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EPIPHYTIC LICHEN DIVERSITY IN BROAD-LEAVED TREE FORESTS IN LATVIA

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Broad-leaved tree forests host a large diversity of epiphytic lichens, but this forest type is rare in Latvia. Epiphytic lichen diversity of broad-leaved trees mostly has been studied in protected areas and there is insufficient knowledge of the general distribution of epiphytic lichens outside the protected areas. The aims of this study were to compare epiphytic lichen diversity among tree species and between broad-leaved tree forest in protected and non-protected areas in Latvia.

Epiphitic lichen diversity in broad-leaved tree woodland was studied in two regions of Latvia: Kurzeme and Zemgale. Altogether 67 lichen species were recorded on 160 sampled trees of 11 tree species in 19 forest stands. Eight of the recorded lichens are listed in the Latvian protected species list, of which 4 are species for which microreserves can be established. Only two were listed in the Latvian Red Data Book. Protected species were found in 18 of the studied 19 stands, but only 6 of these stands occurred in protected areas. One recorded lichen species *Opegrapha niveoatra* is reported as new to Latvia. *Quercus robur* had the highest number of lichen species on the basal trunk. 53.85% of recorded occurences (21 of 39 records) of protected lichen species and 60.42% of recorded occurences (29 of 48 records) of Woodland Key Habitat species occurred outside of protected areas.

Key words: epiphytic lichens, species diversity, broad-leaved forests, fragmentation, protected species, protected areas.

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INTRODUCTION

Biological diversity is the foundation of functioning of ecosystems (Kouki 1994), and involves diversity of species, structures and processes, at various spatial scales (Peterken 1996, Esseen et al. 1997). Broadleaved tree (*Fraxinus excelsior*, *Ulmus glabra, Tilia cordata, Quercus robur*) forests are associated with high epiphytic lichen diversity (Esseen et al. 1997, Jüriado et al. 2003), particularly in boreo-nemoral broadleaved tree woodland compared to boreal coniferous forest (Barkman 1958, Jüriado et al. 2003). Forest age and continuity are two main factors affecting epiphytic lichen diversity (Lesica et al. 1991, Esseen et al. 1996, Esseen et al 1997, McCune 1993, Jüriado et al. 2003). Tree diversity of a woodland is known to promote epiphytic lichen diversity (Fahselt, Krol 1989, Kuusinen 1996a, Kuusinen 1996b, Mežaka et al. 2012).

Greater richness of epiphytic bryophytes and lichens occurs on deciduous in comparison with coniferous trees (Berg et al. 1994). The main factors affecting epiphytic lichen growth are moisture, temperature and light (Hale 1973, Fahselt, Krol 1989, McCune 1993, Esseen et al. 1997), which differ between forest site types.

The impact of man on forests in the temperate zone has been profound (Jones 1945, Esseen et al. 1997), and in Europe natural undisturbed woodland is almost non-existent (Peterken 1981).

In Latvia, which occurs in the transition boreo-nemoral zone between temperate and boreal forest zones, where mixed forest with broadleaved and coniferous trees is common (Sjors 1963), the former area of broadleaved forest has almost disappeared, and *Quercus robur* woodland now covers only about 1.0% of the total forest area (LMD 2017). The broadleaved forests in Latvia are highly fragmented by agricultural land and intensively managed forest, which might be expected to limit successful lichen dispersal (Ellis & Coppins 2007).

However, it is predicted than global change will lead to an increase in area of *Quercus robur* in northern Europe at the expense of coniferous tree species (Hanewinkell et al. 2012).

In Latvia, epiphytic lichen communities have been studied mostly in protected territories and Woodland Key habitats (Mežaka et al. 2008), but publications on the distribution of lichens outside of these areas is lacking. Study is needed to understand the affects of many factors like spatial and temporal continuity on epiphytic lichen diversity and indicators species (Norden & Appelqvist 2001). In this regard, knowledge is needed on occurrence of protected and rare lichen species outside of protected areas, to enable development of conservation strategies (Marmor et al. 2011). The aim of the study was determine the occurrence of lichen species in relation to tree species and protection status of stands in broad-leaved forests in two regions of Latvia.

MATERIAL AND METHODS

Climate

All selected stands were located in South-Western region of Latvia. The climate of the South-Western region of Latvia is mainly attributed to Atlantic cyclones that bring air masses and precipitation from the west and northwest. The average temperature ranges from –3 to –6^{o}C in January, and from 16.5 to 17^{o}C. in July. Annual precipitation ranges from 600 to 850 mm (Turlājs 2011).

Site description

The stands were randomly selected from the Forest Register of the State Forest Service with criteria of broad-leaved trees composition at least 70% (Fig 1). Model territories selected were the Kurzeme and Zemgale regions, which historically had the largest area of broad-leaved tree stands. Three stands (PAD2, PAD12, and MEZ5) of 19 complied with criteria of protected habitats of the European Community 9160 „Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli" and are included in the Natura2000 network (Tab. 1) (Auniņš et al. 2013). Two of these (PAD2 and PAD12) are part of the nature reserve „Tebras ozolu meži" and one (MEZ5) is in the microreserve „Ozoldārzs" (Anonymous 2017). In this study, old wooded city parks (ZAL1, ZAL2, and DOB5) were grouped together with protected areas, as these forests have a history of protection as manor parks (Table 1).

Field study

The study was conducted in August to November 2016. Epiphytic lichens were sampled in each

Table 1. Location and characteristics of the studied forest stands

ID	Studied area	Name of plot	X coordinates*	Y coordinates*	Nr.of Sampled trees	Mean diameter	Minimum diameter
1	Dobele	DOB5***	456121	273451	12	45.71	25.00
2	Dzelda	DZD1	364660	272521	9	37.78	20.00
3	Kazdanga	KAZ3	363704	285176	12	33.63	19.00
4	Ķikuri	KIK1	355279	296965	9	46.11	20.00
5	Mežotne	MEZ1	506418	259605	3	29.67	23.00
6	Mežotne	MEZ2	504951	255603	7	70.07	45.00
7	Mežotne	MEZ3	507937	255941	9	34.72	18.50
8	Mežotne	MEZ4	498488	254948	9	31.89	11.50
9	Mežotne	MEZ5**	502092	255739	6	67.25	19.00
10	Padure	PAD12**	351422	293116	13	47.27	26.00
11	Padure	PAD2**	350890	293087	9	39.00	32.00
12	Padure	PAD9	348218	296687	12	41.17	14.00
13	Platone	PLAT1	477788	251336	8	50.19	29.00
14	Platone	PLAT2	474592	258436	6	34.08	16.00
15	Vītiņi	VIT1	440603	251127	9	49.11	26.00
16	Vītiņi	VIT2	439148	254595	6	55.08	11.00
17	Vītiņi	VIT3	438710	254196	4	55.75	36.50
18	Zaļenieki	ZAL1***	470080	265518	9	51.83	25.00
19	Zaļenieki	ZAL2***	470573	265939	9	36.06	18.00

*Geographical system of coordinates: LKS 1992 Latvia TM.
**Protected territory (LĪADT 1993).
*** Old wooded city park.

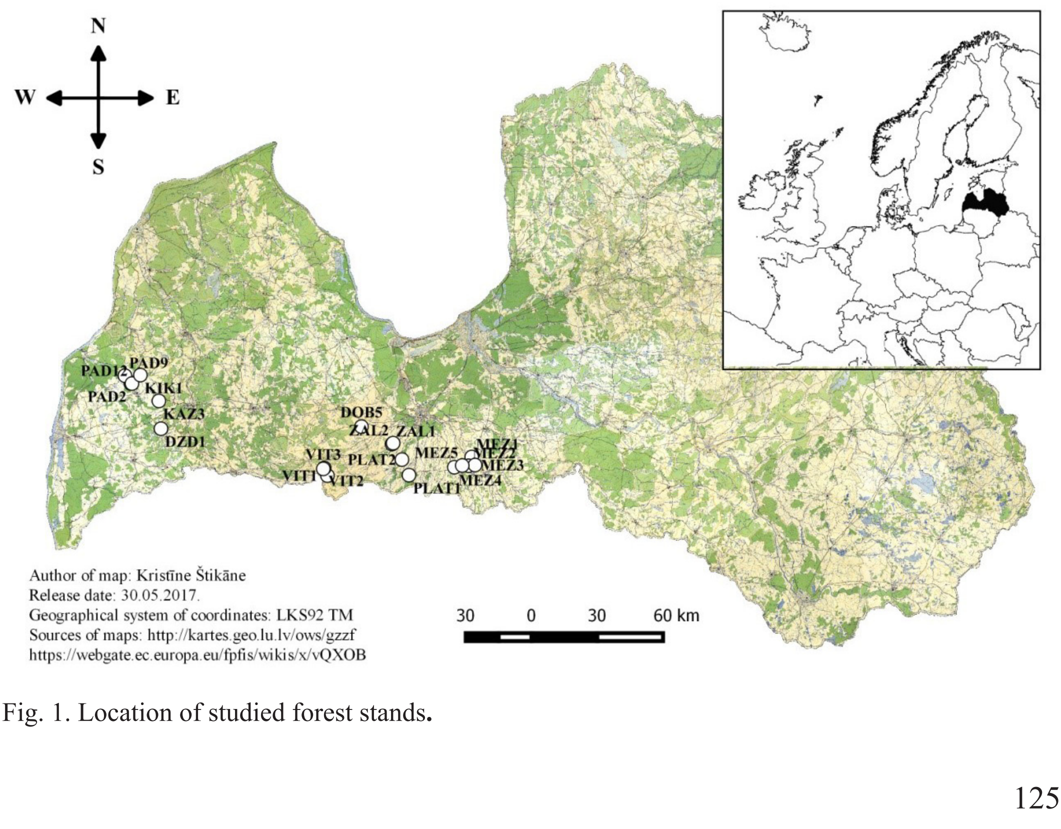

Fig. 1. Location of studied forest stands.

Table 2. Collected signal epiphytic lichen species proportion within studied areas

Species status*	**WKH**	**WKH, P, MR**	**WKH, P**	**WKH, P**	**WKH, P**	**WKH**	**WKH**	**WKH**	**WKH, P, MR, R**	**WKH, P, MR**	**P, R**	**WKH**	**WKH, P, MR**	**WKH**	**P, MR**	**P, WKH, MR**
Lichen species	*Acrocordia gemmata*	*Arthonia byssacea*	*Arthonia leucopellaea*	*Arthonia spadicea*	*Arthonia vinosa*	*Bacidia rubella*	*Graphis scripta*	*Lecanactis abietina*	*Menegazzia terebrata*	*Opegrapha vermicellifera*	*Pertusaria hemisphaerica*	*Phlyctis agelaea*	*Sclerophora peronella*	At least one WKH species	At least one P or MR	Signal species (P, MR or WKH species)
Number of protected stands where recorded	2	3	3	1	1	3	3	0	0	0	0	1	0	5	6	6
Number of non-protected stands where recorded	7	4	5	7	1	3	6	4	1	1	1	3	1	11	12	12
Proportion of protected stands where recorded, %	33.33	50.00	50.00	16.67	16.67	50.00	50.00	0	0	0	0	16.67	0	83.33	100.00	100.00
Proportion of non-protected stands where recorded, %	53.85	30.77	38.46	53.85	7.69	23.08	46.15	30.77	7.69	7.69	7.69	23.08	7.69	84.62	92.31	92.31

*WKH-Woodland Key Habitat species (Auniņš et al. 2013), P – Latvian protected species list (Anonymous 2000), MR – microreserves can be established (Anonymous 2013), R – listed in the Latvian Red Data Book (Andrušaitis et al. 1996).

stand from three randomly selected trees (from the largest ones) for each tree species in the stand. Trees less than 10 cm diameter were not sampled. All lichens present at stem height 5 to 180 cm were sampled. In some cases when less than three trees per species were found, less were sampled. Diameter at breast height (130 cm) was measured for each sampled tree.

Data analysis

The collections were determined using the routine lichenological methods (Smith et al., 2009). Spot-test reactions were checked with 10% KOH (K), sodium hypochlorite (C), para-phenylenediamine in ethanol (Pd), and Lugol's solution (I). The nomenclature of lichenized fungi taxa follows Nordin et al. (2011).

Differences in epiphytic lichen occurrence and richness were examined in relation to tree species and forest stand. Relationship between species richness and stem diameter by tree species was determined using Pearson or Spearman correlation analysis depending on data distribution, using R version 3.2.5 (R Development Core Team 2011).

Table 3. Total and and mean lichen species richness for each tree species

Tree species	Total richness	Mean richness
Populus tremula L., 1753	19	0.63
Betula pendula Roth, 1788	11	0.37
Salix caprea L., 1753	4	0.09
Picea abies (L.) H.Karst., 1881	19	1.07
Ulmus glabra Huds., 1762	11	0.18
Acer platanoides L., 1753	15	0.37
Tilia cordata Mill., 1768	25	1.16
Fraxinus excelsior L., 1753	12	0.32
Quercus robur L., 1753	43	2.38
Pinus sylvestris L., 1753	5	0.12
Quercus rubra L., 1753	3	0.12

Mean lichen richness and total richness were calculated for each tree species. Tree and lichen richness were determined for each stand. Gradient analysis of epiphytic lichen communities in forest stands was conducted using NMS (Non-metric Multidimensional Scaling) with Sorensen-Bray Curtis distance measure (McCune et al. 2002).

RESULTS

Lichen diversity

A total of 67 lichen species (Appendix 1) were recorded on 161 individuals of 11 tree species. Of the studied 19 forest stands in Southwest part of Latvia, of which three were in Natura 2000 teritories and three were old manor parks, only one stand (VIT2) lacked valuable lichen species that were either protected or Woodland Key Habitat indicators. Eighteen of the nineteen stands contained at least one protected species and fourteen contained at least one Woodland Key Habitat (WKH) species (Table 2). Only one of the stands lacked both protected and WKH species.

Opegrapha niveoatra was recorded in Latvia for the first time, in stand VIT1 (Table 1) in Zemgale, on a *Populus tremula* with diameter 37.5 cm, on bark. This stand also contained WKH species like *Acrocordia gemmata* and *Lecanactis abietina* and protected species like *Arthonia leucopellaea* and *Arthonia spadicea.*

Of the examined trees in stands, 58 were in protected stands and 103 in non-protected stands. A total of 58 lichen species were recorded in protected stands and 58 in non-protected stands. The largest number of lichen species (43 of 67 species) were observed on *Quercus robur* stems (Table 3). Eight species were included in the list of protected species in Latvia (Anonymous 2000), of which four (*Arthonia byssacea, Menegazzia terebrata, Opegrapha vermicellifera,* and *Sclerophora peronella* were in the list of protected species for which microreserves can be established (Table 2). Two of the protected species (*Menegazzia terebrata* and *Pertusaria hemisphaerica* are included in the Red Data List for Latvia (Andrušaitis et al. 1996). *Acrocordia gemmata* (WKH indicator species) and *Arthonia spadicea* (protected species) were found in 53.85% (7 no 13) of the non-protected stands. *Arthonia byssacea*, a species for which microreserves can be established, was found in four non-protected stands and *Arthonia leucopellaea*, a protected species, was found in five non-protected stands. All records of *Menegazzia terebrata, Opegrapha vermicellifera, Pertusaria hemisphaerica, Arthonia vinosa* and *Sclerophora peronella,* were from non-protected stands, but each of these species was found in only one stand (Table 2).

Highest total and mean richness of lichen species was found on *Quercus robur* (43 species) and *Tilia cordata* (25 species) and the lowest on *Pinus sylvestris* (5 species) and *Salix caprea* (4 species).

Relationship between tree stem diametar and lichen species richnes was determined for trees with sample size at least 15 trees (*Quercus robur*, *Populus tremula*, *Tilia cordata* and *Picea abies*), but all correlations were non-significant. A significant correlation ($R=0.6521$, $p<0.001$) was found between lichen and tree species diversity in plots.

DISCUSSION

A total of 67 epiphytic lichen species were found in the study. A similar number of lichen species (75) was found in a previous study of WKH broadled forest of ravines and screes (Mežaka et al. 2012). Of the four protected species found, for whch microreserves can be established, three (*Menegazzia terebrata*, *Opegrapha vermicellifera* and *Sclerophora peronella* were found outside of protected areas.

Opegrapha niveoatra ((Borrer) J.R. Laundon, 1963)**,** which was reorded for the first time in Latvia, also was found outside of protected areas, on a *Populus tremula*. Surprisingly, only two (*Menegazzia terebrata* and *Opegrapha vermicellifera*) of the recorded protected lichen species are included in the Red Data List for Latvia (Andrušaitis et al. 1996), indicating that this list needs to be updated.

Three of the 19 studied forest stands (PAD2, PAD12, and MEZ5) had been previously identified as EU protected habitat 9160 Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli and were found in protected areas. These stands contained the protected species *Arthonia byssacea, Arthonia leucopellaea* and *Arthonia vinosa.* However, the epiphytic lichen species that are WKH indicator species were lacking in some protected areas (PAD12, PAD2, and ZAL2), while common in others (for example, on 5 of 6 studied trees in stand MEZ5). Regarding the studied old manor parks, the WKH species *Bacidia rubella* and *Graphis scripta* were found in stand ZAL1 and *Acrocordia gemmata, Bacidia rubella* and *Phlyctis agelaea* in DOB5. It can be assumed that old manor parks were important in maintaining continuity of substrate for epiphytes requiring broad-leaved tree species, and that light conditions were variable and promoting high diversity. It is possible that some of the other sites were part of an ancient wood meadow landscape around manors, with spatial and temporal continuity of broad-leaved trees. Certainly, the presence of some oak with large diameter in some stands suggests past land-use and wooded meadow. Thus, the legacy of previous land-use probably contributed the present high richness of protected and DMB species outside of protected areas. It is likely that some of the studied stands complied with EU protected Habitats, but had not been previously identified as such. This indicates the necessity for further study of the epiphytic lichens in relation to past stand history and spatial continuity of suitable substrate.

Higher lichen richness is associated with *Acer platanoides, Fraxinus excelsior, Quercus robur, Tilia cordata,* and *Ulmus glabra,* compared with *Betula sp.* and coniferous trees (Barkman 1958, Berg et al. 1994, Cieśliński et al. 1995). The high lichen richness on *Quercus robur* and other broad-leaved tree species can be explained by characteristics of bark like porousness (Rose 1974), pH and crevice depth (Mežaka et al. 2012). In comparison with the broad-leaved tree species, 19 lichen species were found on spruce and 19 on birch, only slightly less than on *Tilia cordata*.

While the relationship between tree diameter and epiphytic lichen richness is known (McCune 1993, Esseen et al. 1996, Peterken 1996, Jüriado et al. 2003), in our study we found no such relationship for the tree species investigated, which migh be explained by low sample size and effect of other factors like light, humidity and temperature (Hale 1973, Fahselt, Krol 1989, McCune 1993, Esseen et al. 1997) as well as anthropgenic effect (Hale 1983, Nash 1996, Conti, Cecchetti 2001).

The observed correlation between tree and lichen species diversity can be explained by higher substrate and niche diversity (Fahselt, Krol 1989, Lesica et al. 1991, Kuusinen 1996a, Kuusinen 1996b, Jüriado 2003, Fritz 2009, Mežaka et al. 2012). This preliminary study of 19 stands did not allow objective analysis of lichen species composition in relation to tree species. However, differences were obvious. For example, *Lecanactis abietina* is a common indicator of old *Picea abies* stands (Piterāns 2001) and *Arthonia byssacea, Arthonia vinosa, Arthonia spadicea,* and *Opegrapha vermicellifera* require broad-leaved tree species or *Populus tremula* bark as a substrate (Piterāns 2001). Further study in this direction is being planned.

Some of the stands, like DZD1, are not protected, but presence of species *Menegazzia terebrata* and *Opegrapha vermicellifera* indicate a need to establish new microreserves. A similar stand is MEZ5, where two species for which microreserves can be established (*Arthonia byssacea* and *Arthonia spadicea* and 4 WKH indicator species (*Acrocordia gemmata, Bacidia rubella, Phlyctis agelea* and *Graphis scripta*) were found. The study should be expanded to a greater number of stands, particularly ensuring comparable number of protected and non-protected areas, and with different levels of forest fragmentation and management legacies. It might be expected that after future invesistigation of species distributions, the protection status of some species will change.

CONCLUSIONS

1. Higher tree species diversity can ensure higher lichen species diversity.
2. Higher richness of protected and WKH species has been supported by past land-use as manor parks and wooded meadow landscape.
3. Broad-leaved tree species like *Quercus robur* un *Tilia cordata* and also the pioneer spcies *Populus tremula* support higher lichen richeness than coniferous species.

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Appendix 1

List of taxa of epiphytic lichens recorded during the researh in specific forest stands (Number I D in Table 1)

Acrocordia gemmata (Ach.) A.Massal., 1854 : (1, 8, 9, 12, 13, 15, 16)
Amandinea punctata (Hoffm.) Coppins & Scheid., 1993 : (6)
Arthonia atra (Pers.) A. Schneid., 1898 : (15)
Arthonia byssacea (Weigel) Almq., 1880 : (1, 9, 16, 17, 18, 19)
Arthonia dispersa (Schrad.) Nyl., 1861 : (1, 7)
Arthonia leucopellaea (Ach.) Almq., 1880 : (1, 7, 9, 15, 16, 17)
Arthonia patellulata Nyl., 1903 : (1, 10)
Arthonia radiata (Pers.) Ach., 1808 : (3, 7, 9, 12, 16, 18)
Arthonia sp. Zahlbr., 1903 : (2, 13)
Arthonia spadicea Leight., 1854 : (2, 7, 8, 12, 13, 14, 16, 17)
Arthonia vinosa Leight., 1856 : (4, 10, 11)
Bacidia rubella (Hoffm.) A.Massal., 1852 : (1,

7, 12, 14, 18)
Bacidina arnoldiana (Körb.) V.Wirth & Vězda, 1994 : (1, 9, 13, 14)
Buellia griseovirens (Turner & Borrer ex Sm.) Almb., 1952 : (1, 4, 8, 9, 10, 12, 13, 15)
Calicium salicinum Pers., 1794 : (4)
Calicium viride Pers., 1794 : (18)
Candelariella xanthostigma (Pers. ex Ach.) Lettau, 1912 : (7)
Chaenotheca ferruginea (Turner ex Sm.) Mig., 1930 : (1, 15, 16, 19)
Chaenotheca stemonea (Ach.) Müll.Arg., 1862 : (17)
Cladonia chlorophaea (Flörke ex Sommerf.) Spreng., 1827 : (2, 3, 10, 12)
Cladonia coniocraea (Flörke) Spreng., 1827 : (2, 3, 10, 11, 12)
Cladonia cornuta (L.) Hoffm., 1791 : (10)
Cladonia sp. : (4, 10, 11, 19)
Dimerella lutea (Dicks.) Trevis., 1880 : (3)
Dimerella pineti (Ach.) Vězda, 1975 : (1, 2, 11)
Evernia prunastri (L.) Ach., 1810 : (6, 9)
Graphis scripta (L.) Ach., 1809 : (5, 6, 7, 8, 9, 12, 13, 18, 19)
Hypocenomyce scalaris (Ach.) M.Choisy, 1951 : (1)
Hypogymnia physodes (L.) Nyl., 1896 : (2, 3, 4, 12)
Lecanactis abietina (Ehrh. ex Ach.) Körb., 1855 : (2, 10, 15, 17)
Lecanora chlarotera Nyl., 1872 : (1, 5, 6, 7, 13)
Lecidella elaeochroma (Ach.) M.Choisy, 1950 : (9)
Lecidella euphorea (Flörke) Hertel, 1980 : (1, 5, 6, 7, 8, 9, 13, 15, 16, 18)
Lecidella stigmatea (Ach.) Hertel & Leuckert, 1969 : (7)
Lepraria elobata Tønsberg, 1992 : (1, 2, 4, 11, 14)
Lepraria incana (L.) Ach., 1803 : (1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19)
Lepraria jackii Tønsberg, 1992 : (2)
Lepraria lobificans Nyl., 1873 : (15, 16, 17)
Lepraria neglecta (Nyl.) Erichsen., 1958 : (16)
Melanelixia glabra (Lamy) Sandler & Arup, 2011 : (12)
Melanelixia glabratula (Lamy) Sandler & Arup, 2011 : (1, 3, 13, 19)
Melanohalea olivacea (L.) O.Blanco et al., 2004 : (1)
Menegazzia terebrata (Hoffm.) A. Massal., 1854 : (15)
Opegrapha niveoatra (Borrer) J.R. Laundon, 1963 : (2)
Opegrapha vermicellifera (Kunze) J.R.Laundon, 1963 : (2)
Opegrapha vulgata (Ach.) Ach., 1803 : (10, 13, 14,15, 18)
Parmelia sulcata Taylor, 1836 : (1, 13)
Peltigera praetextata (Flörke) Vain., 1899 : (4, 12)
Pertusaria albescens (Huds.) M.Choisy & Werner, 1932 : (2, 3, 12)
Pertusaria amara (Ach.) Nyl., 1872 : (2, 4, 10, 12, 17)
Pertusaria coccodes (Ach.) Nyl., 1857 : (12)
Pertusaria hemisphaerica (Flörke) Erichsen, 1932 : (3)
Phaeophyscia orbicularis (Neck.) Moberg 1977 : (18)
Phlyctis agelaea (Ach.) Flot., 1850 : (7, 8, 12)
Phlyctis argena (Ach.) Flot., 1850 : (1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19)
Physcia dubia (Hoffm.) Lettau, 1912 : (7)
Physcia tenella (Scop.) DC., 1805 : (7)
Physconia distorta (With.) J.R.Laundon, 1984 : (7)
Physconia grisea (Lam.) Poelt, 1965 : (12)
Platismatia glauca (L.) W.L.Culb. & C.F.Culb., 1968 : (2, 4)
Pseudoschismatomma rufescens (Pers.) Ertz & Tehler, 2014 : (1, 7, 8, 13, 14, 17)
Pyrenula nitida (Weigel) Ach., 1814 : (2, 17)
Ramalina pollinaria (Westr.) Ach., 1810 : (6)
Sclerophora peronella (Ach.) Tibell, 1984 : (7)
Zwackhia viridis (Ach.) Poetsch & Schied., 1872 : (18)

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