May-July 2016. The occurrence of epiphytic bryophytes and lichens were recorded on 91 host trees in 18 sample plots (Table 1). In a single sample plot, epiphytes were studied on five trees (with the exception of the second sample plot, where epiphytes were studied on six trees). We measured each sample tree diameter at breast height (DBH) and assumed DBH as a proxy of tree age. Sample plots and host trees (with a minimal of DBH 0.20 m) were selected randomly. Epiphyte species occurrence was evaluated up to the height of 2 m on each of the selected host trees. Unknown epiphyte samples were collected for the identification by the Rezekne Academy of Technologies laboratory.

Laboratory work

Collected bryophyte and lichen samples were identified in the Rezekne Academy of Technologies laboratory using a stereomicroscope and microscope. Paraphenylenediamine, Chlorox (C), potassium chloride and ethylene were used for lichen identification. Thin Layer Chromatography (with solvent systems A, B, C) were used for *Lepraria* sp. identification (Orange et al. 2001) at the Rezekne Academy of Technologies. Scientific names for bryophytes follow N. Hodgetts (2015) and A. Āboliņa et al. (2015), and names for lichens follow A. Āboliņa et al. (2015) and C. W. Smith et al. (2010).

Data analysis

We applied fourth-corner analysis (Borcard et al. 2018) to test the association between epiphytic bryophyte and lichen functional traits and environmental variables. Our analysis used epiphytic bryophyte and lichen presence/absence data containing at least three records on trees to avoid a random epiphytic species occurrence. Epiphytic bryophyte functional traits were mean shoot length (cm), life strategy and mean spore size (µm) following M. Bernhardt-Römermann et al. (2018) and H. J. During (1979). Epiphytic lichen functional traits were growth form, photobiont, and reproductive strategy according to P. Giordani et al. (2012) and C. W. Smith et al. (2010). We selected the most appropriate functional traits showing variation in Lūznava manor park and that could be used in Latvian geographical conditions. The environmental variables were DBH and tree bark pH. Trees were divided into two groups based on bark pH: trees with high bark pH (*Acer platanoides, Fraxinus excelsior, Tilia cordata, Ulmus glabra, Quercus robur,*) and low bark pH *(Betula pendula, Larix decidua, Picea abies, Pinus sylvestris*) following J. J. Barkman (1958) and A. Mežaka & V. Znotiņa (2006).

The data for fourth-corner analysis consisted of six data matrices (three for epiphytic bryophytes and other three for epiphytic lichens). Two were for species data (20 epiphytic bryophyte and 26 lichen species); two for environmental data (pH and DBH for epiphytic bryophytes on 86 trees and lichens on 90 trees); and two for trait data (species traits for epiphytic bryophytes on 86 trees and lichens on 90 trees). We applied fourth-corner analysis with 999 repetitions for each model, estimating association between functional trait category and environmental variable separately (Borcard et al. 2018) according to Fisher and Chi-squared tests. The fourth-corner analysis was performed using an 'ade4' package (Dray & Dufour 2007) in R program version 3.5.1 (R Core Team 2018).

RESULTS

In total, 78 epiphyte (32 bryophyte, 44 lichen) species were found on studied trees in Lūznava manor park (Table 2, Table 3). Woodland key habitat (WKH) indicator species (Ek et al. 2002) included bryophytes: *Neckera pennata* (also red-listed (Āboliņa 1994, category 3)), *Homalia trichomanoides*; and lichens: *Pleurosticta acetabulum* (also red-listed (category 2, Piterāns & Vimba 1996) and a specially protected (LRMK 2000) lichen species in Latvia), *Acrocordia gemmata, Arthonia spadicea* and *Bacidia rubella*. The most common epiphytic bryophytes were *Radula complanata*, *Hypnum cupressiforme*, *Pylaisia polyantha* and *Pseudoamblystegium subtile*. The most common lichens were *Phlyctis argena* and *Lepraria incana*, which were found on more than half of the studied trees.

Epiphytic bryophytes and lichens represented different functional traits (Table 2, Table 3). The mean epiphytic bryophyte shoot length was 4.49 cm and the mean spore size was 17.77 µm. Perennial stayer was the most common life strategy of epiphytic bryophytes (Table 2). Regarding epiphytic lichens, the most common epiphytic lichen growth forms were crustose and foliose and treboxioid was the most common photobiont. Most of the epiphytic lichen species showed both sexual and asexual reproductive strategies (Table 3).

Epiphytic bryophytes and lichens were studied on nine tree species: *Tilia cordata, Fraxinus excelsior, Quercus robur, Acer platanoides, Ulmus glabra, Betula pendula, Larix decidua, Picea abies, Pinus sylvestris* (Fig. 2). The most common tree species were *Fraxinus excelsior* (17 individuals) and *Larix decidua* (15 individuals). *Acer platanoides* showed the highest epiphytic bryophyte species richness, while *Tilia cordata* showed the highest average epiphytic lichen species richness. The lowest epiphytic species richness was found for *Betula pendula, Larix decidua, Pinus sylvestris* and *Picea abies*. The average tree DBH (m) with standard deviation was 1.39±0.46.

Table 2. Epiphytic bryophyte characteristics in Lūznava manor park. Frequency of occurrence on studied trees. Functional traits follow M. Bernhardt-Römermann et al. (2018) and H. J. During (1979)

Bryophyte species	Frequency of occurrency	Functional traits		
		Mean shoot length (cm)	Life strategy	Mean spore size (µm)
Hepatics				
Lophocolea heterophylla	9.89	2.50	Colonist	15.0
Plagiochila porelloides	1.10	4.25	Perennial stayer	21.0
Ptilidium pulcherrimum	2.20	2.00	Short-lived shuttle	28.5
Radula complanata	34.07	3.50	Perennial shuttle	32.0
Mosses				
Amblystegium serpens	1.10	4.00	Perennial stayer	11.5
Sciuro-hypnum populeum	8.79	1.00	Perennial stayer	16.0
Brachythecium rutabulum	1.10	12.00	Colonist	20.0
Brachythecium salebrosum	19.78	12.00	Colonist	15.0
Brachytheciastrum velutinum	4.40	7.50	Perennial stayer	14.5
Dicranum montanum	28.57	2.50	Perennial stayer	16.0
Dicranum scoparium	3.30	10.00	Perennial stayer	17.0
Herzogiella seligeri	1.10	2.50	Perennial stayer	10.5
Homalia trichomanoides	2.20	6.00	Perennial stayer	15.0
Hypnum cupressiforme	49.45	2.00	Perennial stayer	16.0
Hypnum pallescens	20.88	3.25	Perennial stayer	16.0
Leskea polycarpa	1.10	8.00	Perennial stayer	14.0
Leucodon sciuroides	4.40	2.25	Perennial shuttle	23.0
Neckera pennata	2.20	7.50	Perennial shuttle	22.0
Orthotrichum affine	12.09	2.50	Colonist	20.0
Nyholmiella obtusifolia	3.30	5.00	Colonist	18.0
Orthotrichum pumilum	1.10	5.00	Colonist	14.0
Orthotrichum speciosum	26.37	2.25	Short-lived shuttle	35.0
Plagiothecium cavifolium	1.10	4.00	Perennial stayer	12.0
Plagiothecium laetum	6.59	1.50	Perennial stayer	10.0
Plagiomnium cuspidatum	1.10	2.70	Perennial stayer	27.0
Platygyrium repens	6.59	0.25	Perennial stayer	18.0
Pleurozium schreberi	3.30	12.00	Perennial stayer	15.0
Pseudoleskeella nervosa	3.30	5.00	Perennial stayer	16.0
Pylaisia polyantha	39.56	0.30	Short-lived shuttle	14.5
Sanionia uncinata	2.20	10.00	Perennial stayer	14.0
Sciuro-hypnum oedipodium	6.59	0.50	Perennial stayer	19.0
Pseudoamblystegium subtile	32.97	0.50	Colonist	13.0
Thuidium delicatulum	1.10	4.00	Perennial stayer	18.0

Table 3. Epiphytic lichen characteristics in Lūznava manor park. Frequency of occurrence on studied trees. Functional traits follow P. Giordani et al. (2012) and C. W. Smith et al. (2010)

Lichen species		**Functional traits**		
	Frequency of occurrency	**Growth form**	**Photobiont**	**Reproductive strategy**
Acrocordia gemmata	2.20	Crustose	Trentepohlia	Sexual/Asexual
Anaptychia ciliaris	13.19	Foliose	Chlorococoid	Sexual/Asexual
Arthonia spadicea	2.20	Crustose	Trentepohlia	Sexual/Asexual
Bacidia rubella	10.99	Crustose	Chlorococoid	Sexual/Asexual
Candelariella xanthostigma	13.19	Foliose	Chlorococoid	Sexual/Asexual
Chaenotheca chrysocephala	2.20	Crustose	Treboxioid	Sexual
Chaenotheca ferruginea	24.18	Crustose	Treboxioid	Sexual
Cladonia coniocraea	14.29	Squamulose	Treboxioid	Sexual/Asexual
Cladonia fimbriata	1.10	Squamulose	Treboxioid	Sexual/Asexual
Evernia prunastri	14.29	Fruticose	Chlorococoid	Sexual/Asexual
Hypogymnia farinacea	1.10	Foliose	Treboxioid	Sexual/Asexual
Hypocenomyce scalaris	19.78	Squamulose	Chlorococoid	Sexual/Asexual
Hypogymnia physodes	15.38	Foliose	Treboxioid	Sexual/Asexual
Lecanora albella	1.10	Crustose	Treboxioid	Sexual
Lecanora argentata	4.40	Crustose	Treboxioid	Sexual/Asexual
Lecanora carpinea	3.30	Crustose	Treboxioid	Sexual
Lecanora chlarotera	1.10	Crustose	Treboxioid	Sexual/Asexual
Lecidella elaeochroma	1.10	Crustose	Chlorococoid	Sexual
Lecidella euphorea	10.99	Crustose	Treboxioid	Sexual
Lecanora pulicaris	1.10	Crustose	Treboxioid	Sexual/Asexual
Lecanora varia	1.10	Crustose	Chlorococoid	Sexual
Lepraria lobificans	9.89	Leprose	Chlorococoid	Asexual
Lepraria incana	50.55	Leprose	Chlorococoid	Asexual
Melanohalea exasperatula	6.59	Foliose	Treboxioid	Sexual/Asexual
Melanelixia glabratula	5.49	Foliose	Treboxioid	Sexual/Asexual
Melanelixia subargentifera	2.20	Foliose	Treboxioid	Sexual/Asexual
Opegrapha atra	1.10	Crustose	Trentepohlia	Sexual/Asexual
Opegrapha rufescens	1.10	Crustose	Trentepohlia	Sexual/Asexual
Opegrapha varia	1.10	Crustose	Trentepohlia	Sexual/Asexual
Parmeliopsis ambigua	1.10	Foliose	Treboxioid	Sexual/Asexual
Parmelia sulcata	27.47	Foliose	Treboxioid	Sexual/Asexual
Pertusaria albescens	1.10	Crustose	Treboxioid	Sexual/Asexual
Pertusaria amara	7.69	Crustose	Treboxioid	Sexual/Asexual
Phaephyscia orbicularis	16.48	Foliose	Treboxioid	Sexual/Asexual
Phlyctis argena	58.24	Crustose	Chlorococoid	Sexual/Asexual
Physconia distorta	3.30	Foliose	Treboxioid	Sexual/Asexual
Physconia enteroxantha	3.30	Foliose	Treboxioid	Sexual/Asexual
Physconia perisidiosa	4.40	Foliose	Treboxioid	Sexual/Asexual
Physcia tenella	6.59	Foliose	Treboxioid	Sexual/Asexual
Pleurosticta acetabulum	2.20	Foliose	Treboxioid	Sexual/Asexual
Ramalina farinacea	29.67	Fruticose	Treboxioid	Sexual/Asexual
Ramalina fraxinea	6.59	Fruticose	Treboxioid	Sexual
Xanthoria parietina	6.59	Foliose	Treboxioid	Sexual/Asexual
Xanthoria polycarpa	2.20	Foliose	Treboxioid	Sexual/Asexual

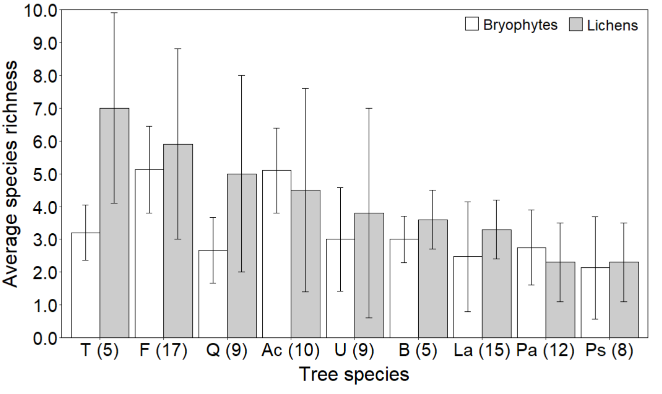

Fig. 2. Epiphytic bryophyte and lichen species richness (±Sdandard deviation) on studied host trees. Horizontal axis – T – *Tilia cordata*, F – *Fraxinus excelsior*, Q – *Quercus robur*, Ac – *Acer platanoides*, U – *Ulmus glabra*, B - *Betula pendula,* La – *Larix decidua*, Pa – *Picea abies*, Ps – *Pinus sylvestris*. The number of tree individuals noted in brackets. *Populus tremula* was excluded from the graph due to the lack of replications.

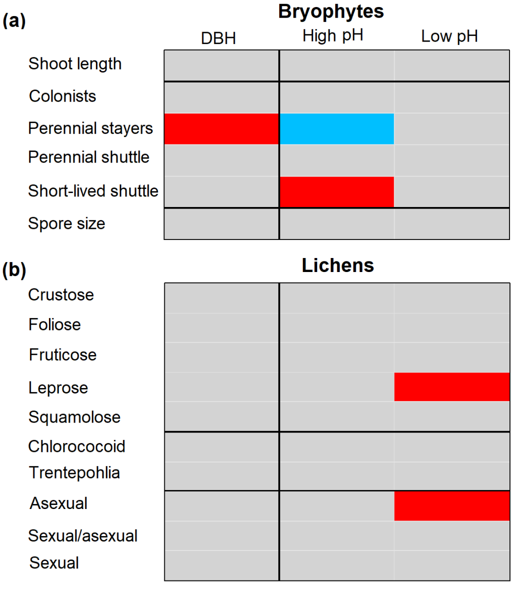

Fig. 3. Results of the fourth-corner tests of epiphytic bryophyte (a) and lichen (b) functional traits in relation to tree diameter at breast height (DBH) and bark pH. Columns refer to High pH: tree species with high bark pH were *Acer platanoides, Fraxinus excelsior, Tilia cordata, Ulmus glabra* and *Quercus robur;* Low pH: tree species with low bark pH were *Betula pendula, Larix decidua, Picea abies* and *Pinus sylvestris* following J. J. Barkman (1958) and A. Mežaka & V. Znotiņa (2006). Rows refer to epiphytic bryophyte and lichen functional traits. Bryophyte traits are shoot length, life strategy (colonists, perennial stayers, perennial shuttle, short-lived shuttle) and spore size (Bernhardt-Römermann et al. 2018, During 1979). Lichen functional traits consist of growth form (crustose, foliose, fruticose, leprose, squamulose), photobiont (chlorococoid, trentepohlia) and reproductive strategy (asexual, asexual/sexual, sexual) (Giordani et al. 2012, Smith et al. 2010). Red rectangles refer to significant positive association between trait or trait category and environmental variable (DBH) or category of the environmental variable (pH), while blue rectangle refers to a significant negative association between trait and environmental variable.

Fourth-corner analysis revealed that some epiphytic bryophyte and lichen functional traits are significantly associated with tree DBH and bark pH (Fig. 3). Epiphytic bryophytes with perennial stayer life strategy were significantly positively associated with DBH, but negatively with high tree bark pH (Fig. 3 a). Bryophytes with short-lived shuttle life strategy were associated positively with high tree bark pH. None of the studied lichen functional traits showed a relationship with DBH (Fig. 3 b.). Lichens with leprose growth form and lichens with asexual reproductive strategy were associated positively with low bark pH trees.

DISCUSSION

Lūznava manor park represents high epiphyte diversity and conservation value. Like Āboliņa and Bambe (2010), our study found that *Pylaisia polyantha* and *Hypnum cupressiforme*, are among the most common epiphytes in rural areas, indicating pollution tolerance. *Pylaisia polyantha* and *Hypnum cupressiforme* have previously been found to be the most common bryophytes in Belgrade parks (Sabovljević & Grdović 2009). In our study, *Radula complanata* was the most common liverwort, while in study of Āboliņa and Bambe (2010), this species in rural areas was not common. In rural areas of Pennsylvania, 46 epiphytic lichen species were found in four study sites (Opdyke et al. 2011), while in our study site alone, we found 44 lichen species. *Lepraria incana* was the most common lichen species in Lūznava manor park. Similarly, *Lepraria* spp. has previously been found among the most common lichens on roadside trees in Tallinn (Marmor & Randlane 2007).

As to whether Lūznava manor park contributes to bryophyte and lichen species conservation, our results show that Lūznava manor park indeed ensures rare epiphytic bryophyte and lichen species conservation. Specially protected species, WKH indicator species, and red-listed species were found in the present study, confirming the Lõhmus and Liira (2013) study conclusions that old rural parks present high conservation value habitats that include epiphyte indicator species. In answering whether epiphytic bryophyte and lichen species functional traits are shaped by DBH and tree bark pH, we obtained the following results: our results did not confirm our first hypothesis that bryophytes with longer shoots and greater spores would be associated with larger DBH and higher substrate pH. We assume that DBH variation was not great enough to reveal an association with shoot length and shoot length may not be related to substrate pH. Some bryophytes (e.g. *Hypnum cupressiforme*) may form long shoots on trees (e. g. *Picea abies*) with lower pH (pers.obs.).

Our results partly support the second hypothesis that bryophytes with colonist ans short-lived shuttle life strategies will be associated with trees with smaller DBH, while bryophytes with perennial stayer and perennial shuttle life strategies will be associated with greater DBH. Our results show that bryophytes with perennial stayer strategy were positively associated with DBH, but other bryophyte life strategies were not associated significantly with DBH. This could indicate that other bryophytes with other life strategies are not time-dependent and may colonize both younger and older trees.

Concerning our third hypothesis (that bryophyte life strategies will not show significant associations with tree bark pH), we found significant associations between bryophyte life strategies and substrate pH. Our results show that several perennial stayers (e.g. *Dicranum montanum*) prefer acidic substrate (Tyler & Olsson 2016), but short-lived shuttle preferred substrate with high pH value. The short-lived shuttle presented only three species, an insufficient number to make objective conclusions.

In response to our fourth hypothesis (that lichens with crustose growth form will be associated with trees with smaller DBH; foliose and squamulose lichens will be indifferent to DBH; but leprose and fruticose lichens will be associated with trees with greater DBH), our results show that lichen functional traits were not associated with DBH. This is in contrast to other studies, where clear

associations in lichen growth and substrate age were found along the succession (Ellis & Coppins 2006, Rasmussen et al. 2018). Another study showed that epiphytic lichen growth form was not associated with tree age on *Fraxinus excelsior* in Sweden (Johansson et al. 2007). The average DBH of trees in our study was more than 1 m and the DBH variation was likely not large enough.
Our results partly confirm the fifth hypothesis that lichen growth form and photobiont will be indifferent to both tree DBH and pH, but for our sixth hypothesis (that lichens with asexual reproduction will be associated with greater tree DBH and high pH, while lichens with sexual and asexual and asexual reproduction will not show any preference to DBH and pH), we did not find an association between lichen asexual reproduction and DBH. Unexpectedly, asexual reproduction strategy was significantly positively associated with low pH. This might be explained by the high frequency of occurrence of leprose lichen *Lepraria incana,* which prefers coniferous trees with low bark pH (Barkman 1958, Mežaka et al. 2012, Rasmussen et al. 2018) and could be about a relationship between asexual reproduction and low pH, because studied *Lepraria* species have only asexual reproduction.

We assume that the main limitation of our study is the small amount of sampled trees (only 91). Compiling data from other manor parks in Latvia would provide more reliable results. Studying bryophyte and lichen functional traits in natural ecosystems would also add to our understanding substantially. The present data contribute to future studies as a reference for evaluating the biodiversity, ecological conditions and air quality in Lūznava.

CONCLUSIONS

The present study shows the importance of Lūznava manor park in epiphytic bryophyte and lichen species conservation; that tree DBH and bark pH are important environmental drivers of some epiphytic bryophyte and lichen functional traits in an urban area; and that epiphytic bryophytes and lichens are useful model organisms to explore the relationship of functional traits and the environment. Future studies are needed using a larger spectrum of bryophyte and lichen functional traits across larger spatial scales.

ACKNOWLEDGEMENTS

The present study was partly financially supported by the Rēzekne Academy of Technologies research grant "Tūrisma produktu attīstības iespēju izpēte Lūznavas muižā" in cooperation with the Nature Conservation Agency and the Latvian countryside consultation and information education center.

RĒZEKNES TEHNOLOĢIJU AKADĒMIJA

The research was elaborated with the financial assistance of Rezekne Academy of Technologies provided through a research grant for the "Tūrisma produktu attīstības iespēju izpēte Lūznavas muižā".

REFERENCES

Āboliņa A. 1994. Latvijas retās un aizsargājamās sūnas. Rīga, Pp 24. (In Latvian).

Āboliņa, A., Bambe, B. 2010. Dažas epifītisko sūnu sastopamības īpatnības apdzīvotajās vietās. In: Ģeogrāfija, Ģeoloģija, Vides zinātne. Latvijas Universitātes 68. zinātniskā konference. Referātu tēzes. Rīga, Pp. 26-28 (In Latvian).

Āboliņa, A., Piterāns, A., Bambe, B. 2015. Latvijas ķērpji un sūnas. Taksonu saraksts. (Lichens and bryopytes in Latvia. Checklist.). Salaspils, 245 lpp. (In Latvian; abstract in English).

Alvey A. A. 2006. Promoting and preserving biodiversity in the urban forest. *Urban Forestry and Urban Greening*, 5: 195-201.

Anonīms 2000. Latvijas pērles. Rīga, 285 lpp. (In Latvian).

Barkman J.J. 1958. Phytosociology and ecology of cryptogamic epiphytes. Van Gorcum. Assen, Pp. 628.

Bernhardt-Römermann M., Poschlod P., Hentschel J. 2018. BryForTrait – A life-history trait database of forest bryophytes. *Journal of Vegetation Science*, 29(4): 798–800.

Borcard D., Gillet F., Legendre P. 2018. Numerical ecology with R. Québec, Pp. 306.

Cornelissen J. H. C., Lavorel S., Garnier E., Díaz, S., Buchmann N., Gurvich, D. E., Reich P. B., ter Steege H., Morgan H. D., van der Heijden M. G. A, Pausas J. G., Poorter H. 2003. A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. Australian *Journal of Botany*, 51(4): 335–380.

Daugavpils Universitātes Sistemātiskās bioloģijas institūts (DUSBI) 2013. Lūznavas parks. Dendroloģiskās inventarizācijas materiāli. Daugavpils, Pp. 20. (In Latvian).

Dray S., Dufour A 2007. "The ade4 Package: Implementing the Duality Diagram for Ecologists." *Journal of Statistical Software*, 22(4): 1-20.

Diaz S., Cabido M., Casanoves F. 1998. Plant functional traits and environmental filters at a regional scale. *Journal of Vegetation Science*, 9(1): 113–122.

During H. J. 1979. Life strategies of bryophytes: A preliminary review. *Lindbergia*, 5: 2–18.

Ellis C. J., Coppins B. J. (2006). Contrasting functional traits maintain lichen epiphyte diversity in response to climate and autogenic succession. *Journal of Biogeography*, 33: 1643–1656

Giordani P., Brunialti G., Bacaro G., Nascimbene J. 2012. Functional traits of epiphytic lichens as potential indicators of environmental conditions in forest ecosystems. *Ecological Indicators*, 18: 413–420.

Ek T., Suško U, Auziņš R. 2002. Mežaudžu atslēgas biotopu inventarizācijas metodika. Rīga, 76. (In Latvian).

Hodgetts N. G. 2015. Checklist and country status of European bryophytes – towards a new Red List for Europe. *Irish Wildlife Manuals*, 84: 125.

Johansson P., Rydin H., Thor G. 2007. Tree age relationships with epiphytic lichen diversity and lichen life history traits on ash in southern Sweden. *Ecoscience*, 14(1): 81–91.

Latvijas Vides ģeologijas un meteoroloģijas centrs (LVGMC) 2016. Latvijas klimats. http://meteo.lv/lapas/laika-apstakli/klimatiska-informacija/latvijas-klimats/latvijas-klimats?id=1199&nid=562. (In Latvian).

Latvijas Republikas Ministru kabinets (LRMK 2000) 2000. Noteikumi par īpaši aizsargājamo sugu un ierobežoti izmantojamo īpaši aizsargājamo sugu sarakstu. Noteikumi nr. 396. Latvijas Vēstnesis. 17.11.2000, 413/417: 4-6. (grozījumi 27.07.2004 not. nr. 627). (In Latvian).

Larsen R.S., Bell J. N. B., James P. W., Chimonides P. J., Rumsey F. J., Tremper A., Purvis O. W., 2007. Lichen and bryophyte distribution on oak in London in relation to air pollution and bark acidity. *Environmental pollution*, 146: 332–340.

Löbel S., Snäll T., Rydin H. 2009. Mating system, reproduction mode and diaspore size affect metacommunity diversity. Journal of *Ecology*, 97(1): 176–185.

Lõhmus K., Liira J. 2013. Old rural parks support higher biodiversity than forest remnants.

Basic and Applied Ecology, 14(2): 165-173.

Marmor L., Randlane T. 2007. Effects of road traffic on bark pH and epiphytic lichens in Tallinn. *Folia Cryptog. Estonica, Fasc*. 43: 23–37.

Mazziotta A., Granath G., Rydin H., Bengtsson F., Norberg J. 2019. Scaling functional traits to ecosystem processes: Towards a mechanistic understanding in peat mosses. *Journal of Ecology*, 107(2): 843–859.

Mežaka A., Znotiņa V. 2006. Epiphytic bryophytes in old growth forests of slopes, screes and ravines in North-West Latvia. *Acta Universitatis Latviensis*, (710): 103-116.

Mežaka A., Brūmelis G., Piterāns A., Printzen C. 2012. Distribution of Lepraria in Latvia in relation to tree substratum and deciduous forest type. *Annales Botanici Fennici,* 49:162-170.

Motiejūnaitė J. 2009. Lichens and allied fungi of two regional parks in Vilnius area (Lithuania). *Acta Mycologica*, 44(2): 185-199.

Nelson P. R., McCune B., Swanson D. K. 2015. Lichen traits and species as indicators of vegetation and environment. *The Bryologist*, 118(3): 252–263.

Opdyke M. R., Dolney B. E., Frost L. L., Roy J. D. 2011. A study of epiphytic lichen communities in urban and rural environments in Southwestern Pennsylvania. *Journal of the Pennsylvania Academy of Science,* 85(4): 151-158.

Orange A., James P.W., White F.J. 2001. Microchemical methods for the identification of lichens. British lichen society, Pp. 101.

Piterāns A., Vimba E. 1996. Red Data Book of Latvia. Rare and endangered species of plants and animals. Fungi and lichens. Riga, Pp. 202.

Purschke O., Schmid B. C., Sykes M. T., Poschlod P., Michalski S. G., Durka W., Kühn I., Winter M., Prentice H. C. 2013. Contrasting changes in taxonomic, phylogenetic and functional diversity during a long-term succession: Insights into assembly processes. *Journal of Ecology*, 101(4): 857–866.

Rasmussen H. N., Nord-Larsen T., Hansen E. S., Hoareau G. 2018. Estimation of life history in corticolous lichens by zonation. *The Lichenologist*, 50(6): 697–704.

R Core Team 2018. R: A language and environment for statistical computing. R version 3.5.1. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Sabovljević M., Grdović S. 2009. Bryophyte diversity within urban areas: case study of the city of Belgrade (Serbia). I*nternational Journal of Botany,* 5(1): 85-92.

Sierra A. M., Toledo J. J., Salazar Allen N., Zartman C. E. 2018. Reproductive traits as predictors of assembly chronosequence patterns in epiphyllous bryophyte metacommunities. *Journal of Ecology*, (June): 1–12.

Smith C.W., Aptroot A., Coppins B.J., Fletcher A., Gilbert O.L., James P.W., Wolseley P.A. 2010. The Lichens of Great Britain and Ireland. The British Lichen Society, London. Pp. 1046.

Sujetuviene G., Sliumpaite I. 2013. Response of Evernia prunastri transplanted to an urban area in central Lithuania. *Atmospheric Pollution Research,* 4: 222-228.

Tyler T., Olsson P. A. 2016. Substrate pH ranges of south Swedish bryophytes—Identifying critical pH values and richness patterns. *Flora*, 223: 74–82.

Received: 29.09.2019.
Accepted: 01.11.2019.